Volume Title: Residential Location and Urban Housing Markets

Volume Author/Editor: Gregory K. Ingram

Volume Publisher: NBER

Volume URL: http://www.nber.org/books/ingr77-1

Publication Date: 1977

Chapter Title: The Influence of Age of Dwellings on Housing Expenditures and on the Location of Households by Income

Chapter Author: Richard F. Muth

Chapter URL: http://www.nber.org/chapters/c4306

Chapter pages in book: (p. 3 - 26)

Chapter One

The Influence of Age of Dwellings on Housing Expenditures and on the Location of Households

Richard F. Muth

In this study I describe the results of an empirical investigation into the determinants of expenditures on housing and of the location of households by income. My principal goal is to explain the intracity variation in such magnitudes. The specific empirical work presented here, though, is concerned with certain implications of a theory of durability of residential structures I advanced in a recent paper (Muth 1973).

MOTIVATION

Most work on economic aspects of urban residential location has been concentrated on the effects of accessibility of a site to the downtown area or central business district (CBD) of a city (especially see Alonso 1964, Mills 1967, Muth 1969, and Wingo 1961). The further CBD workers live from their jobs, the greater their total transport costs, and, hence, the lower the unit prices they pay for housing. Lower housing prices, in turn, mean lower prices for land. Consequently, population density and intensity of use of residential land declines with distance from the CBD. Empirical evidence tends to agree relatively well with the implications of these models (Mills 1969 and Muth 1969).

Models of urban residential land use also have implications for the location of households by income (Alonso 1964 and Muth 1969). A

Note: The research reported on here was supported initially by National Science Foundation Grant GS-39005 and later by the Domestic Studies Program of the Hoover Institution.

condition for the optimal location of a household containing a CBD worker is that the change in the expenditure necessary to acquire the quantity of housing consumed at this location be exactly offset by the change in transport expenditure associated with any change in location. The effect of income differences on household location, then, depends on the relative strengths of income differences on housing consumption and on the marginal costs of transport, including the opportunity costs of time spent in travel. On empirical grounds, it seems reasonable that the effect of increased income on housing expenditures exceeds that on marginal transport costs (see Muth 1969, pp. 29-34). One would thus expect both that higher-income CBD-worker households would live farther from their jobs than others and that the dispersion of population in cities would tend to vary directly with the average income of CBD workers.

My previous empirical work provides some weak support for the proposition that population dispersion in cities increases with average income (Muth 1969, pp. 153-155 and 163-164). I also found strong positive, simple associations between both income and housing expenditure with distance from the CBD. However, these simple positive associations tended to result from the negative intercorrelation between distance from the CBD and age of dwelling units, for when a variable for age of dwelling unit was included in the analysis, the partial effects of distance were negligible. Both average income and expenditures on housing at a given income level in 1950 (1960) tended to vary inversely with the fraction of dwellings built prior to 1920 (1940). (Muth 1969, especially pp. 196-202.) The empirical research begun with this paper was initially aimed at testing alternative explanations for the findings just described.

There are at least two alternative explanations for the finding that distance from the CBD has no apparent effect on average income. The first, suggested by the discussion above, is simply that the effects of increased incomes on housing consumption and marginal transport costs are about the same. If so, the tendency for higher-income households to live farther from the CBD would have to be explained wholly by factors other than accessibility to workplaces. The other explanation is that not every household has a member employed in the CBD, and the income level of a census tract is a weighted average of the incomes of CBD workers and other households. As suggested by Moses (1962) and Muth (1969) if housing prices decline with distance from the CBD, so also must the wage incomes of locally employed workers of given skill. The decline in the incomes of non-CBD-worker households would then tend to offset any tendency for the incomes of CBD-worker households to increase with distance from the CBD. If this second explanation were the correct one, income changes would exert an effect on the rate of housing price decline with distance from the CBD and, thus, population dispersal within urban areas.

Regardless of the reason for the apparent lack of a partial association between income and distance, my earlier work implied that the major reason why higher-income families live farther from the CBD is associated with the age of dwellings. In the literature on real estate and urban economics, the decline in income level of the occupants of a structure as it ages is generally explained by the notion of filtering. (For a typical discussion of filtering see Ratcliffe 1949.) As dwellings age they deteriorate, or grow obsolete, or both. Furthermore, over time incomes rise and more housing is demanded by families at all income levels. Thus, when a family moves from any particular dwelling, its place is taken by one of relatively lower income. On the filtering hypothesis one would expect a more or less steady decline over time in the relative income level of families as dwellings grow older.

Casual observation as well as a recent study of the St. Louis area (Nourse and Phares), however, suggests many instances of older neighborhoods within central cities and whole suburbs that have remained in higher relative income occupancy for long periods of time. At the same time, occupancy of older neighborhoods frequently passes to lower relative income occupancy in a single, rather brief episode. Lower-income immigrants into American urban areas have long tended to concentrate in the older, more centrally located parts of U.S. cities. The immigration into northern and western cities, much of it from the rural South, during and following World War II was no exception. As the size of this group increases, the residential area it occupies spreads outward from the center of the city. This process has been characterized as residential succession (Duncan and Duncan 1957).

In more recent work (Muth 1973), I proposed an explicit theory of how age of dwellings affects the relative income levels of their occupants and rental expenditures at given income levels. In this analysis, housing markets consist of consumers with a given relative income level and preference for housing and producers who sell housing services to them. The relative rental value of dwellings of different sizes is determined by the condition that all such consumers must be on the same indifference curve. If the elasticity of real-income compensated demand is constant and equal to −1.0, the expression for relative rental level is a particularly simple one. Dwelling units may be built to any size, but once built the rate of flow of housing services they provide per unit of time declines at a constant relative rate over time. It is further assumed that real incomes and real construction costs grow at constant relative rates over time. Producers of housing select the size of new dwellings and the length of time to hold them in the housing stock so as to maximize the present value of newly built dwellings. Entry and exit of producers is assumed to equate this present value to zero.

