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CONSUMER CHOICE OF DWELLING, NEIGHBORHOOD AND PUBLIC SERVICES

BY

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I. INTRODUCTION

It is tautological to observe that market demand curves for commodities arise from the discrete consumption decisions of individual households. However, for many commodities, especially durable goods, it is more natural to frame the individual consumption decision as a binary choice -- to buy or not to buy -- in a given period. In a market like the one for housing, where all consumers are observed to choose some dwelling and where alternatives are extremely heterogeneous, the individual consumption decision is the choice of one element unit out of a large set of discrete alternatives. In making these choices, housing consumers presumably sample from a large number of available dwellings. They evaluate the physical characteristics of these dwellings, the neighborhoods in which they are located, and the public services provided to them. On the basis of these evaluations and the prices at which dwellings are offered, the consumer ultimately chooses one dwelling out of the sampled alternatives.

Consumer choice in the housing market thus has three distinguishing features: first, in almost all cases, the consumer selects of one and only one good out of a large population of alternatives; second, the bundle of services provided by any dwelling is extremely heterogeneous; third, consumer choice involves the selection of a price as well as the other characteristics associated with dwellings.

This paper considers the problem of consumer choice in the housing market from this broader perspective. Section II below reviews briefly the basic model of discrete choice, and notes previous empirical analyses applying this model to the housing market. Section III presents an empirical analysis of a somewhat more general treatment of household choice in the market for residential housing. The empirical analysis is a direct generalization of Quigley (1983) and analyzes consumer choice of dwelling unit, neighborhood, and public sector attributes.

II. THE GENERALIZED MULTINOMINAL CHOICE MODEL

When a consumer chooses a dwelling unit i out of the set of all dwellings D, he selects a set of housing characteristics, neighborhood and public service amenities and a journey to work (X_i), as well as price (that is, a monthly rent or purchase price, R_i). Consumers of income y have preferences over the set of public service-amenity packages, housing characteristics, and other goods, $y - R_i$.

Assume the utility function for households consists of a systematic component V and an additive stochastic component ε:

$$(1) \quad U[X_i, y - R_i] = V(i) + \varepsilon$$

Assumptions (maintained hypotheses) about the form of the stochastic component of the utility function permit probability statements about the choice of any specific dwelling to be made. In particular, as is well known, McFadden (1974) demonstrated that: if it is assumed that the stochastic terms are independently and identically distributed according to the Weibull distribution, then the form of the probability statement is:

$$(2) \quad p(i) = \text{prob } [U(i) > U(j)] = \frac{e^{V(i)}}{\sum_j e^{V(j)}}, \qquad \text{for all } j, j \neq i.$$

Equation 2 is a well-behaved probability statement with values bounded by zero and one. The probability of choosing any dwelling unit depends upon the characteristics of all dwellings in the choice set. Equation (2) is estimated by maximizing a log-likelihood function L of the form:

$$(3) \quad \log L \propto \frac{1}{k} \sum_{k} \log \frac{e^{V(i)}}{\sum_{j} e^{V(j)}}$$

for a sample size of k observations on choices i and on available alternatives j.

Finally, if it can be assumed that the systematic component of the utility function is linear in its parameters, McFadden has shown that the likelihood function given in equation (3) is concave, and the parameters are unique up to a factor of proportionality. For the problem of housing choice, a linear relationship (another maintained hypothesis),

$$(4) \quad V(i) = \alpha_i X_i + \beta(y - R_i)$$

renders the parameters α_i and β of the model estimable. This maintained hypothesis is, of course, rather innocuous; any nonlinear function can be approximated by one linear in its parameters.

Under the maintained hypotheses of equations (1), (2), and (4), estimates of the discrete model of housing choice have been presented by a number of researchers (Case, 1981; Ellickson, 1977, 1981; Kain and Apgar, 1977; Lerman, 1977, 1979; Quigley, 1976; Williams, 1979). All of these empirical analyses share at least two limitations.

First, according to equation (2), the odds of choosing housing unit m relative to n are independent of the characteristics of all other alternatives available to consumers. This maintained hypothesis, the so-called independence of irrelevant alternatives (IIA), is simply not testable within the traditional model. The assumption is surely inappropriate in many situations involving the choice of housing and neighborhood characteristics.

Second, there is a real practical problem in maximizing the log-likelihood function in equation (3). Clearly, the theoretical problem solved by consumers in the marketplace is the selection of one specific dwelling unit out of the large number of alternative dwellings (D) actually available on the market. However, for an economist to maximize the likelihood function in equation (3) for any sample of consumers, it is necessary to make the set of alternatives "small enough" somehow to render an iterative solution computationally feasible.[1]

Typically, analysts have "solved" this latter problem in an ad hoc way. They have represented the heterogeneity of the housing, neighborhood, and public services available to consumers by a small number of "types" of residential housing, for example, specified components of the bundle of housing services at particular values. Thus, in practical estimation, the choice problem has been defined as the selection of one housing type out of an arbitrarily defined set of housing types. For example, Case analyzed consumer choice among 9 types of units defined by tenure, size and structure classes; Lerman analyzed consumer

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[1] This latter complication did not arise at all in the original applications of the multinominal logistic model to the choice of transport modes. Inherently, there are a relatively small number of available transport modes. In contrast, however, there are a large number of potential dwelling units available for occupancy by housing consumers.

choice among 145 census tracts.

The bundle of services associated with a dwelling unit can be partitioned into several components: for example, those that vary by dwellings within neighborhoods (or census tracts or towns), X_1 and those that are constant for dwellings within neighborhoods but vary across neighborhoods (or census tracts or towns), X_2. The size or condition of a dwelling unit or its price are examples of the first component; the quality of local schools or the racial composition of the neighborhood are examples of the second.

