Volume Title: Explorations in Economic Research, Volume 3, number 1

Volume Author/Editor: NBER

Volume Publisher: NBER

Volume URL: http://www.nber.org/books/gort76-1

Publication Date: 1976

Chapter Title: Housing Demand in the Short Run: An Analysis of Polytomous Choice

Chapter Author: John M. Quigley

Chapter URL: http://www.nber.org/chapters/c9079

Chapter pages in book: (p. 76 - 102)

3

JOHN M. QUIGLEY
National Bureau of Economic Research
and Yale University

Housing Demand in the Short Run: An Analysis of Polytomous Choice

ABSTRACT: In this paper the author presents a model of household choice among types of residential housing that incorporates intrametropolitan variations in housing prices arising from variations in work site location. Under suitable assumptions, the prices that households face in choosing among alternative types of residential housing are deduced. ¶ The empirical analysis suggests that consumers are responsive to the systematic variation in these prices in their choices among housing types in a metropolitan area. A model relating household choices among some 18 types of residential housing to intrametropolitan price variation is estimated by maximum likelihood methods using conditional logit analysis. The results of the analysis, which is conducted separately for some 30 stratifications of households by income and family size, provide strong evidence of the importance of these intrametropolitan variations in relative prices in motivating choice among alternative types of residential housing.

NOTE: A previous version of this paper was presented at the winter meetings of the Econometric Society, New York, December 1973. I am grateful to Bill Apgar, Jim Ohls, and William Weaton for helpful criticism of an earlier draft, and to Wallace Campbell, Walter Fisher, and Philip Klutznick of the Board reading committee for their comments on the final version of the paper.

Existing empirical studies of the demand for housing, usually based on aggregate cross-section data, ignore (or assume away) several crucial features of the urban housing market. First, these studies measure housing consumption in a single dimension, rental payments (or housing values), despite the obvious heterogeneity of the housing stock. Secondly, these studies either ignore housing prices completely in focussing on the income-expenditure relation, or they rely upon crude measurements of "average" housing prices in an entire metropolitan area.[1]

The few analyses of the demand for housing based upon micro units, i.e. individual households and dwelling units, have established, not surprisingly, that specified types of housing consumers demand particular components of housing services. However, these recent studies have only analyzed the effect of housing prices upon household demand under the implicit assumption that components of housing services may be purchased quite independently of one another.[2]

Theoretical analyses of residential location and the demand for housing stress the importance of the work trip in determining the spatial location of housing consumption and the quantity of "housing services" demanded.[3] Yet with very few exceptions, these theories ignore the existence of durable and differentiated stocks of residential housing. These theoretical analyses in effect assume that the urban area will be built *de novo* during any period of analysis.

Neglect of the heterogeneity of housing in both residential location and housing demand studies is clearly justified in certain situations, notably in the analysis of comparative statistics when the central focus of the investigation is upon the long-run equilibrium of the entire market for "housing services." Since in the long run housing can be converted or built anew at any site, the convenient notion of undifferentiated "housing services," measured by total monthly expenditures, is appropriate in analyses of both consumer demand and choice of location.

Yet it is equally clear that dwelling units emitting the same quantities of "housing services," as measured by contract rent or monthly expenditures, are often viewed as utterly distinct by both housing suppliers and demanders. Indeed, both producers and consumers may view them as much less similar than other units which differ substantially in price. The substantial costs of transforming the characteristics of existing units implies that housing units of various types may earn substantial locational quasi-rents for long periods of time.

Indeed, the first attempts to incorporate distinct components of housing services explicitly into consumer demand theory have already been undertaken by Sweeney.[4] In his insightful theoretical analysis, Sweeney defines a "hierarchy" of housing commodities and derives the equilibrium conditions for a market characterized by discrete housing types that can be ranked identically by all consumers from the "most preferred" to the "least preferred" type. Sweeney also investigates changes in the demand for all housing types in response to a change in the price of any single type. In concentrating upon the "hierarchical" nature of the housing commodity, however, Sweeney ignores the spatial aspects of the housing market.

The polycentric nature of employment locations in real urban areas and the importance of the work trip in determining both residential location and the choice of housing type greatly complicate the problem. The durability and fixity of residential housing suggests that households face differing effective prices for the same types of housing depending upon their work place locations, at least as long as transport is not costless.

This paper extends the theoretical analysis of the demand for housing to incorporate the spatial dimension (and thus the residential location decision), as well as the choice of housing type. In particular, we address the choice of housing type and residential location in a metropolitan area which may have several work places. In this short-run analysis, the spatial distributions of the stocks of various types of housing are given. Although the monocentric assumption of traditional residential location models is abandoned, the analysis relies upon the primary insight of residential location theory—the willingness of consumers to substitute transport costs, specifically work trip commuting costs, for housing prices in choosing residential locations. The theoretical model indicates how choices among housing are related to systematic variations in the relative prices faced by households for the same types of residential housing. The model indicates that these prices, in turn are heavily dependent on the interaction of work place location, the spatial distribution of the stock of housing, and the characteristics of the urban transport network.

The model is estimated empirically, by conditional logit analysis, based upon the actual choices made by a sample of some 3,000 renter households in the Pittsburgh metropolitan area. The results provide rather powerful predictors of the housing choices made by the sample of relocating households; yet the results are not necessarily consistent with the notion of equilibrium in the housing market as a whole. In particular, the results are generally consistent with the possibility, at given prices, of excess demand or excess supply of particular types of housing at certain locations.

In choosing a dwelling unit, households jointly purchase a wide variety of attributes at a particular location. Considerable effort has already been expended by researchers to isolate those attributes of the housing "bundle" that command prices in the market.[5] Without loss of generality, we can classify units into housing "types" or collections of attributes. Each housing type is defined at specified values of the vector of attributes that command market prices. The set of mutually exclusive housing types represents all possible choices that may be made by any housing consumer. We assume that each consumer will choose one (and only one) residence from the set.

During any given period only a small fraction of urban households become "movers" and actively search for new residences in the urban area. Typically these households include:

1. additional workers induced to the urban area;
2. new households formed during the period;
3. those whose preferences for housing attributes have changed;
4. those for whom the relative prices of housing types have changed appreciably.

Since preferences for particular configurations of housing are strongly related to family size, composition, and age as well as family income, the third category includes movers induced by life-cycle changes in households. For reasons discussed below, the fourth category includes households whose work place has changed as well as those with unchanged work places who face changes in relative prices. However, since moving within the urban area imposes economic and other costs upon households, we may suppose that for households with unchanged preferences and work places, appreciable changes in relative prices will be required to induce intrametropolitan mobility.

In any period each household making a residential choice gathers information on the spatial locations of each type of housing and on the market prices of housing types at these locations. Since alternative spatial locations impose costs upon the household, each household similarly gathers information on the accessibility costs associated with different sites. These accessibility costs will reflect the out-of-pocket costs and the opportunity costs of the time expended in commuting and in travelling to other points.

For an individual household, the choice of the best, or "optimal" location, for any *particular* type of housing is straightforward, at least in principle. For each possible location the household adds the accessibility costs to the housing price schedule and calculates the *total* cost of consuming that type of housing at that location. The site at which this *total* cost is a minimum is the optimal location for consuming the *particular* type of residential housing.