The model implies that the demand function for the size of new dwellings is of the same form as the conventional demand curve for housing services. The appropriate price variable is the rate of return on new dwellings multiplied by construction costs per unit of size. Under the assumptions made in the model, the size of new dwellings, the size of dwelling for which the maximum rental per unit of housing is paid, and the maximum rental all grow at constant relative rates over time. The length of time units are held in the housing stock (T) is a function of the income elasticity of housing demand (β) and the rates of depreciation (δ), interest (i), income growth (ρ), and growth in construction costs (λ); T is constant provided the factors just noted are. Rental expenditures, $R_t(u)$, on dwellings of different age (u) at a given moment in time (t) are proportional to the remaining life of the dwellings, namely:

$$R_t(u) = \alpha y(t)^{\beta}(\delta + \beta\rho - \lambda)(T - u) \tag{1-1}$$

where α is a constant.

With unanticipated immigration by a lower relative income group, the rental offers of the latter for older, smaller dwellings, which are closer to the optimum size for the lower-income group, will be higher than offers of the native population. Provided the immigrant group is small enough, the maximum rental per unit of size paid for housing by this group is less than the maximum paid by the native group. Under these conditions, the immigrant group is wholly housed in older dwellings built for the higher-income native group. The ratio of maximum per-unit rentals depends principally upon the size of the immigrant group, the relative income levels of the two groups, and the age of the newest dwellings occupied by the immigrant group. Given the size of the immigrant group, the last will be smaller the greater the population growth rate of the city. The larger the size of the lower-income group the newer the dwellings it inhabits and the higher the maximum rental per unit of housing service it pays.

The relation of rentals paid by the lower-income group to age of dwelling is similar to that for the higher-income group:

$$R_2(u) = \alpha y_2^{\beta}\,[(\delta + \beta\rho - \lambda)(T - u) + (\hat{q}_1/\hat{q}_2)] \tag{1-2}$$

where $\hat{q}_i$ is the size of dwelling yielding the maximum rental per unit of housing service for group i; subscript 1 designates the higher-income group; subscript 2, the lower. The second term in the bracket in (1-2), however, implies that rental expenditures of the lower-income immigrant group tend to be larger, given income and age of dwelling, than for the higher-income group, even though the maximum rental per unit of housing service paid may be smaller because dwellings of a given age that were built originally for the higher-income group are larger than if they had been constructed for the lower-income group.

With residential succession, the average income level in older dwellings is lower than if succession had not taken place. The larger the immigrant group, the lower their relative income level; and the greater the population growth rate, the lower the average income level in dwellings, say, twenty years old or older relative to that in newer dwellings. At the same time, members of the higher-income group who remain in dwellings older than, say, twenty years live in newer, larger dwellings on the average than would have been the case had succession not occurred. By Equation (1-1), then, average rental expenditures in dwellings more than twenty years old are greater than those made on newer dwellings when both kinds are occupied by members of the higher-income group.

INITIAL FINDINGS BASED ON 1970 INCOME DATA

My initial intention was to use only 1970 census income, age, and other data for my investigation. The 1970 census presents both mean and median income data by census tract, a more complete breakdown of dwellings by age than earlier censuses, and data on place of work by census tract. Since in defining residential succession I wished to have income data for comparable areal units for 1950, 1960, and 1970, in selecting cities for analysis I began with the list of all census-tract cities of 1950. My model of residential succession suggests that rate of population growth and size of the immigrant group are important factors in determining the effects of age of dwelling on household income and rental expenditures. Thus, I wanted to examine data for cities differing in those characteristics.

Though the measurement of population growth is straightforward enough, there are many ways of giving empirical content to the notion of a twentieth-century urban immigrant group. The two I selected were the poverty population and immigrants from outside any SMSA. The former was measured by the fraction of families in the urbanized area with incomes below $3,000 per year in 1959 from the 1960 census; the latter, by the ratio of central-city families in 1960 who resided outside any SMSA in 1955 to all families in the particular SMSA (Census 1963, Table 4). The thirty-two urbanized areas for which there are at least thirty quasi-tracts—central city census tracts which were comparable for 1950, 1960, and 1970 or which could be formed into comparable combinations for the three census years—were then divided into eight groups. These groups were defined by the eight possible combinations of above- and below-median values for each of three characteristics: population growth rate, size of poverty population, and size of rural immigrant population. One city was selected at random from each of the eight classes for analysis. (Miami was the only city in its cell in the three-way classification. The specific cities employed are identified in Table 1-2.) Using the eight cities so selected, four comparisons per year can be made on the effects of any of the three characteristics, with the other two held constant.

For each of the eight cities, regressions of mean income on various measures of age of dwelling and accessibility were run. The 1970 census reports a much fuller breakdown of dwellings by year built than previous censuses. The following are available by census tract: 1969-March 1970, 1965-1968, 1960-1964, 1950-1959, 1940-1949, and 1939 or earlier. The 1950 census data, however, are reported mainly for 1919 or earlier; the 1960 data, for 1939 or earlier. Because little housing was constructed during either the depression years of the 1930s or the war years of the early 1940s, about the only comparisons that could be made with earlier census data were between housing less than or more than thirty years old. Using the 1970 census data, however, I calculated a much more detailed distribution of dwellings by age: less than 5 years, 5-10, 10-20, 20-30, and more than 30 years old.

All but one of these fractions were first entered into a regression analysis as explanatory variables. If the regression coefficients for the various age classes were to show a fairly regular decline as average age of dwelling increases, support would be provided for what I take to be the filtering hypothesis. My analysis of residential succession suggests a quite different pattern, however. Up to a certain age, average income would be constant, then a sharp break would occur, followed by a lower constant income level with increasing age in dwellings inhabited by the immigrant group.