From equation (2), under the usual assumptions, the probability of choice of neighborhood (n) and dwelling unit (i) is[2]

$$(5) \quad p(i,n) = \frac{e^{\alpha_1 X_{1i} + \alpha_2 X_{2n}}}{\sum_{j,k} e^{\alpha_1 X_{1j} + \alpha_2 X_{2k}}}.$$

As with any joint probability statement, equation (5) can be decomposed into a marginal and a conditional probability statement. If $\sigma = 0$, then

$$(6a) \quad p(i|n) = \frac{e^{\alpha_1 X_{1i}/(1-\sigma)}}{e^{I_n}}$$

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[2] For exposition only, the notation describes the choice made by a household of given income, so that $(y-R_i)$ can be treated as one component of the vector X_{1i} that varies across dwellings. Since income y is invariant among choices, in this linear form choice probabilities are unaffected by level of income.

$$\text{(6b)}\quad p(n) = \frac{e^{\alpha_2 X_{2n} + (1-\sigma) I_n}}{\sum_k e^{\alpha_2 X_{2k} + (1-\sigma) I_k}}$$

$$\text{(6c)}\quad I_n = \log \Sigma \frac{e^{\alpha_1 X_{1i}}}{1-\sigma}$$

is arithmetically identical to equation (5). The parameters of the choice model can be estimated directly by using equation (5) or sequentially. The latter procedure involves estimating α_1 from equation (6a) using the parameters to calculate I_n for each neighborhood (or census tract or town) and then estimating α_2 from equation (6b). The sequential approach "involves some loss of efficiency relative to direct estimation of the joint choice model" (McFadden 1977); it is, however, merely an alternative way of approaching the same problem.

The same sequential approach can of course be used to estimate the value of $(1-\sigma)$, as well as X_1 and X_2, and thus to test whether σ is different from zero. McFadden and Domencich (1975) have shown that the joint probability function consistent with equation (6) is of the form

$$\text{(7)}\quad p(i,n) = \frac{e^{V(i,n)/(1-\sigma)}\ [\Sigma\ e^{V(j,n)/(1-\sigma)}]^{-\sigma}}{[\Sigma\Sigma\ e^{V(j,k)/(1-\sigma)}]^{(1-\sigma)}}$$

This is a direct generalization of the traditional problem of joint choice. If σ is indeed equal to zero, then equation (7) reduces to equation (2), that is, to a choice model with the IIA property. If σ is equal to one, then from equation (6b) the choice of neighborhood depends only upon neighborhood attributes; that is, all housing units within a neighborhood are viewed as identical. Thus sequential estimation of equation (6) provides a direct statistical test of the degree of independence of irrelevant alternatives.

Now consider the problem of estimating the theoretically correct choice model -- the selection of one dwelling unit out of a large number of discrete alternatives. To estimate the choice model using as observations the entire set of metropolitan housing alternatives facing each consumer is clearly out of the question. If, however, for each consumer we select a subset of alternatives, d, and observe the consumer's choice among elements in this subset, then it may be possible to derive consistent estimates of the theoretically correct choice model. In particular, suppose $f(d|i)$ is the sampling rule for obtaining subset d, conditional upon the observed choice of dwelling unit i. McFadden (1977) has shown that if the sampling rule satisfies certain properties, that is,

$$(8) \quad \text{if } f(d|i) > 0 \qquad \text{then } f(d|j) > 0 \quad ,$$

then maximization of the modified likelihood function,

$$(9) \quad \log L \propto \frac{1}{k} \sum_{k} \log \frac{e^{V(i) + \log f(d|i)}}{\sum_{(j \text{ in } d)} e^{V(j) + \log f(d|i)}},$$

yields consistent estimates of the parameters of the choice function. Equation (8) specifies a sampling rule with the property that if rejected alternative j is assigned to the subset d, then it is logically possible that j could have been the observed choice. Under these conditions, McFadden's result indicates that the likelihood function need only be modified to take into account the sampling rule for selecting d. Thus it is possible to estimate, consistently at least, the parameters of the model that views households as choosing one specific dwelling unit out of the entire set of available units in the metropolitan housing market.

Two papers have applied these results in a partial manner in the analysis of the housing market:

First, Lerman's analysis (1977) of household choice of census tract includes a variable representing the logarithm of the number of households in each tract. Lerman interprets the coefficient of this variable as providing a direct test of the IIA assumption, that is, as a measurement of the degree of substitution among dwelling units, given census tracts.

This is because equation (6c) can be written as:

$$(10)\quad I_n = \log \Sigma\, e^{\alpha_1 X_{1i}/(1-\sigma)}$$

$$= \frac{\overline{X}_1}{(1-\sigma)} + \log N_n + \log \frac{1}{N_n} \sum_{N_n} \frac{e^{(\alpha_1 X_{1i} - \overline{X}_1)^2}}{1-\sigma}$$

where

$$\overline{X}_1 = \frac{1}{N_n} \sum_{N_n} \alpha_1 X_{1i}$$

and N_n is the number of dwellings in neighborhood n.

If all dwellings within a neighborhood are identical, the last term in the above equation is zero and the coefficient on log N_n is $(1 - \sigma)$, the degree of independence of irrelevant alternatives within a census tract.

Second, Quigley's recent analysis (1983) of housing choice is based upon a research design which samples dwellings according to equation (8), thereby providing consistent estimates of the choice of individual dwellings. However, the sampling structure adopted did not permit any analysis of the degree of substitution of neighborhoods or towns.[3]

III. EMPIRICAL ANALYSIS

In this section, we consider the household choice of dwelling. This choice involves consideration of the physical characteristics of structures and parcels, the selection of a neighborhood, the social and economic characteristics of neighbors and the accessibility of that neighborhood to the planned economic activities of the household. The selection of a particular dwelling is also inextricably linked to the choice of a city or town -- and to the collection of public services and taxes provided by that political jurisdiction.

The empirical results discussed below are based upon analysis of a home interview sample conducted in 1967 in the Pittsburgh metropolitan housing market by the Southwestern Pennsylvania Regional Planning Commission (SPRPC). The basic data file consists of information on 24,626 households and the dwellings they occupied. From this sample of households, we randomly selected a subsample of renter households who had moved into their present dwellings within the past year and for whom complete data were available. The subsample consists of observations on the housing choices of 584 recent mover rental households in the Pittsburgh metropolitan area. Table 1 presents a summary of the characteristics of these households, generally lower middle income renters with small families.

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[3] Given the sampling rule employed, which generated only a small sample of rejected alternatives for each household did not ensure any geographical clustering of observations, it was only possible to consider the degree of substitution of central city and non-central city dwellings.