The household's ultimate choice among housing types is systematically related to this cost minimizing calculus. After calculating the optimal (i.e. the minimum cost) location for each type of residential housing, the household chooses among locationally subscripted housing types on the basis of its preferences for the underlying housing characteristics and the relative costs (or effective prices) of the alternatives. Note that the total cost of each housing type at its minimum priced location is the relevant price in considering the choice among housing types. If, as the assumption of residential location theory suggests, work trips are the most important component of accessibility costs, the effective price facing different households for consuming a particular type of housing varies with the placement of their work sites relative to concentrations of the available stock. If travel time is related to alternative wages, the price will also vary for households with different wages.

In a city where work places and incomes are not identical and where durable and heterogeneous residential structures exist, our theory suggests that consumers' choices among housing types will be dependent upon these relative prices.

For simplicity assume that each household entering the housing market possesses perfect information about housing prices and the spatial distribution of housing units; that is, assume that each moving household knows the surface of prices and housing stock densities in the urban area for every housing type.

For most households, the single most important component of the accessibility costs of any site is commuting expenditures. For example, studies of household trip-making behavior indicate that work trips alone account for 40–45 percent of total trips and account for more than twice as many trips as any other class. In addition work trips are, on average, longer than other types of trips, so their share of accessibility costs is much larger than their share of total trips. Finally, work trips are typically made on a regular basis to particular sites and most other trips are made to diverse destinations. It has been found, for example, that "the [accessibility] costs to any single point [other than work place] are almost always trivial."[6] In contrast, journey-to-work costs are typically incurred to reach a particular destination and their magnitude is substantial. These factors suggest that work trip costs are a good approximation to total accessibility costs. In particular, we will assume that households have an inelastic demand for trips to the work site and that all other trips are made to ubiquitous and substitutable destinations. This assumption is fairly common in models of residential location.

In contrast, however, to traditional residential location theory, we do not assume that all households have the same work place. We recognize the polycentric nature of urban areas by assuming instead that locating households have known and fixed work places.

Under these assumptions the household can calculate the total cost of consuming each type of housing at each location. By searching for the minimum, the household can discover the optimal site and its associated cost for each type of housing. As noted previously the optimal site and the cost associated with it will vary with work place and wages or incomes.

(1) $P^*_{ijy} = \min_m [P_{ijym}] = \min_m [R_{im} + T_{jmy}]$

Definitions for the variables appear in the following list:

R_{im} is the contract price (monthly rent) of housing type i at residential site m.

T_{jmy} is the (monthly) cost of work trips between work place j and residence site m for workers with income y.

P_{ijym} is the total (monthly) cost of housing type i at location m for workers of income y with work site j.

P^*_{ijy} is the effective or minimum (monthly) price of consuming housing type i for workers with income y and work site j.

$i = 1, 2, \ldots, I$ identifies housing types;

$m = 1, 2, \ldots, M$ identifies residence sites;

$j = 1, 2, \ldots, J$ identifies work sites;

$y = 1, 2, \ldots, Y$ identifies incomes.

Households with given work places, j, and income, y, face a budget constraint of the form

(2) $y = P_z z + P^*_i$

where z is the amount of other (nonhousing, nontransport) goods consumed at price P_z, and P^*_i is defined in equation 1 (with the work place and income subscripts suppressed) as the cost of consuming housing type i at its minimum priced location.

For each of the I discrete types of residential housing we define X_i as the vector of their underlying characteristics $(x_{1i}, x_{2i}, \ldots, x_{ni})$, $i = 1, 2, \ldots, I$.

Households are assumed to value the underlying characteristics of the housing types as well as other goods z, i.e., they have utility functions of the form,[7]

(3) $U(X, z)$

Since each locating household occupies but a single housing unit, each household makes one choice out of the range of discrete housing bundles, in addition to its choices of other (nonhousing, nontransport) goods. For a household of given income, knowledge of the housing type consumed and its effective price determines the amount of other goods that may be purchased. Thus for given incomes, each housing bundle and its price represent a complete choice over all goods, i.e., the mixed direct-indirect utility function

(4) $U(X_i, P^*_i)$

represents the budget-constrained level of utility derived by a household with income y living in housing type i. The consumer's problem is to select the housing type i which yields the highest level of utility.

Preferences for particular underlying characteristics defining housing types depends upon certain attributes of the households, notably family size and composition, or "life cycle" attributes. If we consider households with common incomes, y, and life cycle attributes a, utility maximization implies that housing type i will be chosen if

$$(5)\quad U_{ya}(X_i, P_i^*) > U_{ya}(X_j, P_j^*) \text{ for all } j \neq i$$

Since some of the influences upon consumer tastes are unobserved even if households are stratified by income and household attributes, the deviations of individual preferences from the average of the socioeconomic group (y, a) may be summarized in a stochastic component.[8]

$$(6)\quad U_{ya}(X_i, P_i^*) = W_{ya}(X_i, P_i^*) + \epsilon_{ya}$$

where W_{ya} represents the preferences of the "representative" consumer, and ϵ_{ya} summarizes the influences upon preferences of all factors which are unobserved.

Thus if the preference functions are interpreted as having a stochastic component, the probability (ρ_{yai}) that a particular household of class (y, a) will choose housing type i over all other types depends on the probability that the utility of housing type i exceeds the utility of each other type j, i.e.

$$(7)\quad \rho_{yai} = \text{prob}\,[U_{ya}(X_i, P_i^*) > U_{ya}(X_j, P_j^*)] \text{ for all } j \neq i,$$

and

$$(8)\quad \rho_{yai} = \text{prob}\,[\epsilon_{yaj} - \epsilon_{yai} < W_{ya}(X_i, P_i^*) - W_{ya}(X_j, P_j^*)] \text{ for all } j \neq i$$

Equation 8 indicates that the probability of choosing any particular housing type depends on the vector of housing characteristics of *all* housing types and their total costs and on a vector of stochastic elements. If the vector of stochastic terms follows some known distribution, it is possible to derive an explicit formula for p.

In particular, as McFadden has demonstrated,[9] if ϵ_i and ϵ_j are statistically independent with the reciprocal exponential distribution

$$(9)\quad \text{prob}\,(\epsilon_i \leq Z_i) = e^{-e^{-Z_i}}$$

then

$$(10)\quad \text{prob}\,(\epsilon_i - \epsilon_1 \leq Z_i) = \frac{1}{1 + \sum_{i=2}^{I} e^{-Z_i}} = \frac{\sum_{i=2}^{I} e^{Z_i}}{1 + \sum_{i=2}^{I} e^{Z_i}}$$

and

$$(11)\quad p_{\nu a i} = \frac{e^{W_{\nu a}(X_i, P_i^*)}}{\sum_{j=1}^{I} e^{W_{\nu a}(X_j, P_j^*)}}$$

In equation 11 the probability of choosing any particular housing type i depends on the attributes and prices of each of the available types. The sum of the probabilities over the I housing types is 1 and the probability of choosing any single type will lie between 0 and 1. In short, equation 11 represents a well-behaved probability function. From equation 11, the odds of choosing i over alternative j may be expressed as

$$(12)\quad \frac{p_{\nu a i}}{p_{\nu a j}} = \frac{e^{W_{\nu a}(X_i, P_i^*)}}{e^{W_{\nu a}(X_j, P_j^*)}}$$

or

$$(13)\quad \log \frac{p_{\nu a i}}{p_{\nu a j}} = W_{\nu a}(X_i, P_i^*) - W_{\nu a}(X_j, P_j^*)$$

Equation 13 implies that the choice between any two housing types is independent of the characteristics of the other housing types. Since, by definition, the set of housing types represents the entire range of choice, an individual's ranking of all possible housing types is completely determined by a series of paired comparisons. This property, the so-called "independence of irrelevant alternatives," implies that if those characteristics which define housing types are chosen correctly, the analysis can be generalized to address the probability of choosing "new" types of housing (i.e., combination, of housing characteristics which may not be observed in a given sample).