If the filtering hypothesis were correct, the appropriate variable to employ would be a measure of the average age of dwellings. Two age measures were used. For *AVAGE*1 it was assumed that dwellings built prior to 1940 averaged forty-five years in age in 1970. For *AVAGE*2, average age for those more than thirty years old was calculated from the negative exponential distribution implied by the city's average population growth rate from 1900 to 1960 (see Muth 1973, p. 147). On the residential succession hypothesis, however, a single age class would be sufficient to describe the effects of age of dwelling on income. The analysis described in the first section suggests that for sensible parameters, the newest dwellings occupied by the immigrant group would be between twenty and thirty years old (Muth 1973, Table 4). Measures of the fractions of the immigrant group occupying dwellings no more than twenty and thirty years old were employed in turn to test the succession hypothesis and to compare it with that of filtering.

This same regression analysis also permitted a test of the two explanations for the apparent lack of a partial association between income and distance from the CBD once age of dwelling is controlled. For the first time, the 1970 census reports place of work by census tract, although income is not shown separately for families whose heads work in the CBD. In what follows the latter are designated by subscript 1; all others, by subscript 2; the fraction of families whose heads work somewhere other than in the CBD, by f; income, by y; and distance in miles from the CBD, by k. Then, let $y_1 = a + bk$; $y_2 = c + dk$; and therefore, $y = (1 - f)y_1 + fy_2$, or

$$y = a + bk - (a - c)f - (b - d)fk \qquad (1\text{-}3)$$

With the fraction of non-CBD-worker households and its interaction with distance held constant, the coefficient of distance reflects the increase in income of households whose heads work in the CBD. Since it is anticipated that $b > 0$ and $d < 0$, as described in the first section, the coefficient of the interaction term fk is expected to be negative. However, if there were no locational advantages to higher-income CBD-worker households in living farther from the CBD, b would be zero.

The 1970 regression results were full of surprises. In the first runs, the signs of the b and d coefficients in (1-3) were generally as anticipated, but their numerical values were absurdly large. A little checking quickly revealed the reason: simple correlation coefficients between k and fk of about 0.99 in all cities. Checking further, I found that there was little variation among quasi-tracts in the fraction of workers employed outside the CBD and virtually no correlation of the latter with distance. (The simple correlation was positive in four cities and negative in four, but never greater than 0.2 numerically.) This lack of any correlation bears out what I have long suspected from casual observation—that the residences of workers employed in the CBD are uniformly scattered throughout the city. The virtual constancy of f, however, prevents estimation of separate income versus distance effects for households with and without a CBD worker.

Once fk was deleted, the collinearity problem cleared up, but I was presented with two more surprises. The first was that the coefficients of age of dwelling were quite small and erratic. The numbers that were positive and significant at the one-tailed, 5 percent level are shown in Table 1-1. Of the entries shown there, only two coefficients for 5-10 and 10-20-year-old dwellings give any statistical grounds for rejecting the null hypothesis that age of dwellings had no effect on the income level of their inhabitants. The age coefficients exhibit virtually no pattern from one age class to the next or from one city to the next. Likewise, the form in which age effects were entered into the regression made virtually no difference to the results.

On the other hand, the coefficients of distance from the CBD were remarkably strong in all cities and quite uniform among them (Table 1-2). (To facilitate comparisons among years primarily, the coefficients and standard errors shown in the table are expressed relative to average income for all quasi-tracts in the particular city and year.)

Table 1-1. Sign and Significance of Age-of-Dwelling Coefficients, 1970 Regressions[a]

Dwelling Variable	Coefficient (no. of cities)	
	No. Positive	No. Significant (1-tail, 5% level)
Age (years)		
Less than 5	3	0
5-10	5	2
11-20	5	2
21-30	0	0
20 years or older	6	1
30 years or older	3	1
–*AVAGE*1	4	1
–*AVAGE*2	3	1

[a]Separate regressions are marked off by rulings.

Table 1-2. Summary of Partial Coefficients[a] of Income on Distance for Full[b] Regressions

Year	*Migrants[c] High*		*Migrants[c] Low*	
	Poverty High	*Poverty Low*	*Poverty High*	*Poverty Low*
	Population Growth Rate High			
	Kansas City	*Indianapolis*	*Miami*	*Akron*
1950	.11 (.066)	.23 (.050)	–.0145 (.061)	–.0136 (.070)
1960	.17 (.024)	.24 (.027)	.055 (.062)	–.000 (.062)
1970	.20 (.028)	.14 (.025)	.16 (.068)	.034 (.031)
	Population Growth Rate Low			
	Omaha	*Milwaukee*	*Baltimore*	*Buffalo*
1950	–.007 (.061)	.070 (.021)	.11 (.031)	.039 (.049)
1960	.19 (.074)	.11 (.018)	.17 (.021)	.096 (.037)
1970	.15 (.048)	.13 (.021)	.14 (.030)	.11 (.034)

[a]Increase in income per mile divided by average income for all quasi-tracts in the particular city and year.

[b]All variables for age of dwelling included.

[c]From outside SMSAs.

When four age-class variables were used, the coefficient of distance was positive and statistically significant in seven of the eight cities. (In six of the eight, income increased from roughly $1,100 to $1,500 per mile.) In the eighth, Akron, the distance coefficient was roughly twice its standard error when only one age variable was used in the regression. Also, Akron was the only one of the eight for which the age effects were at all robust.