The modal family size is two and the average is about three persons per household. About seventy percent of the households had one worker, but the average was 1.3 workers per household. More than ninety percent of household heads were employed full time. Five sixths of the households were classified as white, and more than eighty percent included an adult male. The average household income was $7,300 in 1967 dollars (or about $18,700 in 1980 dollars).

Table 1

Characteristics of 584 Sample Households

	Mean	Standard Deviation	Minimum	Maximum
A. Summary Characteristics				
Family Size	2.921	1.603	1	13
Number of Workers	1.339	0.578	1	5
Household Income (thousands of 1967 dollars)	7.313	3.993	2.5	35.0

B. Frequency Distributions	Percent
Family Size	
One	16.1
Two	30.0
Three	26.4
Four	14.2
Five or More	13.3
Number of Workers	
One	70.5
Two	25.9
Three	2.9
Four or More	0.7
Head's Employment	
Full time	90.0
Part time	3.6
Student	4.6
Unemployed	0.9
Race	
White	83.2
Non-white	16.8
Composition	
Adult Male Present	80.8
No Adult Male Present	19.2

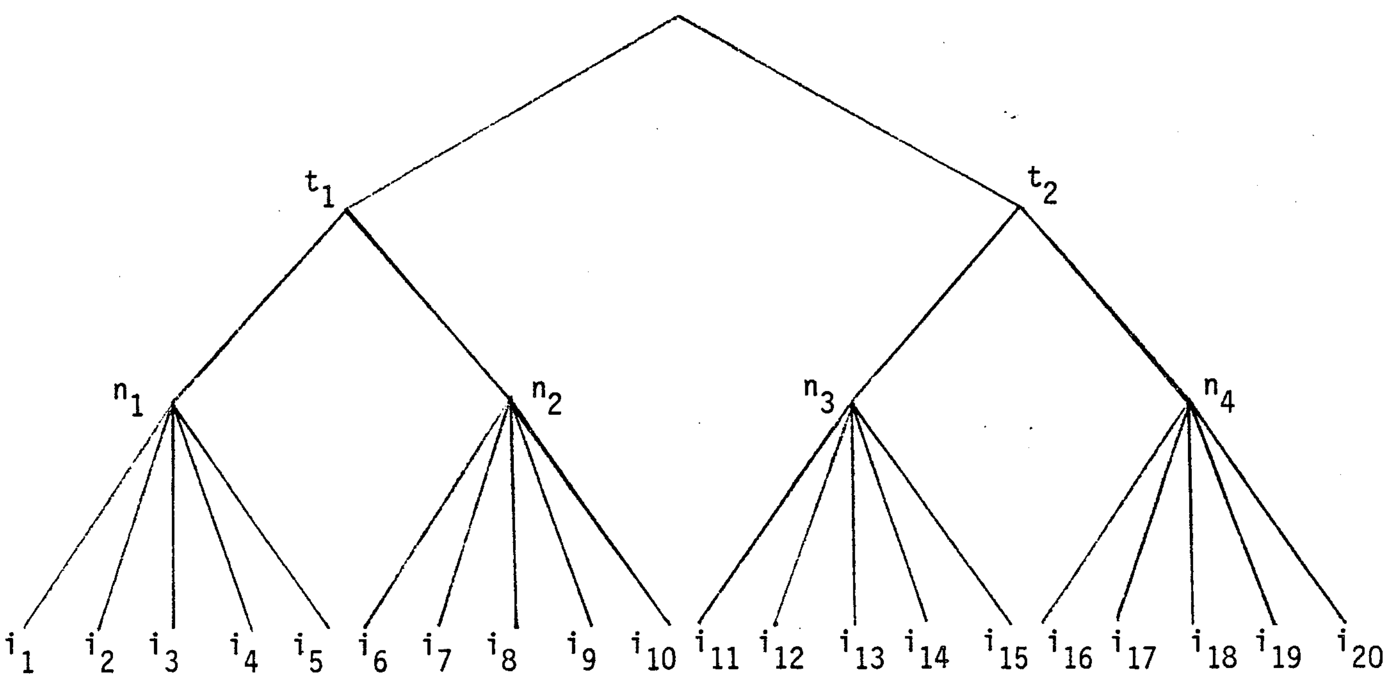
Source: Sampled from Southwestern Pennsylvania Regional Planning Commission home interview conducted in 1967.

A. The Nested Choice Model

We consider household choice in three stages: the choice of dwelling, given neighborhood and town $P(i|n,t)$; the choice of neighborhood, given town $P(n|t)$; and the marginal choice of the services and amenities provided by any town, $P(t)$. Figure 1 illustrates the structure of the nested logit analysis and indicates the rule used to generate the sample of alternatives. From in Figure 1 suppose that we observe that some household has chosen dwelling i_1, in neighborhood n_1, and town t_1. Suppose further that we observe 19 rejected dwellings, including 4 in the chosen town. Observations on chosen dwelling i_1, and rejected dwellings i_2 through i_5 for some sample of households permits the parameters of the conditional probability function $p(i|n,t)$ of the form of (6a) to be estimated. These parameters, in turn permit an estimate of the inclusive value I_n to be computed for each of the four neighborhoods.

Figure 1

Nested Structure of Dwelling, Neighborhood and Public Sector Choice



For example, the coefficients α_i of the dwelling characteristics permit estimates of the mean value $\overline{X}_n$ for a dwelling within a neighborhood and its variance W_n to be computed

$$(11)\quad \overline{X}_n = (1/5)\ \Sigma\ \alpha_i X_{1i}$$

$$(12)\quad W_n = (1/4)\ \Sigma\ (\alpha_i X_{1i} - \overline{X}_n)^2$$

and thus, the inclusive value for neighborhoods can be estimated as

$$(13)\quad I_n = \frac{1}{(1-\sigma)}\ \overline{X}_n + 1\ \log N_n + \frac{1}{2(1-\sigma)^2}\ W_n\ .$$

where N_n is the number of dwellings in neighborhood n.