The logic of equation 11 also implies a separability property in the choice of housing characteristics. Even if housing characteristics are only available in discrete bundles or types, for any given price vector a household's probability of choosing specified levels of two characteristics can be decomposed into an independent marginal and a conditional probability.

In the empirical analysis that follows, it will be assumed that $W_{\nu a}$ is linear in its parameters.[10] In this case,

$$(14)\quad W_{\nu a}(X_i, P_i^*) = \sum_{l=1}^{n} b_{\nu a l}\, x_{li} + b_{\nu a, n+1} P_i^*$$

the statistical model is a multinomial generalization of the logit model often applied to situations involving binary choice, and the parameters can similarly be estimated by maximum likelihood methods. In addition, if preferences can be approximated by any function linear in its parameters, McFadden has shown that the likelihood function is concave, implying that iterative estimation procedures converge upon the unique maximum likelihood estimator of the b parameters.[11]

Equations 13 and 14 imply the multinomial logistic model to be estimated separately for each stratification of income and socioeconomic characteristics (y, a).

$$(15) \quad \log (p_i/p_j) = b_1 (x_{1i} - x_{1j}) + \ldots + b_n (x_{ni} - x_{nj}) + b_{n+1} (P_i^* - P_j^*)$$

Empirical estimates of the demand for housing types and individual housing characteristics are obtained by using information from a large-scale home interview survey conducted in 1967 in the Pittsburgh Metropolitan Area.[12] The empirical analysis uses price and housing stock information gathered on some 25,000 dwelling units to analyze the housing choices made by approximately 3,000 rental households who made location decisions within the seven year period 1960–1967.

The central hypothesis is that the multiplicity of work places interacts with the location of durable stocks of differentiated housing types to create systematic variation in the relative prices of housing types that confront households in the urban area. These systematic variations in relative prices are derived from variations in journey-to-work costs, and by hypothesis they affect households' choices among housing types or housing configurations.

Besides testing this hypothesis in some detail, the analysis allows empirical testing of several other hypotheses concerning housing market behavior. These hypotheses are developed following the definitions of the particular variables used in the analysis. The operational definitions of the types of residential housing, their component characteristics, and the calculation of the effective prices facing each household are first discussed in turn.

THE TYPES OF RESIDENTIAL HOUSING

As previous analyses have stressed, payment for housing services includes payments for a wide variety of qualitative and quantitative attributes of residential structures. In defining discrete housing types, or combinations of these underlying attributes, theoretical considerations suggest two rough guidelines. On the supply side, the existence of discrete housing types or submarkets implies that it must be costly to transform housing units among submarkets. On the demand side, housing units within any submarket must be viewed as (virtually) identical, but housing units in different submarkets must be viewed as separate and distinct entities.

Both the empirical and theoretical literature suggest that households of differing income and family size will choose units of varying residential density (or lot size) and varying interior size. In addition, the qualitative characteristics of residential structures are valued by households.

Based upon these considerations and available sample information, 18 types or submarkets of rental housing are defined by proxies for residential density, quality, and interior size. Residential density (or effective lot size) is proxied by structure type, which is reported in three categories; single detached units, common-wall units (including row and duplex houses), and multifamily (apartment) units.

The age of the dwelling unit is used as a proxy for housing quality and obsolescence.[13] Units are classified into two categories: those built before 1930 and those built after 1930. The cutoff year for defining age categories was chosen from considerations of sample size with respect to the data source. It should also be noted that there was relatively little new residential construction in the Pittsburgh metropolitan area during the period 1930–1945.

Although it would have been preferable to use floor space in describing interior size, the only available information in the sample is the number of bedrooms in each dwelling unit. Interior size is thus proxied by the number of bedrooms in the unit, reported in three categories: less than two bedrooms, two bedrooms, and three or more bedrooms.

The types of rental housing are thus described by 18 combinations: three structure types by two quality levels by three interior size measures.

The Effective Prices of Housing Types

For each of the 18 types of residential housing, the surface of contract prices (monthly rents) is estimated by the average price in each of 50 locations (zones) in the metropolitan area. The available stock of each type of housing is similarly described by the number of units in each zone. Calculations made by households of the costs of commuting to work are facilitated by reference to a set of 330 work sites (zones) and 130 residence sites (zones).

Thus from equation 1 the surface representing the total cost of consuming housing of type i is

$$(16)\quad P_{ijym} = R_{im'} + T_{jmy}$$

where

$i = 1, 18$ housing types
$j = 1, 330$ work places
$m = 1, 130$ residence places
$m' = 1, 50$ residence places
$y = 1, Y$ incomes

To estimate the monthly cost of work trips we make two strong assumptions. First, we assume that households are free to choose the number of hours they work; secondly, we assume that workers neither value the act of traveling nor the intrinsic characteristics of travel modes. These assumptions imply that the time spent traveling is valued at the (marginal) wage rate and that the choice of mode is made solely on the basis of time and money costs.

Thus for an individual with (marginal) wage w_y, the monthly transport costs (TC_{jmy}) from fixed work place j to residence place m will be equal to the minimum of the cost of a single trip on public transit (TP_{jmy}) or the cost of a trip by private auto (TA_{jm}) multiplied by the number of work trips per month (N); i.e.,

$$(17) \quad T_{jmy} = N \cdot \min (TP_{jmy}, TA_{jmy})$$

The cost of trips by public transit is composed of out-of-pocket fares (F_{jm}) and time costs. Let T^{p}_{jm} be the elapsed time by public transit between work place j and residence site m.

$$(18) \quad TP_{jmy} = F_{jm} + T^{p}_{jm} \, w_y$$

Similarly the cost of trips by private auto includes the out-of-pocket cost of fuel and maintenance[14] (expressed as E dollars per minute), the cost of parking at the destination (expressed as half the costs of all day parking at the work site, C_j) and the costs of time (where T^{a}_{jm} is the interzonal travel time for an auto trip):