FURTHER FINDINGS ON INTRACITY INCOME VARIATION

Because the 1970 findings were so different from what I had anticipated, I decided to make as nearly the same comparisons as census data permitted for 1950 and 1960. From tract income distributions for the earlier years, mean income was calculated using a Pareto approximation to the upper open-end class. (In a few cases this approximation broke down; so the regressions for 1950 and 1960 are based upon somewhat fewer observations.) For 1950 it was possible to calculate separate age effects for dwellings no more than ten years old, ten to twenty years old, and twenty to thirty years old. For 1960, however, only dwellings no more than ten and ten to twenty years old could be distinguished in the published data on age of dwelling.

Age effects were stronger and distance effects weaker for the 1950 comparisons than for the 1970 ones. Neither was as much so, however, as my earlier published results for 1950 (Muth 1969, pp. 200-202). Except for dwellings no more than ten years old, each age variable was generally positive in six of the eight cities, significantly so in three. Though the probability of three or more significantly positive coefficients in eight observations is less than one in a hundred if no true relation exists, these effects varied considerably from city to city. The distance coefficients were positive in only five cases, but were significantly so in four. These findings thus suggest that, contrary to my earlier conclusion, distance effects on income existed in 1950.

For my 1960 regressions, age effects were even weaker than in 1970. More than half of each of the age-of-dwelling coefficients were negative, and only one out of the eight was positive and significant statistically. Distance effects were somewhat stronger in 1960 than in 1950 but somewhat weaker than in 1970. Seven of the coefficients were positive, and six of these were significant. Taken together, the findings suggest distance effects have become progressively stronger over time but that only for 1950 were age effects of any appreciable importance.

The pattern of simple correlation coefficients provides some insight into the statistical reasons for these findings. Between 1950 and 1970, the distributions of the eight simple correlation coefficients of income on distance were remarkably similar. Indeed, the median of the eight fell slightly, from 0.53 to 0.47. However, the simple correlation of income on age became much weaker. For 1950, seven of the eight coefficients of income on proportion of dwellings no more than thirty years old were 0.48 or greater, the median also being 0.53. In 1970, though, only one of the coefficients of income on the fraction of dwellings twenty years old or less was as large as 0.48, and the median was only 0.20.

The intercorrelation of distance and age of dwelling also became much weaker. For 1950, seven of the eight coefficients for distance and proportion thirty years old or less were 0.7 or greater. In 1970, in contrast, only one of the coefficients of distance on proportion twenty years old or less was as large as 0.7. From all this I would conclude that the true effect of age on income did indeed become weaker, that of distance stronger. Distance effects, however, became increasingly less masked by the intercorrelation of distance and age.

Though my experimental design was originally chosen to compare various factors affecting the size of age effects, the contrasts of distance effects revealed by Table 1-2 is suggestive of a substantive explanation for my findings. In only eight of twelve possible comparisons is the poverty effect relatively strong, and in only six does high population growth produce a relatively large distance coefficient. (For such sign comparisons, at least ten or more out of twelve agreements are needed for significance at the two-tailed, 5 percent level.) For eleven of the twelve paired comparisons, however, the city with the above-median rate of immigration from outside SMSAs had the largest distance coefficient. A closely related finding is that in thirteen out of sixteen cases, the later year has the larger distance coefficient relative to the city's mean income level.

One explanation for the finding that income increases more rapidly with distance where immigration of poor families is above average might run as follows. Initially, low-income immigrants into urban areas settle in parts close to the city center, possibly because the oldest dwellings are there. The effect of boundary externalities on housing prices of the kind discussed by Bailey (1959) are sufficiently strong relative to the differential advantages of dwellings of different ages that expansion of the area occupied by this immigrant group is made into locations immediately adjacent to group's previous location. The observed increase in household income with distance is thus due primarily to the difference in average incomes between the immigrant group in an inner annulus and a native group in an outer one. The larger the immigrant group the greater its average distance from the center; hence the greater the average increase in household income per mile. This explanation is consistent with findings that the larger the migrant population, the stronger the effects of distance upon income in cities at a given time and the stronger those distance effects over time.

Though it is relatively easy conceptually to think in terms of two different income groups and expansion of the lower of the two into the area previously occupied by the higher, it is much harder to give empirical content to such a notion. There were principally two ways by which I tried to do so. One was to define dummy variables for lower-income occupancy in 1950 and for shifts from higher- to lower-income occupancy during the 1950s and 1960s, respectively. This was done in an admittedly quite subjective way based upon an examination of mean income, percent black, and percent five years (one year) old or more residing in the same dwelling five years (one year) earlier in 1970 and 1960 (in 1950). Whether or not a given tract was spatially contiguous to another lower-income tract in the same year also influenced my classification of doubtful cases, since most of the obvious instances of lower-income occupancy were spatially contiguous to another such tract.

Another variable used (*SNY*, below) was the ratio of mean tract income for an earlier to a later census year if tract income for the later year was below the mean for all central-city combinations of tracts used, and *SNY* was zero otherwise. The larger the value of this variable, presumably, the greater the degree or likelihood of succession. In analyzing the 1970 income data and expenditure-income ratios (the latter are described more fully in the following section), four different measures of succession were tried: the sum of my three subjective dummies; the sum of the dummies for succession during the 1950s and during the 1960s; and *SNY*, using both 1950 and 1960 as the earlier year. All four yielded very much the same results. In what follows I discuss results obtained using *SNY*, since it is more objective and thus reproducible; on a-priori grounds, 1950 seems more appropriate for the earlier year.

In addition to *SNY*, I also included two measures of the race characteristics of a tract's population: *NG*1, which equaled 1 if the percent black was at least 70; and *NG*2, which equaled 1 if the percent black was at least 5 but less than 70; and zero otherwise. The variables were included in the income comparisons to remove the effect on the increase in average income with distance that arises because blacks not only have lower incomes than whites but are concentrated closer to the city center. Inclusion of *SNY* and the two racial dummies generally had little effect on the age variable I used: the fraction of dwellings in 1970 built since 1949. Without these three, only two of eight age coefficients were positive and significant at the one-tailed, 5 percent level; with them only 1 was. The effect of including the succession and race variables was, generally, to reduce the size of the distance coefficients by about half. The median of the distance coefficients was about $1,100 per mile without them and $570 per mile with them included. With these three included, though, the distance coefficient was significantly positive in five of the eight cities; in only two of the cities did the distance coefficient become insignificant statistically when succession and race were held constant. Quite similar results were found using 1960 income data. I would conclude, therefore, that the increase in income that is observed as one moves farther from the city center reflects something in addition to the concentration of low-income groups toward the center.