Given this information, observations on chosen neighborhood n_1 and rejected neighborhood n_2 permit the parameters of the conditional probability function P(n|t) of the form of (6b) to be estimated, as well as the coefficient on the inclusive value I_n. Finally, these parameters allow an estimate of the inclusive value I_t to be computed for each of the two towns; this permits an estimate of the marginal probability function p(t) of the form of (6b) to be obtained. Together, these coefficients permit estimation of the joint probability function p(i,n,t), of the form of (7). Besides the stochastic utility parameters associated with dwelling unit, neighborhood, and public service characteristics, this sequential approach yields estimates of coefficients of two inclusive values: the inclusive value for neighborhoods given town, indicating the degree to which dwellings are perceived to be similar within neighborhoods, and the inclusive value for towns, indicating the degree to which neighborhoods within towns are perceived to be similar. If these coefficients are each equal to one, it follows that the "independence of irrelevant alternatives" assumption is consistent with household behavior.

B. The Sampling Rule

Sequential estimation of the choice model considers, in the first stage, observations on the chosen dwelling and on rejected dwellings in the chosen neighborhood. In the second stage, it considers observations on the chosen neighborhood and one rejected neighborhood in the same town. In the third stage, it considers observations on the chosen town and on one or more rejected towns.

Consider the following sampling rule for obtaining subset d. Choose d by including the chosen alternative and by selecting at random ω rejected alternatives in the same neighborhood. Then the sampling rule is merely

$$(14) \quad f(d|i) = \frac{\omega}{N_n - 1}$$

This sampling rule is clearly consistent with equation (8), i.e., if any alternative appears in the subset d it has the logical possibility of being the observed choice from that subset. Sampling rule (14) implies a much stronger property however; each alternative appearing in subset d has equal probability of being the observed choice. For this special sampling rule, with the so-called "uniform conditioning property" (McFadden 1978), the terms containing log f(d) in equation (9) simply cancel. Maximization of the likelihood function based on a sample of observations on choice i out of subsets d yields consistent estimates of the parameters obtained by maximizing the likelihood function based on observations on choices i out of the set of all possible alternatives D.

Table 2 summarizes the application of this rule, equation (14), to the sample of 584 Pittsburgh renter households. Column 1 reports the average characteristics of the dwellings chosen by each of these households. About 20 percent chose single detached rental units and about 32 percent chose units in duplex structures. On average, dwellings were 47 years old, contained 1.9 bedrooms and 1.1 bathrooms. On an ordinal scale of 1 (sound), 2 (deteriorated), 3 (dilapidated), the average dwelling was 1.3; monthly rent averaged $80 in 1967 dollars.

On average, these renter households chose neighborhoods (census tracts) that were 25 minutes from their work places by car and about 38 minutes by public transit. They chose neighborhoods that were 83 percent white, where home ownership rates were 41 percent and where the vacancy rate for rental housing was about 8 percent. The median monthly rent reported in the chosen neighborhoods (census tracts) was $111 in 1969 dollars. These households chose political jurisdictions where school expenditures were $762 per pupil, where the non-white students comprised 35 percent of the public school student body and where local government expenditures were $3,500 per household.

Column 2 reports the average characteristics of four rejected dwellings sampled (i.e., ω=4) for each household. Each of these dwellings is located in the same political jurisdiction and neighborhood. The dwelling units not chosen by these households tend to be in more dense structure types and slightly newer. They also average about $5 a month lower in rent than the dwellings chosen by these households. Together, the dwelling units described in columns 1 and 2

TABLE 2
AVERAGE CHARACTERISTICS OF SAMPLED DWELLINGS, NEIGHBORHOODS AND TOWNS
(Standard Deviations in Parentheses)

	Chosen Town			Rejected Town	
	Chosen Census Tract		Rejected Census Tract	Rejected Census Tract	Rejected Census Tract
	Chosen Dwellings	Rejected Dwellings	Rejected Dwellings	Rejected Dwellings	Rejected Dwellings
Dwelling Characteristics[a]					
Structure Type					
Single Detached (%)	20.034	18.793	20.274	33.082	33.425
Duplex (%)	31.507	30.479	36.952	28.733	28.767
Apartment (%)	46.575	49.315	41.027	37.740	37.534
Age of Structure (Years)	47.356 (12.11)	45.140 (11.98)	49.429 (13.14)	40.078 (13.91)	39.761 (11.68)
Condition (1=Sound; 3=Dilapidated)	1.269 (0.52)	1.296 (0.55)	1.320 (0.58)	1.255 (0.52)	1.246 (0.51)
Bedrooms	1.888 (0.93)	1.845 (0.96)	1.909 (0.96)	2.072 (0.96)	2.066 (0.88)
Baths	1.068 (0.40)	1.045 (0.36)	1.034 (0.35)	1.086 (0.36)	1.079 (0.36)
Monthly Rent (1967 dollars)	80.190 (44.12)	75.785 (43.14)	67.835 (40.50)	70.670 (38.93)	69.977 (36.84)
Census Tract Characteristics[b]					
Auto Time[a] To Work (Minutes)	25.060 (9.40)	25.060 (9.40)	29.116 (9.33)	44.491 (17.62)	44.372 (17.81)
Transit Time[a] To Work (Minutes)	38.464 (25.63)	38.464 (25.63)	47.327 (23.59)	73.253 (42.73)	72.625 (42.79)
Percent Nonwhite	17.410 (29.19)	17.410 (29.19)	20.648 (33.17)	2.049 (7.51)	2.800 (8.10)
Percent Owner Occupied	41.272 (24.35)	41.272 (24.35)	44.503 (24.66)	66.350 (17.466)	65.408 (18.28)
Percent Available Vacant	7.624 (11.67)	7.624 (11.67)	7.621 (11.15)	3.908 (8.52)	4.406 (10.92)
Median Monthly Rent (1969 dollars)	110.647 (41.85)	110.647 (41.85)	110.605 (45.40)	117.802 (55.41)	118.522 (54.55)
Percent Husband-Wife Families	51.454 (17.63)	51.454 (17.63)	52.448 (17.07)	69.580 (12.81)	68.937 (13.93)

TABLE 2
(Continued)
AVERAGE CHARACTERISTICS OF SAMPLED
DWELLINGS, NEIGHBORHOODS AND TOWNS
(Standard Deviations in Parentheses)