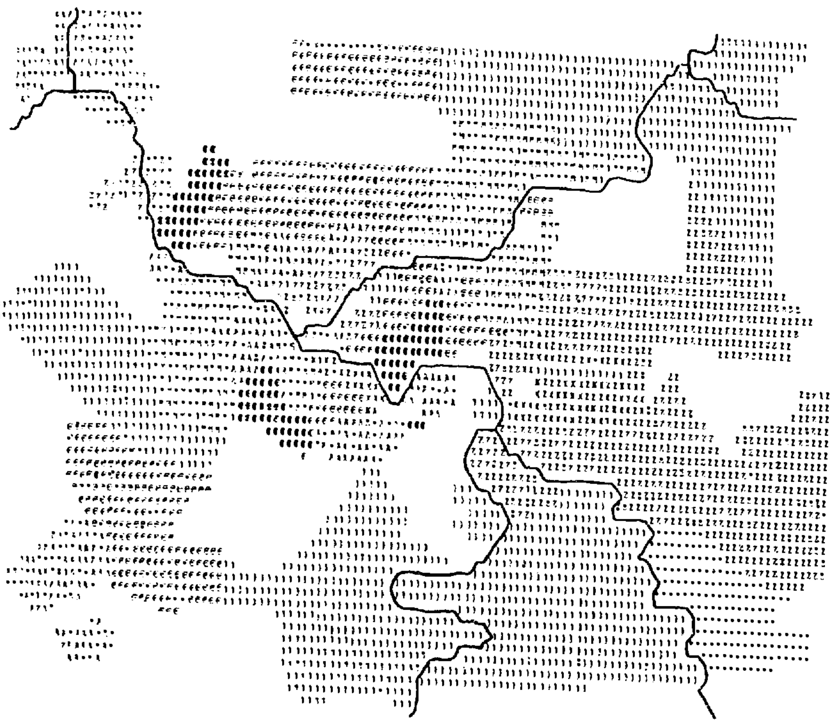
$$(19) \quad TA_{jmy} = \frac{C_j}{2} + T^{a}_{jm} \, (E + w_y)$$

The total expenditure required to consume housing type i at any residential location m may be computed as

$$(20) \quad P_{ijym} = R_{im'} + N \min \left\{ (F_{jm} + T^{p}_{jm} \, w_y), \left(\frac{C_j}{2} + T^{a}_{jm} \, [E + w_y] \right) \right\}$$

Figures 1 and 2 illustrate schematically the spatial distribution of monthly contract prices and the cumulative distribution of total housing costs for a particular housing type facing a particular worker. Figure 1 maps the surface of contract prices $R_{im'}$ for a particular housing type in the analysis area. As the schematic is drawn, darker shades correspond to higher monthly rents for this type of housing at different spatial locations. Figure 1 in effect presents the average monthly rents of a particular housing type in 50 zones in the metropolitan area. Although the price pattern reveals some tendency for prices to decline with distance from the Central Business District (CBD), the surface is characterized by irregular peaks and valleys and by conspicuous "holes" where the type of housing is simply unavailable. Figure 2 plots the ordered distribution of the total costs of

FIGURE 1 Schematic of the Surface of Monthly Rents for New Two Bedroom Common-Wall Units in the Pittsburgh Metropolitan Study



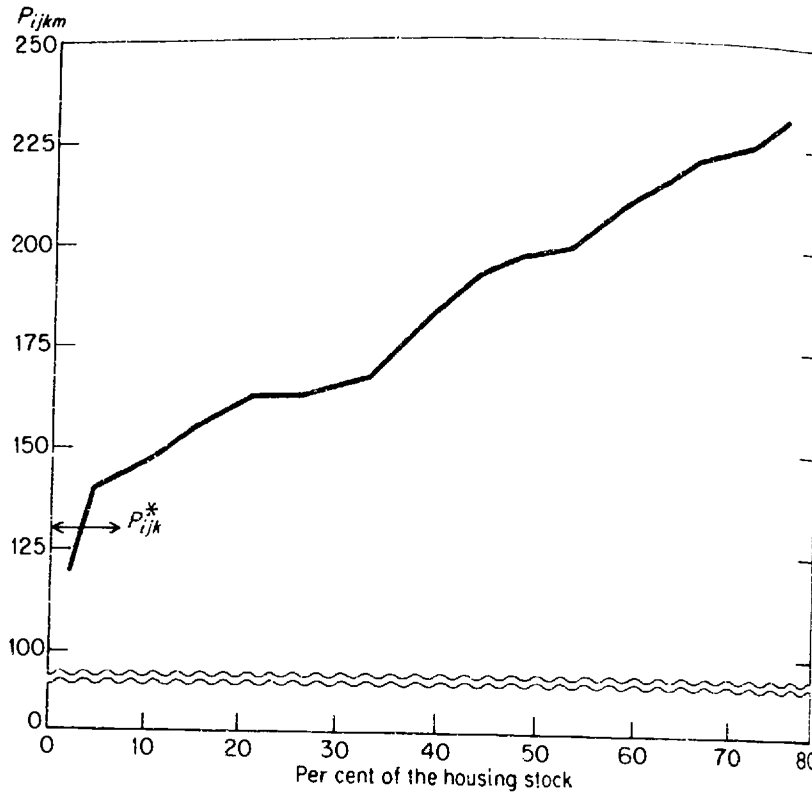
consuming this type of housing faced by an individual with wage rate of $7,000 employed in the CBD. The figure was plotted by applying equation 20, using the three travel matrices, F_{jm}, T^{r}_{jm}, and T^{a}_{jm} (130 × 330), and the vector of parking costs C_j (1 × 330) aggregated from the 1967 Pittsburgh survey.

If households possessed perfect information, the optimal residential location for this type of housing for the individual represented in Figure 2 and its effective price to him would be the actual minimum of the cumulative price distribution, $122 on the diagram.

Because housing market information is costly and because the individual estimates of total housing costs are subject to measurement error, the empirical analysis does not rely upon the single minimum total price as an estimate of the effective housing price facing an individual. Instead the average total price of the lowest five percent of the stock of each housing type is used to estimate the effective price minimum. Figure 2 illustrates this computation and shows an estimated minimum price of $128.

In addition to these price estimates, a variable measuring the total number of units of each housing type available in the metropolitan area is

FIGURE 2 Ordered Distribution of Total Cost of Consuming New Two Bedroom Common-Wall Units Facing a Household Employed in the CBD With an Annual Income of $7,000



included. This additional measure is used to proxy for the information available to consumers about the location and prices of alternative housing types.

The Complete Model and Some Additional Hypotheses

As stated and developed in previous sections, the model to be estimated in this section is the multinomial logistic. For each cross-classification of income and family size, the logarithmic odds of the choice between any two types of residential housing is a linear function of the attributes of each housing type (in this case proxies for residential density, interior size, quality, and availability in the metropolitan area) and the effective price of each housing type (which may vary for particular households). From equation 15, the specific model is:

$$\text{(21)} \quad \log (\rho_i/\rho_j) = b_1 (CW_i - CW_j) + b_2 (APT_i - APT_j) + b_3 (BR_i - BR_j) + b_4(AGE_i - AGE_j) + b_5 (P^*_i - P^*_j) + b_6 (ST_i - ST_j)$$

where

CW_i is a dummy variable with a value of 1 if i is a common-wall unit
APT_i is a dummy variable with a value of 1 if i is an apartment unit
BR_i is the number of bedrooms in type i
AGE_i is a dummy variable with a value of 1 if i was built before 1930
P^*_i is the effective monthly cost of consuming housing type i

and

ST_i is the number of units of housing of type i in the sample

The parameters of equation 21 are estimated separately for each of 30 combinations of income and family size. Equation 21, together with the error term assumption in equation 9, define the likelihood function (L) whose logarithm is:

$$\text{(22)} \quad \log \quad L = -\sum_{r=1}^{R} \sum_{i=1}^{18} \left\{ D_{ir} \log \left[\sum_{k=1}^{18} b_1 (CW_{kr} - CW_{ir}) + \ldots + b_6 (ST_{kr} - ST_{ir}) \right] \right\}$$

where

R is the sample size for each stratification of income and family size and $r = 1, 2, \ldots, R$ is the index of observations, and
D_{ir} is a dummy variable with a value of 1 if the rth household chooses housing type i.