EXPENDITURE-INCOME RATIOS

Equations (1-1) and (1-2) imply that housing expenditures (R) in relation to income (y) and average age of dwellings are of the form

$$R/y = y^{\beta-1}(a - bu + cs) \tag{1-4}$$

where s is a variable indicating the presence of succession. Form (1-4) was chosen for estimation in order more nearly to equalize the residual variance of housing expenditure at different income levels. Form (1-4), or any other form of (1-1) and (1-2), presents problems of nonlinearity of the equation in the coefficients to be estimated. To get around these problems I decided to fix β, the income elasticity of housing demand, at various values in what I believed was a plausible range: $1 \leqslant \beta \leqslant 1.5$. With $\beta = 1$, of course, the expenditure-income ratio is a straightforward linear regression on u and s, and for fixed $\beta > 1$ it is a linear regression on $y^{\beta-1}$, $y^{\beta-1}u$, and $y^{\beta-1}s$ without a constant term. Furthermore, taking $\beta = 1.25$ and $\beta = 1.5$ for 1970 data essentially divided the coefficients for $\beta = 1$ by 10 and by 100 (y averaged about \$10,000 per year), making them implausibly small but not appreciably affecting the fit of the equation. Therefore, I decided to take $\beta = 1$.

I did a considerable amount of other experimenting with the data for 1970. It was indicated earlier that four different measures of residential succession were tried, and *SNY* using 1950 for the earlier year was selected. Two measures of average age of dwelling were tried, differing in the value assumed for the open-end age class. For *AVAGE*1 it was assumed that buildings built prior to 1940 were on average built in 1925; hence they averaged 45 years of age in 1970 and 35 in 1960. For 1950 it was also assumed, as for 1970, that dwellings more than thirty years old averaged 45 years of age. *AVAGE*2 was estimated for each year as described earlier. I used *AVAGE*1 as my age measure because it gave numerically larger and more plausible coefficients than *AVAGE*2.

In calculating housing expenditure from census data, a rental-to-value ratio must be applied to census data on average value of single-family, owner-occupied dwellings. Here I experimented with various values in the range 0.08 to 0.16, and even attempted to estimate this ratio by regressing the product of the renter fraction and the ratio of average contract rent to income on the product of the owner fraction and the ratio of average value to income and other variables. I used a rent-to-value ratio of 0.10 in my final runs because it yielded somewhat stronger coefficients for *SNY* than any larger values, although somewhat weaker ones for *AVAGE*1.

The results obtained for my succession measure were not particularly strong for 1970. Three of the *SNY* coefficients were negative, although in the five cities with positive coefficients three were significant at the one-tailed, 5 percent level. The three significant coefficients were of some quantitative importance; multiplying them by the mean of *SNY* where its value was positive increased the estimated expenditure-income ratio for a 35-year-old structure from about 0.12 to 0.13. In only one of eight cities, though, did inclusion of *SNY* appreciably reduce the coefficient of *NG*1, the dummy variable indicating predominantly black occupancy.

When I repeated the regressions using 1960 data, however, the *SNY* coefficient was negative for six cities, and only one of the two positive coefficients was significant at the 5 percent level. Since the final form of the equation was chosen in part to make the succession coefficients as strong as possible, I would reject the hypothesis that housing expenditures are larger than otherwise where residential succession has occurred. The further results described below thus refer to regressions with *SNY* omitted.

The coefficients of *AVAGE*1 were considerably stronger than those of *SNY* and rather more consistent from year to year. These are shown in Table 1-3 for the three census years. For each of the three years seven of the eight age coefficients were negative, and at least four were significantly so at the 5 percent level (five in 1960). The coefficients were reasonably stable numerically, their medians being −0.82 in 1950 and 1970 and −1.2 in 1960. Likewise, the coefficients indicate a fairly strong quantitative importance. For 1970, a coefficient of −0.8 converts an expenditure-income ratio of 0.15 for a new dwelling to 0.12 for a 35-year-old one. One fact literally jumps out of the table: The coefficients are much larger numerically and a higher proportion are significant for cities with low population growth rates than for those with high growth rates. Ten of the twelve coefficients for the former groups are significant, but only three of the latter.

Also shown in Table 1-3 are the constant terms in the regressions. For each of the three years there is some variability from city to city, but much less than for the other coefficients estimated. Clearly, though, there is a strong tendency for expenditure-income ratios to

Table 1-3. Coefficients of Variables in Regressions[a] for Expenditure-Income Ratios (figures in parentheses are estimated standard errors)