	Chosen Town			Rejected Town	
	Chosen Census Tract		Rejected Census Tract	Rejected Census Tract	Rejected Census Tract
	Chosen Dwellings	Rejected Dwellings	Rejected Dwellings	Rejected Dwellings	Rejected Dwellings
Town Characteristics[c]					
School Expenditures Per ADM ($)	761.687 (89.67)	761.687 (89.67)	761.687 (89.67)	963.955 (501.58)	956.722 (499.79)
Percent Nonwhite (Local Public School)	35.384 (9.54)	35.384 (9.54)	35.384 (9.54)	9.520 (15.49)	9.631 (15.46)
Local Public Expenditures Per Household (thousands)	3.567 (0.07)	3.567 (0.07)	3.567 (0.07)	4.425 (1.44)	4.414 (1.44)
Number of Observations	584	2,336	2,920	2,920	2,920

Notes:

a: From SPRPC home interview survey and zone to zone travel time matrices. See Quigley (1972) for details.

b: From 1970 Census of Housing.

c: Computed from 1970 Census of Governments data using methodology reported in Quigley, Trask, and Trask (1976).

correspond to units i_2 through i_5 in Figure 1.

The third column of Table 2 presents the average characteristics of dwellings i_6 through i_{10}. The dwellings were selected by choosing 1 rejected census tract within the chosen town (ω=1) according to sampling rule (14) and then choosing 5 dwelling units at random (ω=5). Column 4 presents the average characteristics of dwellings i_{11} through i_{15}, again by choosing at random one rejected town, one census tract, and five dwellings; the last column presents the average characteristics of dwellings i_{16} through i_{20} obtained by choosing another census tract in the rejected town, and five dwelling units within that tract.

Altogether we observe the specific dwelling chosen by each household and a sample of 19 rejected dwellings nested in four neighborhoods and two towns.

C. Results

Table 3 presents estimates of the parameters of the conditional choice of dwelling in several variants. The model includes two measures of residential density (dummy variables representing single detached dwellings and units in duplexes), two measures of the quality of dwellings (an index of structural condition, and the age of the structure), two size measures (the number of bathrooms and the number of bedrooms per person), and the amount of money left over for consumption of "other goods," i.e., monthly income minus rental payments.

Model 1 reports the coefficients of each of these variables in the model predicting dwelling choice, conditional upon the choice of neighborhood and political jurisdiction. The results suggest that these households prefer less dense housing (i.e., single detached dwellings are preferred to duplexes; both are

TABLE 3
COEFFICIENT ESTIMATES FOR DWELLING UNIT CHOICE,
GIVEN NEIGHBORHOOD AND TOWN
(t-ratios in parentheses)

Variable	Model 1	Model 2	Model 3
Structure Type			
Single Detached	0.371	0.106	-0.723
	(2.53)	(0.73)	(1.36)
Duplex	0.256	0.096	-0.62
	(2.05)	(0.77)	(1.45)
Age of Structure	-0.004	-0.019*	-0.791*
	(1.50)	(0.29)	(1.51)
Condition	0.066	-0.174*	1.974*
	(0.64)	(1.08)	(2.73)
Baths	0.299	0.262*	(0.339*
	(2.10)	(0.84)	(0.43)
Bedrooms/Person	0.738	0.101*	-0.625*
	(5.68)	(0.59)	(1.29)
(Income-Rent)/month	0.056	0.156*	0.819*
	(3.94)	(0.28)	(0.60)
$(\text{Income-Rent})^2$/month			-1.050*
			(2.05)
Log Income Times:			
Single Detached			0.483
			(1.60)
Duplex			0.459
			(1.88)
Age of Structure			-0.011
			(2.07)
Age of Structure^2			0.230
			(1.93)
Condition			-0.952*
			(4.03)
Condition^2			0.337
			(0.42)
Baths			0.453
			(1.71)
Baths^2			-1.360
			(1.46)
Bedrooms/Person			0.582
			(2.44)
Bedrooms/Person^2			-3.340
			(8.92)
Log Likelihood	-914.12	-936.09	-821.27
Likelihood Ratio Statistic (χ^2)	48.36	4.43	234.06

*Denotes variable measured in natural logarithms.

preferred to apartment dwellings, the left out category). The coefficients on the size variables are highly significant, suggesting that households would prefer more space and additional baths. The coefficient on the "other goods" term indicates that, ceteris paribus, households would prefer more income and lower housing prices.

Model 2 reports the coefficients of a similar model expressed in logarithmic form. As compared to the simple linear model, the coefficients on the logarithmic form are smaller and, in all cases, insignificantly different from zero. The likelihood ratio statistic is clearly insignificant in this formulation.

Model 3 reports the results of a more complex specification -- the model includes the same basic measures, but it includes the logarithms of the measures and the interaction of the log of income with each other variable and its square. In this specification, it is more difficult to interpret the sensitivity of household choice to dwelling characteristics. The results present some evidence on the importance of dwelling condition, age, size, and rent on the probability of choice. In general, the results suggest that consumers prefer dwellings of increased size, but that preferences increase with income at a decreasing rate.

Table 4 presents estimates of the choice of neighborhood conditional upon town, and tests for the independence of irrelevant alternatives across dwellings. The model includes variables measuring the proportion of owner occupants in the census tract (neighborhood) and the median rent of dwellings. Presumably, neighborhoods with a larger fraction of owner occupants are more desirable, as are neighborhoods where average rents are higher. The model also includes two measures of accessibility -- the commuting time by auto and public

TABLE 4

COEFFICIENT ESTIMATES FOR NEIGHBORHOOD CHOICE, GIVEN TOWN

(t-ratios in parentheses)

Neighborhood Characteristics	Model 1	Model 2	Model 3
Proportion Homeowners	0.0443 (0.13)	-0.1261 (0.38)	-0.0314 (0.09)
Median Rent (1970 Dollars)	0.0001 (0.05)	-0.0002 (0.09)	0.0011 (0.59)
Auto Travel Time (Monthly Commute in Hours)	-0.0405 (4.39)	-0.0371 (4.09)	-0.0393 (4.28)
Public Transit Travel Time (Monthly Commute in Hours)	-0.0008 (2.17)	-0.0117 (3.05)	-0.0102 (2.60)
Proportion Black:			
White Households	-0.0169 (2.15)	-0.7183 (2.61)	-0.6512 (2.35)
Black Households	1.1248 (2.08)	0.9431 (1.79)	1.1426 (2.11)
Inclusive Value			
Log (Dwelling Units), log N_n	0.0150 (0.18)	-0.0024 (0.03)	-0.0008 (0.01)
Mean, $\overline{X}_n$	0.2433 (4.53)	0.5303 (2.58)	-0.0004 (0.71)
Variance, W_n	0.6950 (1.13)	-4.9100 (0.82)	-0.0002 (3.47)
Log Likelihood	-320.21	-327.82	-322.18
Likelihood Ratio Statistic (χ^2)	163.64	148.42	159.70