Maximum likelihood estimates of the parameters of equation 22 are obtained by an iterative process. If this model of housing choice is appropriate, several hypotheses about the signs and magnitudes of the estimated parameters can be addressed. First, from equation 11 the own-price elasticity of choice among housing types is

$$\text{(23)} \quad N_{ij} = P^*_i b_5 (1 - \rho_i)$$

and the cross-price elasticity is

$$\text{(24)} \quad N_{ij} = P^*_j b_5 \rho_j$$

To insure a negative own-price elasticity and a positive cross-price elasticity, the estimate of b_5 should be negative for each stratification of income and family size.

We should also expect the parameter b_4 to be negative since, *ceteris paribus*, households prefer higher quality dwelling units, that is, holding structure type and size constant, housing types indexed by quality form a "commodity hierarchy." Similarly, holding structure type and quality constant, housing types indexed by size form a "commodity hierarchy"; thus we expect the estimate of b_3 to be positive. The coefficient of the housing stock term, b_6, should be positive, since households can obtain more information, at the same search cost, for housing types in greater supply.

Holding income constant, we should expect that larger families demand larger units and more exterior space. Thus for larger families with the same income we should expect that the estimate of b_3 will be larger than for small families. Similarly, the estimates for b_1 and b_2 should be smaller in magnitude (or more negative) for larger families than for smaller families.

Holding family size constant, we expect that higher incomes are associated with greater consumption of higher quality, larger units with more exterior space. Thus for the same family size we expect that the estimate of b_3 will be larger for the higher income households than for lower income households. Similarly, the estimates of b_1, b_2 and b_4 should be more negative for higher income households than for lower income households.

Table 1 presents the coefficients of the multinomial logistic model, estimated by the maximum likelihood method, for each of thirty combinations of income and family size. The model is estimated separately for each of five family sizes (corresponding to households of 1, 2, 3, 4, and 5 or more members) for each of six income classes (corresponding to annual incomes of less than \$3,000–\$4,999, \$5,000–\$6,999, \$7,000–\$9,999, \$10,000–\$14,999, and \$15,000 or more).

For each household in the sample, the total cost was calculated for each of the 18 types of residential housing at each possible location by using equation 20 and the mid-points of the income classes to derive hourly wage estimate w_y;[15] the minimum total cost (P_i^*) including housing and transport cost, was estimated for each housing type by calculating the average price of the cheapest 5 percent of the stock for each household. One type of residential housing was chosen as a numeraire; the prices facing each household are relative to this numeraire.[16]

For each of the 30 nonlinear regressions, the results reported in Table 1 were obtained by specifying a convergency criterion of .01. In most cases five or six iterations were required. For each set of results the sample size is noted and the asymptotic t ratios of the coefficients appear in parentheses.

In 26 of the 30 equations the relative price coefficient has the anticipated sign; the estimated coefficient exceeds its standard error in 22 equations and it appears highly significant in 16 stratifications. The t ratios of the relative price coefficients are substantially lower for the two higher income groups. For renter households earning between \$10,000 and \$15,000 a year, three of the estimates coefficients are significant at about the .05 level and the other two are insignificant. For renter households earning more than \$15,000 a year, none of the price coefficients are significant.

TABLE 1 Estimated Coefficients of the Multinomial Logistic Model by Family Size and Income Class:

$$\log(\rho_i/\rho_j) = b_1(CW_i - CW_j) + b_2(APT_i - APT_j) + b_3(BR_i - BR_j) + b_4(AGE_i - AGE_j) + b_5(P^*_i - P^*_j) + b_6(ST_i - ST_j)$$

Family Size	Number of Observations	Common Wall (*CW*)	Apartment (*APT*)	Number of Bedrooms (*BR*)	Structure Age (*AGE*)	Relative Price (*P**)	Stock (*ST*)
			Income $3,000 and Below				
1	48	2.560 (2.91)**	1.958 (3.69)**	0.538 (0.97)	−1.743 (2.20)*	1.392 (0.51)	0.015 (4.79)**
2	61	1.045 (2.34)**	2.379 (5.05)**	−0.478 (1.69)*	−1.428 (2.45)**	−3.167 (1.62)*	0.006 (6.34)**
3	41	−2.679 (3.64)**	−0.902 (1.88)*	3.309 (5.25)**	−3.210 (4.04)**	−4.400 (2.31)**	0.136 (55.52)**
4	15	−3.619 (1.62)*	0.089 (0.09)	5.187 (2.38)**	−0.201 (0.10)	−20.571 (1.96)**	0.015 (2.11)**
5+	25	−22.891 (2.86)**	2.280 (0.59)	50.013 (3.55)**	−22.926 (3.27)**	−86.251 (3.01)**	0.162 (3.50)**
			Income $3,000–$4,999				
1	104	1.023 (3.02)**	2.438 (6.68)**	−0.757 (3.54)**	−0.650 (1.64)*	−6.866 (5.50)**	0.004 (5.92)**
2	140	0.075 (0.28)	1.792 (6.58)**	−0.261 (1.27)	−1.930 (4.82)**	−2.170 (2.08)**	0.007 (9.41)**
3	95	−1.523 (4.59)**	−0.276 (0.92)	1.687 (5.92)**	−2.548 (5.70)**	−6.475 (4.60)**	0.010 (9.01)**

TABLE 1 (continued)

Family Size	Number of Observations	Common Wall (*CW*)	Apartment (*APT*)	Number of Bedrooms (*BR*)	Structure Age (*AGE*)	Relative Price (*P**)	Stock (*ST*)
4	88	−1.054	−0.810	1.770	0.455	−6.364	0.006
		(3.00)**	(2.40)**	(5.20)**	(1.20)	(3.87)**	(5.93)**
5+	87	−1.278	−1.930	3.282	−0.247	−3.998	0.010
		(3.72)**	(4.34)**	(8.91)**	(0.67)	(2.90)**	(9.15)**
				Income $5,000–$6,999			
1	91	0.150	2.564	−1.222	−3.049	−1.888	0.009
		(0.31)	(5.50)**	(3.21)**	(4.26)**	(1.20)	(6.54)**
2	223	0.291	0.874	−0.223	−0.223	−2.906	0.003
		(1.65)*	(4.29)**	(5.13)**	(1.25)	(3.98)**	(7.79)**
3	224	−1.500	−0.849	2.020	−2.383	−4.465	0.010
		(7.06)**	(4.45)**	(10.92)**	(9.03)**	(5.87)**	(14.89)**
4	194	−2.693	−0.903	3.823	−2.738	−4.140	0.014
		(10.12)**	(4.23)**	(13.54)**	(8.86)**	(4.91)**	(14.16)**
5+	223	−1.591	−2.013	3.170	−0.893	−6.116	0.008
		(7.53)**	(7.32)**	(13.46)**	(3.89)**	(6.61)**	(12.16)**
				Income $7,000–$9,999			
1	79	0.664	1.561	−0.586	−3.179	−0.491	0.006
		(1.55)	(3.73)**	(2.39)**	(6.11)**	(0.44)	(5.54)**