City	*Constant* 1950	1960	1970	*AVAGE1* $\times 10^3$ 1950	1960	1970	*NG1* $\times 10^2$ 1950	1960	1970
Population growth rate high									
Kansas City	.186	.172	.141	−0.028	−0.812	−0.484	0.62	1.80*	−1.45
	(.016)	(.019)	(.015)	(0.464)	(0.609)	(0.385)	(1.31)	(0.54)	(0.41)
Indianapolis	.193	.140	.117	−1.08*	−0.442	−0.366	1.28	2.17*	1.59*
	(.015)	(.016)	.017)	(0.41)	(0.467)	(0.412)	(0.97)	(0.55)	(0.60)
Miami	.221	.179	.154	2.25	1.09	0.687	4.40*	4.51*	0.60
	(.020)	(.015)	(.017)	(1.18)	(0.70)	(0.683)	(2.34)	(1.14)	(1.03)
Akron	.209	.200	.176	−0.557	−1.52*	−1.23*	b	1.89*	0.232
	(.016)	(.010)	(.007)	(0.516)	(0.35)	(0.19)		(0.93)	(0.369)
Population growth rate low									
Omaha	.196	.189	.155	−0.161	−1.42*	−0.908	−2.44	−0.729	1.95*
	(.025)	(.013)	(.022)	(0.733)	(0.45)	(0.602)	(2.37)	(0.768)	(0.81)
Milwaukee	.270	.236	.151	−2.52*	−2.69*	−0.725*	b	1.57*	0.090
	(.013)	(.015)	(.010)	(0.34)	(0.45)	(0.242)		(0.48)	(0.341)
Baltimore	.231	.150	.132	−1.74*	−1.06*	−1.03*	5.97*	5.12*	3.44*
	(.011)	(.008)	(.008)	(0.33)	(0.27)	(0.21)	(1.27)	(0.45)	(0.44)
Buffalo	.243	.249	.197	−2.33*	−3.51*	−2.13*	b	b	0.685
	(.023)	(.031)	(.029)	(0.65)	(0.94)	(0.71)			(0.728)

*Significantly less than zero at the one-tailed, 5 percent level.

[a]*SNY* excluded, *NG*1 and *NG*2 included whenever more than one observation equaled unity.

[b]Omitted from regression where at most one combined tract had a value of unity.

decline over time. In all cases but one, the ratio is smaller in a later than in an earlier year for the same city. One interpretation of this decline is that the income elasticity of housing demand is less than 1.0, with the result that with rising incomes a smaller proportion is spent on housing. I am reluctant, though, to accept this explanation, in view of the substantial body of other evidence that suggests housing expenditures increase at least in proportion to income (see de Leeuw 1971). Another explanation is that as central-city taxes have risen relative to those in suburban areas, central-city housing prices have fallen relative to those in suburban areas, thus eliminating the net advantages of one location over the other.

Finally, the coefficients of $NG2$, which stands for mixed neighborhoods, was negative about as often as positive. The one or two cases a year that were significant at the two-tailed, 5 percent level, though, were positive. The coefficients of the black neighborhood variable, $NG1$, are shown in Table 1-3. Virtually all are positive, many significantly so at the one-tailed, 5 percent level. Both their magnitude and significance tend to increase from 1950 to 1960 and then to decline in 1970. A coefficient of 2.0, more or less typical of the significant ones in 1970, indicates the expenditure-income ratio for 35-year-old dwellings would be 0.14 in black neighborhoods as compared with 0.12 in white ones.

CONCLUSIONS AND TENTATIVE IMPLICATIONS

Any inferences based upon empirical work are necessarily tentative. Because the findings discussed above differ so strikingly from some of my earlier ones, I have been made all the more aware of this often-forgotten methodological point. If anything can be concluded from these results, though, it would seem to be that age of dwelling no longer has any appreciable effect upon the pattern of location of households by income level in urban areas. These findings cast considerable doubt upon the empirical validity of the filtering hypothesis in urban housing markets. Equally, they suggest to me that the pattern of neighborhood succession which takes place as an immigrant population grows is not very much affected by the age of dwellings.

While I am not yet prepared to abandon the notion of an immigrant population, the results suggest the poverty population does not correspond particularly well to this notion. Migrants from rural areas, rather, would seem to produce stronger effects upon the locational patterns of households classified by income level. Neither am I yet willing to abandon the belief that as the incomes of

CBD-worker households rise, their housing expenditures rise relative to their marginal costs of transport. The major explanation for the observed rise in household income with distance from the city center is to be found elsewhere, however. For in the cities studied, only about 10 percent of employment was located in the CBD; the CBD-worker-household effect is simply not a very important one in the income data. And, indeed, as the relative rate of decline in housing prices becomes smaller over time as average income and the speed of urban automobile travel has increased, the locational advantage to higher-income CBD-worker households in living farther from the center would have declined. Yet my findings suggest that the relative increase in household income per mile has risen over time.

Not only is neighborhood succession not very closely associated with age of dwelling, but there is little tendency for housing expenditures to be high in relation to income in parts of cities that have succeeded to lower-income occupancy. My vintage model thus appears to be of little help in understanding neighborhood succession, but predictions regarding the effects of age of dwelling on housing expenditure seem more successful. Qualitatively, seven of the eight cities exhibited negative coefficients in each of the three census years I examined, and four or five each year were significant. The age coefficients are moderately stable from year to year, but my theory did not lead me to expect these coefficients to vary inversely with a city's population growth rate.

Are the a and b coefficients of (1-4) quantitatively consistent with Equation (1-1)? Some calculations relating to this question are shown in Table 1-4. While I have a fairly good idea of the other parameters necessary to calculate the coefficients, it was necessary to estimate α from the data. Since

$$R = \alpha y^{\beta}\left[1 + 1n\frac{q(u)}{\hat{q}}\right]$$

α can be calculated from the rental of dwellings $\hat{u}$ years old, whose size, q, is equal to the optimal current size, $\hat{q}$. The vintage model as formulated in my earlier paper (Muth 1973) implies $\hat{u} = T - (\delta + \beta\rho - \lambda)^{-1}$. (The calculation of T, the age at which units are retired from the housing stock, is discussed in Muth 1973.) From median values of my a and b coefficients I then calculated $\alpha = (R/y)(\hat{u}) = 0.152 - 0.00082\hat{u}$, which, together with other values shown in Table 1-4, permits calculation of expected values of a and

Table 1-4. Effects of Alternative Depreciation Rates on Dwelling Characteristics[a]

	$\delta = 0.02$	$\delta = 0$
T	43.7	87.1
$\hat{u}$	15.1	20.4
α[b]	0.140	0.135
a	0.214	0.176
b	0.0049	0.0020
$-\ln W'(20)$	0.061	0.019

[a]Assuming $\beta\rho = 0.025$, $\lambda = 0.01$, $i = 0.07$.