TABLE 4A

ESTIMATES OF DEGREE OF INDEPENDENCE OF IRRELEVANT ALTERNATIVES FOR CHOICE OF DWELLING

$$(1-\sigma_n)\, I_n = R\, \overline{X}_n + (1-\sigma_{n_1}) \log N_n + \frac{1}{2(1-\sigma_{n_2})} \dot{W}_n$$

	Point Estimate	95 Percent Confidence Intervals		
Model 1				
R	0.2433	0.1380	to	0.3486
σ_{n_1}	0.9850	0.8217	to	1.1483
σ_{n_2}	0.2810	0.0200	to	1.980
Model 2				
R	0.5303	0.1275	to	0.9331
σ_{n_1}	1.0024	0.8466	to	1.1592
σ_{n_2}	1.1018	0.9293	to	1.0296
Model 3				
R	-0.0004	-0.0015	to	0.0007
σ_{n_1}	1.0008	0.8432	to	1.1576
σ_{n_2}	-0.2499×10^4	-0.4999×10^4	to	0.1666×10^4

transit from the home census tract to the tract containing the workplace for the head of household. The model also contains variables measuring the fraction of black households in the neighborhood, multiplied by a dummy variable indicating the race of the household.

The three models differ in the computation of the inclusive value, included as the three variables in equation (10). Models 1, 2 and 3 differ in relying upon the coefficients from models 1, 2 and 3 respectively in Table 3 to compute the variables X_n and W_n representing the mean and variance of the inclusive values.

Regardless of the specification of X_n and W_n, the coefficients of the other variables are quite stable. There is little evidence that the fraction of homeowners or the median rent makes a neighborhood more attractive to these lower-middle income renter households. Both measures of accessibility are highly significant, indicating that the probability of choosing a neighborhood, within town, is highly sensitive to the accessibility of the neighborhood to the worksite of the household. Other things being equal, a given reduction in auto commuting time has three or four times the importance in affecting choice as an equivalent reduction in commuting time by public transit.

The racial composition of the local area is clearly important in affecting household choice of neighborhood. Ceteris paribus, black households are considerably more likely to choose dwellings in neighborhoods containing a larger fraction of blacks, and white households are less likely. On the basis of the Model alone, we are unable to distinguish whether this results from self segregation by race or from the operation of a discriminatory housing market.

Table 4 also reports the coefficients of the three variables related to the inclusive value for dwelling units: the logarithm of the number of dwellings within a given census tract; the mean value of X_n estimated for that tract; and an estimate of its variance. The implications of these coefficients are indicated in Table 4A. According to the theory, the coefficient R of the mean value of X_n should be 1, the coefficient of the number of dwellings should be $1-\sigma_n$, and the coefficient of the variance term should be $1/(2(1-\sigma_n))$. Each model thus provides two estimates of σ_n. To be consistent with utility maximization, the value of σ_n should lie between 0 and 1. As the table indicates, the point estimates of σ_n derived from the log N term are very close to 1.

Table 5 presents marginal estimates of town choice for the 584 households. The model includes school expenditures per student, municipal expenditures per household, and measures of the racial composition of the political jurisdiction: the proportion black multiplied by a dummy variable for black households or another dummy variable for white households. Although the magnitudes are quite small, these results suggest that these households choose to live in towns where school expenditures and other public expenditures are lower. In the metropolitan Pittsburgh context, this means ceteris paribus that they are far more likely to choose residences outside the central city. In contrast to the results reported for neighborhoods, there are essentially no differences in the racial composition of towns selected by black and white households. The coefficients of the racial composition variable are virtually identical for black and white households.

When the transit time variables are added to the models, they have the anticipated sign. Presumably, however, the principal role of accessibility variation has been accounted for in the choice of neighborhood.

TABLE 5
ESTIMATES OF TOWN CHOICE
(t-ratios in parentheses)

	Model 1		Model 2		Model 3	
	A	B	A	B	A	B
Town Characteristics						
School Expenditures per ADM (x 10^4)	-0.0365 (3.00)	-0.0365 (2.85)	-0.0428 (3.56)	-0.4316 (3.37)	-0.0444 (3.86)	-0.04263 (3.42)
Public Expenditures per household (x 10^4)	-0.0013 (3.28)	-0.0013 (3.28)	-0.0013 (3.71)	-0.0013 (3.51)	-0.0013 (4.06)	-0.0013 (3.55)
Proportion Black in Schools:						
White households (x 10^4)	0.1335 (6.02)	0.1328 (5.90)	0.1425 (6.64)	0.1359 (5.87)	0.1356 (6.52)	0.1257 (5.70)
Black Households (x 10^4)	0.1402 (1.91)	0.1380 (1.85)	0.1415 (1.99)	0.1354 (2.02)	0.1465 (2.19)	0.1471 (2.20)
Auto Transit Time		-0.0085 (0.10)		-0.1247 (1.82)		-0.2202 (3.13)
Transit Travel Time		-0.0033 (0.17)		-0.0282 (1.20)		-0.0482 (2.80)
Inclusive Value						
Log (Dwellings) log N_t	0.6683 (1.68)	0.6644 (1.66)	0.6100 (1.66)	0.6749 (1.75)	0.5219 (1.46)	0.6767 (1.78)
Average $\overline{X}_t$	0.7939 (6.06)	0.7399 (1.50)	0.7987 (6.51)	0.0457 (0.10)	0.7326 (6.43)	-0.4874 (1.27)
Variance W_t	2.0215 (3.28)	2.0162 (3.25)	1.2966 (3.26)	1.3458 (3.10)	0.9686 (2.32)	1.1321 (2.59)
Log Likelihood	-43.45	-43.44	-48.99	-46.56	-53.75	-47.26
Likelihood Ratio Statistic (χ^2)	722.69	722.72	711.61	716.47	702.10	715.00