2	228	0.196 (0.87)	0.350 (1.65)*	0.479 (3.39)**	−1.881 (7.81)**	−1.403 (2.26)**	0.006 (11.67)**
3	218	−1.242 (5.43)**	−0.490 (2.37)**	2.272 (11.92)**	−2.955 (10.95)**	−3.490 (4.95)**	0.010 (14.24)**
4	166	−2.340 (9.18)**	−0.616 (1.85)**	4.193 (11.70)**	−4.304 (9.63)**	−3.565 (3.54)**	0.015 (12.50)**
5+	173	−2.096 (8.46)**	−1.561 (5.17)**	4.159 (12.12)**	−0.750 (3.00)**	−5.035 (4.90)**	0.009 (11.82)**
			Income $10,000–$14,999				
1	24	−1.267 (0.92)	−1.736 (1.16)	0.493 (0.68)	−4.651 (2.92)**	1.105 (0.22)	0.020 (3.44)**
2	153	−0.108 (0.40)	0.391 (1.51)	0.060 (0.44)	−1.503 (6.46)**	−1.262 (1.83)*	0.003 (6.59)**
3	83	−0.640 (1.99)*	−0.284 (0.82)	1.368 (5.72)**	−1.051 (3.25)**	−1.711 (1.81)*	0.004 (5.52)**
4	56	−2.566 (4.63)**	2.134 (2.72)**	7.477 (6.89)**	−6.366 (5.49)**	−2.031 (1.10)	0.023 (6.94)**
5+	67	−2.511 (5.78)**	−3.769 (4.40)**	4.743 (7.39)**	−2.674 (4.99)**	−3.348 (1.76)*	0.010 (6.20)**
			Income $15,000 and Above				
1	17	−19.346 (0.03)	−10.694 (0.02)	1.256 (0.01)	−3.686 (0.01)	−3.321 (0.00)	0.040 (0.03)

TABLE 1 (concluded)

Family Size	Number of Observations	Common Wall (*CW*)	Apartment (*APT*)	Number of Bedrooms (*BR*)	Structure Age (*AGE*)	Relative Price (*P**)	Stock (*ST*)
2	50	−1.656	−0.230	1.926	−3.534	0.084	0.011
		(2.31)**	(0.47)	(4.28)**	(5.48)**	(0.06)	(5.68)**
3	24	−3.605	1.531	3.466	−0.093	−1.572	0.000
		(3.45)**	(1.15)	(4.21)**	(0.11)	(0.63)	(0.00)
4	14	−2.324	−1.390	3.347	−3.446	−2.458	0.012
		(2.10)**	(1.32)	(3.30)**	(2.46)	(0.79)	(2.77)**
5+	10	−0.251	9.609	13.027	−0.867	2.343	0.002
		(0.13)	(0.09)	(0.12)	(0.50)	(0.21)	(0.31)

NOTE: Asymptotic *t* ratios in parentheses.
**indicates coefficient different from zero at .01 level.
*indicates coefficient different from zero at .05 level.

The patterns of significance suggest that the choices of housing types for the overwhelming proportion of rental households (i.e. those lower and middle income rental households that, for this sample, comprise 85 percent of the rental market), are strongly influenced by relative prices. The table also suggests a clear pattern in the magnitude of the relative price coefficients for families of different sizes. Within each income class, the magnitude of the price coefficient increases with family size. Larger families with greater demands for necessities are more responsive to relative prices in their choices among housing types.

The estimated coefficient of the structure age variable has the anticipated sign in 29 of the 30 equations and is highly significant in 22 of the stratifications. Again, the *t* ratios suggest that renters in the highest income class are least sensitive to structure age, but there does not seem to be a strong pattern in the magnitudes of the estimated coefficients across income classes and family sizes.

The coefficients of the number of bedrooms indicate a systematic pattern across income classes and family sizes. The coefficients are statistically significant with the correct sign in 19 of the stratifications. For each of the six income classes, the magnitude of the coefficient on the bedroom variable increases with family size. There is also a tendency for the coefficient to increase with income level for a given family size.

The coefficient of the variable for common-wall units is statistically significant in 20 of the 30 equations; the coefficient of the variable representing apartment units is significant in 15 stratifications. The pattern of coefficients suggests, *ceteris paribus,* that single detached units are preferred to either of these types of families with three or more members. Holding family size constant, the coefficients also indicate that single detached rental units are preferred by those of higher incomes.

In general, the model performs less well for renters of the highest income class, those earning more than $15,000 a year. In part, this may be a reflection of the smaller sample sizes for households in this category. However, the results may also suggest that the definitions of the housing types are inadequate to model the behavior of the highest income group; the aspects of housing which motivate the residential location and housing choices of the highest income households are not well represented by only 18 types of residential housing.

Tables 2 and 3 illustrate the differences in housing consumption attributable, *ceteris paribus,* to variations in the socioeconomic characteristics of households. The tables indicate the predicted probabilities of consuming several housing characteristics using the coefficients of Table 1 and assuming each household in the metropolitan area faced the same effective housing prices (P^*). These probability estimates may be interpreted as those observed under the monocentric or equilibrium assumptions of the

TABLE 2 Predicted Probabilities of Housing Type Choice, p_{yai}, for Selected Incomes Across Family Sizes:

$$p_{yai} = e^{W_{ya}(X_i, P_a^*)} \Big/ \sum_{j=1}^{l} e^{W_{yj}(X_i, P_j^*)}$$

where

$$W_{ya}(X_i, P_a^*) = \sum_{l=1}^{n} b_{yal} x_{il} + b_{ya,n+1} P_a^*$$

Type of Dwelling	Family Size 1	2	3	4	5+
			Income $3,000–$4,999		
Common-wall units	.11	.11	.37	.39	.69
Apartments	.84	.82	.38	.27	.06
Single detached	.04	.07	.25	.34	.25
One bedroom	.78	.79	.35	.12	.03
Two bedrooms	.20	.20	.53	.42	.48
Three bedrooms	.02	.01	.12	.46	.49
			Income $5,000–$6,999		
Common-wall units	.03	.22	.54	.52	.52
Apartments	.94	.60	.23	.11	.08
Single detached	.02	.17	.24	.37	.40
One bedroom	.95	.66	.23	.10	.03
Two bedrooms	.05	.28	.61	.61	.33
Three bedrooms	.00	.06	.16	.29	.64

classical theory. If all households were employed at a single work site they would, of course, face identical effective prices for the same type of residential housing.[17] The probability estimates were obtained by substitution into equations 11 and 14 and by then forming the marginal totals.

Table 2 illustrates the probabilities for two income classes over the five family size categories. The table indicates that, as family size increases, households are less likely to choose multifamily units and are more likely to choose common-wall units and single detached units. For income levels of $3,000 to $5,000, the probability of choosing apartment dwellings declines from .84 for one-person households to .06 for five-person households; the probability of choosing common-wall units increases from .11 to .69. Similarly the probability of choosing single detached units increases from .04 to .25 as family size increases from one to five members.