[b]Estimated from $\alpha = R/y(\hat{u}) = 0.152 - 0.00082\,\hat{u}$.

b. For $\delta = 0.02$ these are much larger than my estimates; for $\delta = 0$ they are only somewhat larger than my estimates, especially the calculated b for cities with high rates of growth of population.

Some additional insight into this question is provided by examining the relative rate of decline of the market value of dwellings over time. The latter, of course, is the integral of discounted future quasi-rents. My vintage model implies that the market value (W) as a function of age is

$$W(u) = \frac{\alpha y^{\beta}(\delta + \beta\rho - \lambda)}{(i - \beta\rho)^2} \quad (i - \beta\rho)(T - u)$$

$$- \quad 1 - \exp\left[-(i - \beta\rho)(T - u)\right]$$

As such the relative rate of decline of market value varies with age, increasing rapidly as a dwelling nears replacement age. As shown in Table 1-4 for twenty-year-old dwellings, $\delta = 0.02$ implies a relative decline in value of about 6 percent per year; $\delta = 0$, about 2 percent. The latter agrees closely with the annual relative rate of decline estimated by Grebler, Blank, and Winnick (1956, pp. 377-382). If the implication is previously mentioned spatial patterns of income emerges. To "validate" this over time, then my vintage model is reasonably consistent with the decline both in observed rentals and market values of dwellings over time. The vintage model explanation for these declines and the ultimate replacement of dwellings is that, being fixed, the flow of housing services given off by dwellings declines relative to the market demand for housing, not absolutely.

Though I feel it reasonable to claim some modest empirical success for my vintage model, the model would appear to provide little help in understanding the locational pattern of households by income level in urban areas. It seems clear, however, that average incomes increase with distance from the city center and that this rate of increase has grown relatively greater over the postwar years. Work done by some of my students suggests that the average income of a census tract both affects and is affected by the rental value of its dwelling units. Breuckner (1975), in particular, has found that succession as measured by the variable I call *SNY*, tends to occur principally in parts of the city where dwellings are smaller than average. The age of dwellings, however, is not a very good surrogate for size of dwelling, as is assumed in the vintage model. To explain the location of households by income and the pattern of neighborhood succession would seem to require a theory of the distribution of dwelling units by size in urban areas.

REFERENCES

Alonso, William. 1964. *Location and Land Use.* Cambridge, Mass.: Harvard University Press.

Bailey, Martin J. 1959. "Note on the Economics of Residential Zoning and Urban Renewal." *Land Economics*, August.

Brueckner, Jan. 1975. "The Determinants of Residential Succession." Processed.

Census. 1963. U.S. Bureau of the Census, *U.S. Census of Population: 1960*, Final Report PC(2)-2C, Mobility for Metropolitan Areas. Washington, D.C.: Government Printing Office.

de Leeuw, Frank. 1971. "The Demand for Housing: A Review of Cross-Section Evidence." *Review of Economics and Statistics*, February.

Duncan, Otis Dudley, and Beverly Duncan. 1957. *The Negro Population of Chicago.* Chicago: University of Chicago Press.

Grebler, Leo; David M. Blank; and Louis Winnick. 1956. *Capital Formation in Residential Real Estate: Trends and Prospects*, Princeton, N.J.: Princeton University Press for NBER.

Mills, Edwin S. 1967. "An Aggregative Model of Resource Allocation in a Metropolitan Area." *American Economic Review*, May.

_______. 1969. "The Value of Urban Land." In Harvey S. Perloff, ed. *The Quality of the Urban Environment.* Washington, D.C.: Resources for the Future.

Moses, Leon N. 1962. "Toward a Theory of Intra-Urban Wage Differentials and Their Influence on Travel Patterns." *Papers and Proceedings of the Regional Science Association.*

Muth, Richard F. 1969. *Cities and Housing.* Chicago: University of Chicago Press.

_______. 1973. "A Vintage Model of the Housing Stock." *Papers and Proceedings of the Regional Science Association.*

Nourse, Hugh O. and Donald Phares. 1974. "The Filtering Process: Aging or Arbitrage." In Solomon Suther and Sara Suther, eds. *Racial Transition in the Inner Suburb.* New York: Praeger.

Ratcliff, Richard V. 1949. *Urban Land Economics.* New York: McGraw-Hill.
Wingo, Lowden, Jr. 1961. *Transportation and Urban Land.* Washington, D.C.: Resources for the Future.

Comments on Chapter One

William C. Wheaton

In this study Muth tries to analyze the underlying reason for a pervasive locational pattern in America: the higher the income of a household, the further it is likely to be living from the urban center. The explanation Muth offers is derived from his earlier development (Muth 1973) of a vintage model of the urban housing stock. In that model, housing built in one period deteriorates in relative terms as time passes. New housing is built in response to increases in aggregate demand and, hence, an age distribution of the stock emerges. The market allocates older units to low-income households because of their inability to bid high enough to capture new housing. Since older housing is more centrally located, the previously mentioned spatial pattern of income emerges. To "validate" this theory, Muth proposes to see if the simple correlation (positive) between income and commuting distance vanishes as age of unit is introduced. If it does the model is purported to be verified; if not, other explanations must be sought.

My first reaction to this study involves its general methodology. Given the proposition Muth wishes to test, I cannot see how the accompanying empirical work serves as validation. It is a well-known problem in causal inference (Blaylock 1971) that a vanishing partial correlation coefficient cannot distinguish between the following two cases at hand:

1. Because of the gradual evolution of the stock, location determines the age of unit which in turn determines the income of occupant.