TABLE 5A

ESTIMATES OF DEGREE OF INDEPENDENCE OF
IRRELEVANT ALTERNATIVES FOR CHOICE OF NEIGHBORHOOD

$$(1-\sigma_{t_t})I_t = R\overline{X}_t + (1-\sigma_{t_1}) \log N_t + \frac{1}{2(1-\sigma_{t_2})} W_t$$

	Point Estimate	95 Percent Confidence Internals		
Model 1A				
R	0.7939	0.5371	to	1.0507
σ_{t_1}	0.3317	-0.4480	to	1.1113
σ_{t_2}	0.7729	0.3853	to	0.8453
Model 1B				
R	0.7399	-1.2797	to	2.7595
σ_{t_1}	0.3356	-0.4489	to	1.1201
σ_{t_2}	0.7520	0.3752	to	0.8453
Model 2A				
R	0.7987	0.5582	to	1.0292
σ_{t_1}	0.2900	-0.3300	to	1.1100
σ_{t_2}	0.6144	0.0329	to	0.7592
Model 2B				
R	0.0457	-0.8540	to	0.9414
σ_{t_1}	0.3251	-0.4308	to	1.0810
σ_{t_2}	0.6285	-1.1057	to	0.7723
Model 3A				
R	0.7326	0.5093	to	0.9559
σ_{t_1}	0.4781	-0.2225	to	1.1787
σ_{t_2}	0.4838	-4.3266	to	0.7202
Model 3B				
R	-0.4874	-1.2396	to	0.2648
σ_{t_1}	0.3233	-0.4218	to	1.0681
σ_{t_2}	0.5583	-2.6311	to	0.7486

Table 5A presents the implications of the coefficients of the X_t, W_t and log N_t variables.

For Model 1, the estimate of R is insignificantly different from one, the value implied by the theory. The confidence intervals for σ_t computed from the coefficient on log N_t include the entire [0,1] interval with 95 percent confidence, while the confidence interval computed from the coefficient on W_t is somewhat narrower and excludes the values of 0 and 1. The estimates computed from Models 2 and 3 are far less precise.

IV. IMPLICATIONS OF THE MORE GENERAL MODEL OF CONSUMER CHOICE

On the criterion of consistency with economic theory, model 1 appears superior to the other specifications. Stochastic utility maximization requires that the estimates of σ_n and σ_t lie between 0 and 1 and that the estimate of σ_t exceed the estimate of σ_n. For model 1 (in contrast to model 2) the coefficients of dwelling attributes are highly significant (see Table 3). Moreover, in contrast to model 3, all point estimates of the σ's lie between 0 and 1 (see Table 4A). Parsimony further suggests that Model 1A is preferred, and the requirements for utility maximization, $\sigma_t \geq \sigma_n$, indicate that the estimates of σ computed from the variance term are to be preferred (i.e., $\sigma_t = .7729$, $\sigma_n = .2811$, respectively).

The economic implications of the coefficient estimates of model 1A appear plausible, especially when the results of the more general analysis are compared to those derived assuming $\sigma_t = \sigma_n = 0$. For example, the coefficients reported in Table 3 suggest that households are willing to pay \$13.18 per month (.738/.056) for an additional bedroom and \$5.34 for an additional bath. These households appear to be willing to pay \$6.63 per month more for a single detached unit and \$4.57 more for a duplex than for higher density apartment accommodations.

From the coefficients in Tables 3 and 4, it appears that households are willing to bid a substantial premium for a more accessible location. For example, to save one hour of commuting time by car per month, households are willing to pay \$2.29 per month in higher rent (i.e., .0405/[.056(1-.7729)/(1-.2811)]), or about 62 percent of the average pre tax hourly wage. Interestingly, if the implicit value of accessibility is computed using the conventional IIA assumptions (i.e., $\sigma_n = \sigma_t = 0$), the estimated value of commuting time is considerably lower, \$0.72 (i.e., .040/.056) or less than 20 percent of the wage.

It is possible to compare the predictions of the well specified model with those implied maintaining the assumption that $\sigma_n = \sigma_t = 0$. Given the double nested form of the utility function, the log odds of choosing dwelling i in neighborhood j and town k relative to dwelling x in neighborhood y and town z may be expressed as

$$(15)\quad \log\,[P(i,j,k)/P(x,y,z)\,] = \frac{[A_i]/(1-\sigma_n) + [B_j + (1-\sigma_n)\; I_j]/(1-\sigma_t) + [(1-\sigma_t)\; C_k + (1-\sigma_n)\; I_k]/(1-\sigma_t)}{[A_x]/(1-\sigma_n) + [B_y + (1-\sigma_n)]I_y]/(1-\sigma_t) + [(1-\sigma_t)\; C_z + (1-\sigma_n)\; I_z]/(1-\sigma_t)}$$

where A_p, B_q and C_r are, respectively, the sums of the housing, neighborhood and town variables for dwelling p in neighborhood q and town r multiplied by their coefficients reported in tables 3, 4, and 5, and I_q and I_r are the inclusive values for neighborhood q and town r.

Table 6 presents estimates of the odds of choosing between two representative dwellings in each of two neighborhoods in each of two towns. Dwelling 1 is a 10 year old single detached unit in sound condition with one bedroom per person and two baths. Dwelling 2 is a 25 year old duplex unit, deteriorating, with one bath and half a bedroom per person. Dwelling 1 rents for $10 more per month than dwelling 2. The neighborhoods differ in racial composition and accessibility. Neighborhood 1 is more accessible to work (6 hours a month by auto and 15 hours by public transit) and has a 20 percentage point larger black population than neighborhood 2. The towns differ in that an additional $1,000 per household and $300 per student is spent in town 2. The table contains separate estimates for white and black households.

For the properly specified model, within town 1 and neighborhood 1, the choice of house 1 is about three times as likely (1 ÷ .35), and within town 2 and neighborhood 1, the choice of house 1 is about 2.8 times as likely (.88 ÷ .31) for white and black households. For the model which assumes the independence of irrelevant alternatives the comparisons, each about 1.5 times as likely (1 ÷ .65, .88 ÷ .58), are very different indeed.