For a higher level of income, the table indicates that larger family sizes also systematically choose less dense housing configurations. In contrast to the lower income group, households earning between $5,000 to $7,000 have higher probabilities of consuming larger effective lot sizes at each

TABLE 3 Predicted Probabilities of Housing Type Choice, ρ_{yai}, for Selected Family Sizes Across Income Classes:

$$\rho_{yai} = e^{W_{ya}(X_i, P_i^*)} \Big/ \sum_{j=1}^{J} e^{W_{yj}(X_i, P_i^*)}$$

where

$$W_{ya}(X_i, P_i^*) = \sum_{l=1}^{n} b_{yal} x_{li} + b_{ya,n+1} P_i^*$$

Type of Dwelling	Less than $3,000	$3,000–$4,999	$5,000–$6,999	$7,000–$9,999	$10,000–$14,999	$15,000+
			Three-person Families			
Common-wall units	.54	.37	.54	.59	.36	.01
Apartments	.24	.38	.23	.23	.32	.82
Single detached	.21	.25	.24	.18	.32	.18
One bedroom	.18	.35	.23	.18	.14	.00
Two bedrooms	.64	.53	.61	.62	.39	.03
Three bedrooms	.18	.12	.16	.20	.47	.97
			Five-or-more-person Families			
Common-wall units	1.00	.69	.52	.46	.49	.37
Apartments	.00	.06	.08	.13	.02	.13
Single detached	.00	.25	.40	.41	.49	.50
One bedroom	1.00	.03	.03	.01	.00	.00
Two bedrooms	.00	.48	.33	.24	.19	.03
Three bedrooms	.00	.49	.64	.75	.80	.97

family size. Holding family size constant, higher income households systematically choose less dense types of residential housing.

Within each income class, Table 2 indicates that increased family size is associated with the choice of housing types with larger interior sizes (as measured by numbers of bedrooms). However, the comparison for the two income classes reveals that at the same family size, higher income households are generally more likely to choose two and three bedroom units than lower income households.

Table 3 illustrates the differences in housing consumption across the six income classes for two stratifications of family size. The table indicates that for three-person families, the probabilities of consuming units with larger interiors are very similar for households earning less than $7,000 a year. (The predicted average numbers of bedrooms are 2.0, 1.8, 1.9 and 2.0, respectively for the lowest four income classes.) Only for the two highest income classes, where the predicted average number of bedrooms increases to 2.3 and 3.0 respectively, does higher income increase the likelihood of choosing housing types with larger interior sizes.

In contrast, for larger families the probability of choosing larger units increases systematically with income level. As income rises from $3,000 to $15,000 a year the probability of choosing a three bedroom unit increases from .00 to .97. The predicted average number of bedrooms for the six income classes are 1.0, 2.5, 2.6, 2.7, 2.8, and 3.0 respectively.

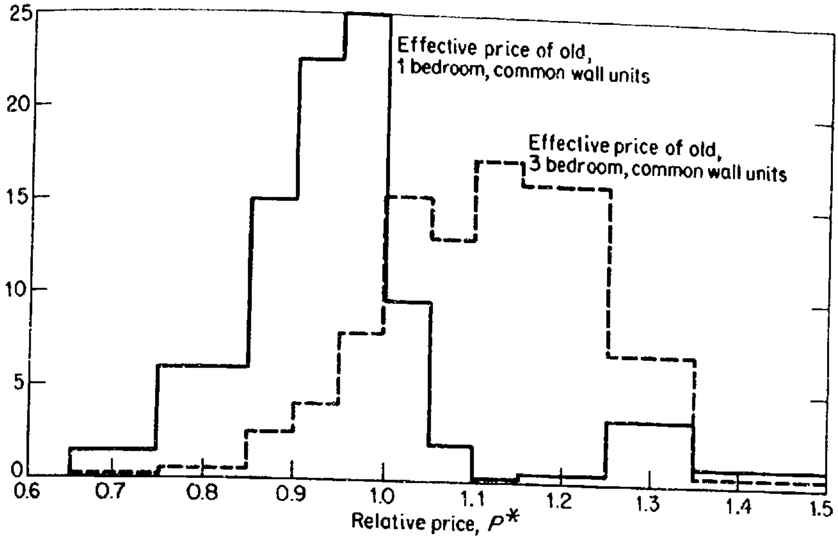
For smaller families, the differences in the predicted probability of choosing different structure types do not vary systematically with income. For larger families, however, the estimates in Table 3 suggest that increases in income are associated with higher probabilities of choosing single detached units. The predicted probability of choosing single detached units increases from .00 to .50 as family income rises from $3,000 to $15,000 a year.

As has been emphasized throughout this discussion, the variation in the effective prices (P^*) facing different households arises from the interaction of contract housing prices and the accessibility costs to the specific work sites of different households. Within the sample, substantial variation exists in the effective prices facing otherwise identical households. By way of illustration, Figure 3 presents the frequency distribution of the effective prices (P^*) facing households of a single income class for two housing types. The figure indicates the effective prices relative to the numeraire used in the empirical analysis. The variation in the prices faced by individual households arises because the spatial location of the minimum price and its magnitude varies with work site, the transport network, and the surface of contract prices.

To indicate the importance of these price differences in affecting the choice of housing types, we have used the equations estimated in Table 1 to calculate the predicted probabilities of choice among the housing types for otherwise identical households which are employed at four specific work places in the metropolitan area. One of these work sites is located in the heart of the Pittsburgh CBD; a second is located in the inner city, east of the CBD; a third is located on the outskirts of the central city, and a fourth is located in the suburbs east of Pittsburgh. Table 4 presents the predicted probabilities of choice for households of the same income and family size who face the effective prices calculated for these four work sites. The predicted probabilities of choice for four-person households earning between $5,000 to $7,000 a year and employed at the four work sites are presented in the first section of Table 4. The predicted probabilities for a five-person household earning income in the same range and employed at the same locations are presented in the second section. In the third section of the table the probabilities predicted for a five-person household of a lower income class are indicated.

The table clearly shows the differences in the consumption of housing attributes which arise from the variations in relative prices. For households

FIGURE 3 Frequency Distribution of Relative Prices for Two Types of Housing Facing Households Earning Less Than $3,000 a Year



NOTE: Both prices are relative to the effective price of new, one bedroom, common-wall units.

earning between $5,000 to $7,000 a year, the probability of choosing apartments declines systematically for four-person households whose work place is more distant from the Central Business District. Similarly, the probability of choosing single detached housing types increases systematically for four-person households with less central work places. For five-person households. The same regular pattern of structure-type choices is revealed for the four work places. For larger households at the same income, however, those employed at noncentral places are more likely to choose larger effective lot sizes than smaller households.

For five-person households of a lower income class, the probability of choosing single detached housing increases with less central employment locations, but the probabilities are substantially lower than for households with larger incomes. The probability of choosing common-wall units similarly declines at noncentral employment sites, but the probabilities are uniformly higher than for households with larger incomes.

Even at the same family size, variations in the effective prices affect households' choices of the interior size of units. For four-person families, there is a small but systematic increase in the probability of choosing housing types with more bedrooms at less central work sites. For five-person households of both income classes this tendency is more pronounced.

TABLE 4 Predicted Probabilities of Housing Type Choice, p_{yat}, for Otherwise Identical Households at Four Work Sites

Type of Dwelling	CBD	Inner City	Central City	Suburbs
			Work Places	
	Four-person Families—Income $5,000–$6,999			
Common-wall units	.51	.54	.50	.42
Apartments	.40	.29	.19	.11
Single detached	.09	.17	.30	.47
One bedroom	.16	.13	.13	.14
Two bedrooms	.63	.63	.61	.57
Three bedrooms	.21	.23	.26	.28
	Five-person Families—Income $5,000–$6,999			
Common-wall units	.58	.51	.36	.19
Apartments	.28	.15	.07	.02
Single detached	.15	.33	.58	.78
One bedroom	.05	.05	.06	.07
Two bedrooms	.46	.43	.37	.33
Three bedrooms	.49	.53	.57	.60
	Five-person Families—Income $3,000–$4,999			
Common-wall units	.74	.69	.60	.48
Apartments	.14	.10	.06	.04
Single detached	.12	.21	.33	.48
One bedroom	.57	.04	.05	.06
Two bedrooms	.39	.55	.52	.47
Three bedrooms	.09	.41	.43	.47

Table 4 clearly shows how variations in the intrametropolitan costs of configurations of residential housing affect households' choices of consuming several attributes of the residential housing "bundle".