2. Location determines income and age separately, but the latter has no causal connection with the former.

Thus Muth's "test" is ill-designed in the first place. Interestingly, the results of the empirical work show that the introduction of age does not appreciably weaken the income-location linkage, but rather that the age-income partial is weak. Here again, however, Muth's use of a single-equation model does not allow even a rejection of the hypothesis that age has a separate effect. At a minimum there should be a recursive system of equations in which the indirect effect of location on income (by determining age) can be compared with its direct impact.

Even this, however, might not be sufficient, for there is the serious question of simultaneity. Throughout Muth's work, there is the assumption that unit "age" is not desired by consumers. Ceteris paribus, I find this a highly questionable assumption. Many and perhaps even a majority of the older houses in today's stock are large, spacious, well-constructed units. If age had not brought with it deterioration and changing neighborhoods, these units might be the most sought after. My own work on hedonic indexes with Boston data indicates that many households prefer older units—ceteris paribus with respect to other attributes. If, however, condition is not controlled for (which is the case here) some of its effect is picked up by unit age and accounts for the slight negative effect of the latter on income. The problem then is that "age" (including the condition effect) is determined by income in addition to being its determinant. Since the location by income pattern affects unit maintenance, and hence "age," we have substantial simultaneity—an issue Muth never mentions. In short, Muth's empirical work is not an appropriate test of his hypothesis. This leads me to a second issue—whether the hypothesis itself can shed much light on the evolution of the spatial distribution of income in the United States.

The income location pattern in any city is the evolving outcome of a competitive process between households of vastly different wealth and tastes. In this context, I doubt that any aggregate statistical analysis can "explain" the emerging market outcome. Even if all variables besides age were controlled, what would a negative partial between the latter and local income tell us? Only that ceteris paribus, wealthy people live in newer units, not necessarily that they *prefer* these units or that this relationship is at all important in explaining *why* they live there. It is only with a disaggregated analysis of consumer preferences and supply behavior that we will gain an appreciation of how and why the market produced its observed outcome. Within such a framework there has been some recent research that approaches the same question Muth raises—that of explaining the locational pattern by household income in American cities.

As Muth mentions, both some of his earlier work and that of Mills (1972) suggest that location in the long run, when capital is mobile, occurs as the result of a tradeoff between travel costs and housing expenditure. A problem with this approach is the use of a one-dimensional measure of housing services. If in fact housing has many attributes (and it does) and consumers have different orderings over this commodity space (and they do), then the theory of aggregation tells us that no single measure of housing services exists. This raises some question as to whether empirical estimates of parameters in the model mean very much. Alonso (1965) avoids this problem by viewing location as a tradeoff between travel and land expenditure. With capital mobile in the long run, housing is implicitly treated as an "other" good that can be freely supplied in any quantity at any location. The supply parameter of some nonexistent commodity called housing "services" does not affect location—it is consumer preferences for low-density living and minimal travel time that do—and both of these can be estimated for different households.

Within Alonso's framework, the characteristics of the existing housing stock do not influence the long-run locational pattern. Since existing units can in principal be modified to any density or size, the pattern of income by location must be caused by differences in the preference for land and travel. If, as income increases, land demand rises more rapidly than the disutility of travel, wealthier households will have relatively flat "bid price surfaces" and will outbid lower-income groups for more distant sites. If greater income has little effect on land demand, but significantly increases the disutility of travel, the reverse holds and the market solution will be for income to decrease with distance.

Using an extensive home-interview survey for San Francisco, I recently estimated utility parameters for several socioeconomic classes of households for a series of housing attributes including size, condition, age, travel time, land, and neighborhood quality (Wheaton 1973a). Comparing the results across income groups I found that both the demand for land and the disutility of travel increased with wealth, and at about the same rate. Using these results to simulate a long-run market equilibrium, I generated a locational pattern in which income increased ever so slightly with distance to the CBD (Wheaton 1973b). At first glance then, this might seem to indicate that differences in consumer preferences for land and travel are sufficient, on their own, to explain the U.S. spatial pattern. A closer examination, however, revealed that the equilibrium locations in the simulation resulted from exceedingly small differences in the bids between income classes. The rich lived on the periphery of urban areas because they outbid the poor, but by less than 10 percent! This verifies that while income does result in greater concern both for land and travel, the two effects almost cancel each other out. Differences in demand for these commodities (at least by income), then, are probably *not* an important determinant of U.S. land use.

Where does this leave us, in our search for an explanation of American locational patterns? The deteriorating housing stock is ruled out because, first, it can always be rehabilitated and, second, the housing problem is caused by low-income occupancy. Differences in the preference for land and travel have now also been ruled out, and so we are left with one remaining consideration—externalities, both those resulting from the city itself (noise, pollution) and those arising from the presence of low-income residents (crime), and pecuniary externalities that result from urban fiscal fragmentation. These factors have been well-elaborated elsewhere, and the builders of urban models should begin to incorporate them explicitly.

REFERENCES

Alonso, William. 1965. *Location and Land Use.* Cambridge, Mass.: Harvard University Press.

Blaylock, Herbert. 1971. *Causal Models in the Social Sciences.* Chicago: Aldine-Atherton.

Mills, Edwin S. 1972. *Studies in the Structure of the Urban Economy.* Washington, D.C.: Resources for the Future.

Muth, Richard, 1973. "A Vintage Model of the Housing Stock." *Papers and Proceedings of the Regional Science Association.*

Wheaton, William. 1973a. "A Bid Rent Approach to Housing Demand." Processed. Cambridge, Mass.: Massachusetts Institute of Technology.

_______. 1973b. "Income and Urban Residence: An Analysis of the Consumer Demand for Location." Processed. Cambridge, Mass.: Massachusetts Institute of Technology.