For the model which incorporates the degree of independence of irrelevant alternatives, white households are 4 times as likely to choose neighborhood 1 in town 1 (1 ÷ .23) and 4.4 times as likely in town 2 (.88 ÷ .20). For the less general model, the comparisons, each about 1.4, are again very different. Other comparisons also reveal substantial differences in the odds of choice estimated using the two models.

Table 6

Comparisons of the Odds of Choice Among Dwellings, Neighborhoods, and Towns Computed By Assuming The Independence of Irrelevant Alternatives with Odds Estimated From More General Model

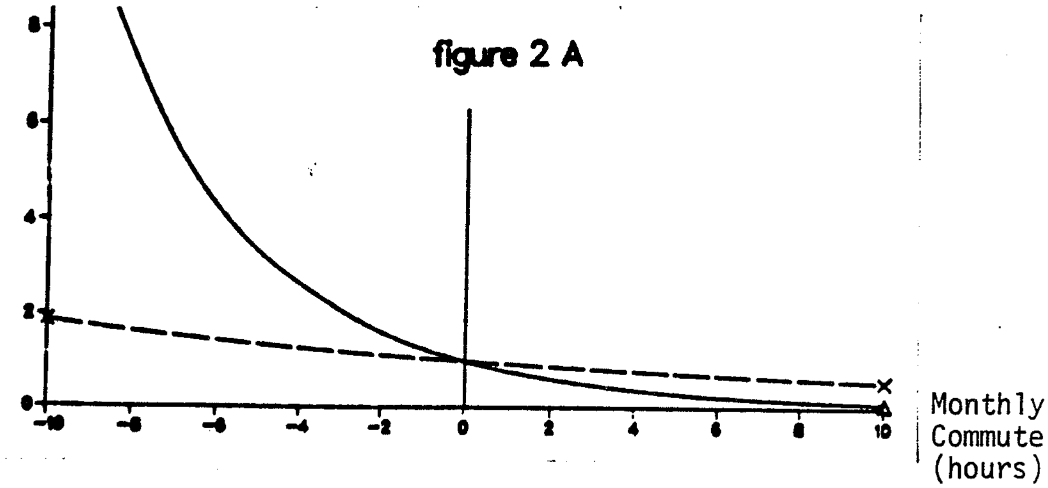
White Households	Assuming IAA $\sigma_n = \sigma_t = 0$		Estimating Degree of IIA $\sigma_n = .281$, $\sigma_t = .773$	
	House 1	House 2	House 1	House 2
Town 1				
Neighborhood 1	1.00	0.65	1.00	0.35
Neighborhood 2	0.69	0.45	0.23	0.08
Town 2				
Neighborhood 1	0.88	0.58	0.88	0.31
Neighborhood 2	0.61	0.40	0.20	0.07
Black Households				
Town 1				
Neighborhood 1	1.00	0.65	1.00	0.35
Neighborhood 2	0.50	0.33	0.06	0.02
Town 2				
Neighborhood 1	0.88	0.58	0.88	0.31
Neighborhood 1	0.44	0.29	10.05	0.02

Note: odds are expressed as ratio of probability of choosing a dwelling relative to House 1 in Neighborhood 1 in Town 1. Computations are made assuming the same number of dwellings in each neighborhood and the same number of neighborhoods in each town.

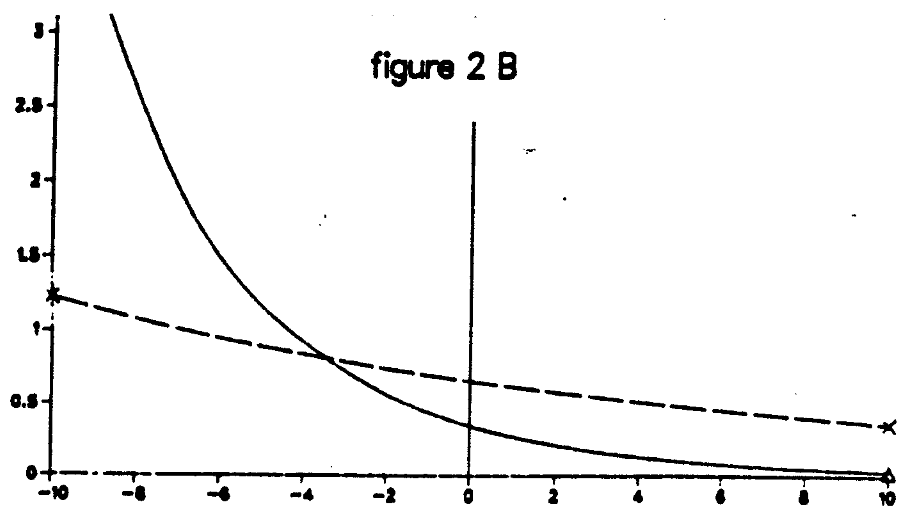
FIGURE 2

HOUSING CHOICE AS A FUNCTION OF ACCESSIBILITY

A. Odds of choice between two identical houses at various auto commute times.



B. Odds of choice between two different houses at various auto commute times.



Δ for $\sigma_n = \sigma_t = 0$;   0 for $\sigma_n = .28$, $\sigma_t = .77$

Finally, Figure 2 is indicative of the differences between the two models. The figure illustrates how the odds of choice between the two houses vary, *ceteris paribus* as the accessibility varies. Part A presents the odds of choice between two identical houses (of the "house 1" variety) as a function of accessibility differences as measured by auto commuting times. According to the model, if the IIA property is assumed, an identical dwelling that saves four hours a month in auto commuting time due to its superior location is preferred by about 1.5 to 1. According to the more general model, however, that dwelling is preferred by about 3 to 1. Similarly, the restricted model indicates that an 8 hour per month saving in commuting time increases the odds of choice to about 1.75 to 1; the more general model suggests that the more accessible unit is preferred by about 9 to 1.

Part B presents similar information for the choice between different houses (a "house 1" type relative to a "house 2") as auto accessibility varies. The sensitivity of choice to accessibility differences is much more pronounced for the more general estimates.

The results indicate quite clearly that, at least for this particular body of data, implications of the more general model make a substantial difference in the economic interpretation of the choice model.

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