The theory of the housing market and the computation of the effective prices of housing units used in the empirical analysis suggest that these price variations arise because: existing housing units are costly to transform and the spatial distribution of housing types changes slowly in response to market forces; households employed at different sites face different accessibility costs to the available supplies of durable housing units. By neglecting these considerations, many analyses of household location and demand for "housing" have overlooked a crucial link in understanding why households choose particular spatial locations and why households choose components of the bundle of housing services.

NOTES

1. Aggregate studies which neglect housing prices in focusing on income expenditures include: Margaret Reid. *Housing and Income* (Chicago: University of Chicago Press. 1962): Alan R. Winger. "Housing and Income." *Western Economic Journal*. June 1968. pp. 226–232. Muth's study includes an index of construction costs (the Boeckh Index) across cities. and de Leeuw's intercity analysis uses the Bureau of Labor Statistics city-worker budget to provide an average price for a "standard" bundle of housing services. See Richard F. Muth. "The Demand for Non-farm Housing." in *The Demand for Durable Goods*. Arnold C. Harberger. ed. (Chicago: University of Chicago Press. 1962): Frank de Leeuw and Nkanta F. Ekanem. "The Demand for Housing: A Review of the Cross-Section Evidence." *Review of Economics and Statistics*, February 1971. pp. 1–10.
2. See Mahlon R. Straszheim. "Estimation of the Demand for Urban Housing Services from Household Interview Data." *Review of Economics and Statistics*. February 1973. pp. 1–8: Mahlon R. Straszheim. *An Econometric Analysis of the Urban Housing Market* (New York: National Bureau of Economic Research. 1975): John F. Kain and John M. Quigley. *Housing Markets and Racial Discrimination: A Microeconomic Analysis* (New York: National Bureau of Economic Research. 1975): John M. Quigley. "Racial Discrimination and the Housing Consumption of Black Households." in *Patterns of Racial Discrimination. Vol. 1: Housing*, George M. Von Furstenberg, ed. (Lexington. Mass.: D.C. Heath. 1974): A. Thomas King. "Households in Housing Markets: The Demand for Housing Components" (College Park. Md.: Bureau of Business and Economic Research. University of Maryland. 1973).
3. The classic references include: Richard F. Muth. *Cities and Housing* (Chicago: University of Chicago Press. 1969): Lowdon Wingo, *Transportation and Urban Land* (Washington. D.C.: Resources for the Future. 1961): William Alonso. *Location and Land Use* (Cambridge: Harvard University Press. 1964).
4. James L. Sweeney. "Quality. Commodity. Hierarchies. and Housing Markets." Stanford University. Department of Engineering-Economic Systems. mimeographed. October 1972.
5. These estimates of the implicit prices of housing attributes are derived from Lancaster's analysis of hedonic goods. See Kelvin J. Lancaster. "A New Approach to Consumer Theory." *Journal of Political Economy*. April 1966. pp. 132–156: Sherwin Rosen. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition." *Journal of Political Economy*. January/February 1974. pp. 34–55. For a recent survey of this literature as related to housing markets see Michael J. Ball. "Recent Empirical Work on the Determinants of Relative House Prices." *Urban Studies*. June 1973, pp. 213–233.
6. John F. Kain. "The Journey to Work as a Determinant of Residential Location." *Papers and Proceedings of the Regional Science Association*. 1962. pp. 137–161.
7. It may be that the I types of residential housing form a "hierarchy" in the sense defined by Sweeney. i.e. that

$$\text{(N1)} \quad U(X_{i+1}, z_0) > U(X_i, z_0)$$

for all consumers. More generally. since x is multidimensional. it is likely that only some housing types are strictly hierarchical. For example, if the components of x include "housing quality" and "size." it may be true that all consumers prefer higher quality to lower quality units and larger dwelling units to smaller units: consumers may have mixed preferences. however, regarding the tradeoff between larger. lower quality units and smaller, higher quality units.

8. H. Bloch and J. Marschak, "Random Orderings and Stochastic Theories of Response," in *Contributions to Probability and Statistics*, I. Olkin, ed. (Stanford: Stanford University Press, 1960).
9. Daniel McFadden, "The Revealed Preferences of a Government Bureaucracy," Technical Report W. 17, Institute of International Studies, University of California-Berkeley, November 1968; Charles River Associates, "A Disaggregated Behavioral Model of Urban Travel Demand," Report CRA-156-2, March 1972; Daniel McFadden, "Conditional Logit Analysis of Qualitative Choice Behavior," in *Frontiers in Econometrics*, P. Zaremka, ed. (New York: Academic Press, 1974).
10. Although this assumption (as well as the assumed error term distribution in equation 9) is made solely in the interest of tractability, it is not quite as restrictive as it may appear, since a wide variety of functional forms may, in principle, be accommodated by dummy variables and piecewise linear approximations.
11. McFadden, 1968 (see note 9).
12. Details concerning the survey instruments and the underlying data may be found in John M. Quigley, "Residential Location with Multiple Workplaces and a Heterogeneous Housing Stock," Discussion Paper Number 80, Program on Regional and Urban Economics, Harvard University, September 1972.
13. For evidence on the relationship between housing age and "objective measures of housing quality," see John F. Kain and John M. Quigley, "Evaluating the Quality of the Residential Environment," *Environment and Planning*, Vol. 2, 1970, pp. 23-32.
14. Cost estimates were obtained from John B. Lansing and G. Hendricks, "How People Perceive the Cost of the Journey to Work," No. 197, Highway Research Board, 1967, pp. 44-55.
15. For the six income classes the (assumed) midpoints and the associated hourly wages (based upon a 40 hour week for 50 weeks per year) are:

income class (y)	**income mid-point**	**hourly wages (W_y)**
$ 0-2,999	$ 2,500	$1.25
3,000-4,999	4,000	2.00
5,000-6,999	6,000	3.00
7,000-9,999	8,500	4.24
10,000-14,999	12,500	6.25
15,000-	17,500	8.75

16. Although the methodology can be briefly stated, the calculation of the effective prices involved estimating the entire surface of total housing costs facing each household for each type of housing and "scanning" each surface to find the average price of the cheapest five percent of the stock of each type. For each household, its work place and income class (hence an estimate of its wage rate) are sufficient to calculate the accessibility cost of each residential location. Knowledge of this cost plus the estimate of contract prices at each residential location for each housing type allowed a surface of total housing costs to be defined for each type of housing. For each type of housing, the prices and the number of units at each residential location were scanned to estimate the average total cost of the cheapest five percent of the stock when viewed from the work place of each household at its wage rate. The price of one bedroom common-wall units built after 1930 was used as the numeraire.
17. Alternatively, if several work places existed and the markets for each type of residential housing were in equilibrium, differences in the effective prices facing similar households could arise only if wages for identical labor inputs varied by work place.