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4

THE DEMAND FOR HOUSING ATTRIBUTES AND THE CHOICE OF NEIGHBORHOOD

1. INTRODUCTION

In Alonso's classic formulation, a household's choice of a location and amount of space consumed depends on income, tastes, and the shape of land-price and transport gradients. While Alonso assumed that all households worked in the center, his utility maximization framework for analyzing individual households' decisions can easily be generalized to the case where housing services are regarded as multidimensional and where households are employed at any work site in which the household confronts a tradeoff between longer and more expensive commutation and cheaper housing prices. As previously noted, there is a large spatial variation in housing units of different types. Consequently, households employed at different work sites confront different housing markets and may be expected to have diverse patterns of housing consumption.

The rudiments of this postulate that work site affects residential housing choices were tested in a study by Kain using household interview data for Detroit in 1953. Kain's approach was an implicit analysis of variance, in which comparisons of means revealed significant work-site effects. Kain stratified households by place of work, defining six concentric rings around the city center. While he had no evidence describing the shape of the rent surface, his assumption of a declining rent gradient was a realistic one for virtually every major city at that time. He found that households employed in the core made longer work trips than those employed in suburban rings, but because the latter had greater access to suburban housing markets, they were more likely to occupy one-family structures. Such occupancy also serves as a proxy for the choice of tenure. While the sample data did not include income, an occupation classification into eight broad groups served as an income proxy. Those central workers with the highest-income occupation made the longest commuting trips and were most likely to occupy single-family structures. Centrally employed workers in lower-income occupations made shorter work trips. Family size also proved relevant as an explanatory variable, with those households with the largest families most likely to occupy single-family structures.[1]

The empirical analysis below is based on a much richer data base, which includes detailed information on housing prices and housing consumption. An extension of the Alonso utility maximization model, together with explicit assumptions about the shape of price gradients, provides the conceptual basis for the empirical tests. The substantial variation in relative prices of housing confronting households employed at different work sites permits estimation of direct-price and cross elasticities and also a much more extensive documentation of the relationship between housing consumption and commuting costs. Other empirical studies of housing demand have encountered difficulty in estimating price effects because of the inability to observe price variation in aggregate cross-section data (either city-wide or by Census tracts) uninfluenced by unspecified variation in the type of housing, the neighborhood, or its particular location.

2. EXTENDING ALONSO'S APPROACH

In the analysis below, households are assumed to choose a set of housing attributes, $q_1, \ldots, q_k$, and a location such as to maximize utility subject to a budget constraint. While households are likely to consider both dwelling-unit characteristics and neighborhood characteristics as making up the bundle of residential housing services, the analysis here is confined to a set of attributes directly related to the characteristics of the housing unit (for example, age and lot size). Households employed at different work sites are assumed to confront a different set of housing prices and transport time and cost functions. In order for this problem to lend itself to the usual calculus solution, some simplifying assumptions must be made. First, space must be treated in one dimension, distance to the work site. Second, the opportunity-cost surface must be continuous. In its most general formulation, the price

1. John Kain, "The Journey to Work as a Determinant of Residential Location," *Papers and Proceedings of the Regional Science Association* (1962), pp. 137–60; idem, "A Contribution to the Urban Transportation Debate: An Econometric Model of Urban Residential Location and Travel Behavior," *Review of Economics and Statistics* (February 1964), pp. 55–65.

of any housing attribute i will depend on how much of i and all other attributes are purchased. Let $P_{qi}(q_1, \ldots, q_k, t)$ = price of acquiring q units of housing attribute i. The utility maximization problem is to maximize

$$U = u(Z, q_1, \ldots, q_k, t) \tag{1}$$

subject to

$$P_z Z + \sum_i (P_i q_i) + P_t(t) = Y. \tag{2}$$

The first-order conditions are as follows:

$$\frac{\partial u}{\partial z} - \lambda P_z = 0; \tag{3}$$

$$\frac{\partial u}{\partial Q_i} - \lambda \left[P_{Qi} + \sum_{j=1}^{k} q_j \left(\frac{\partial P_{Qj}}{\partial q_i} \right) \right] = 0; \; i = 1, \ldots, k; \tag{4}$$

$$\frac{\partial u}{\partial t} - \lambda \left[\sum_{j=1}^{k} q_i \frac{\partial P_{Qi}}{\partial t} + \frac{\partial P_t(t)}{\partial t} \right] = 0. \tag{5}$$

The first-order conditions have a convenient interpretation. At the optimum location, the ratio of marginal utilities of any two attributes i and j equals the ratio of the dollar costs of buying more of each:

$$\frac{\partial q_i}{\partial q_j} = \frac{P_{Qj} + \sum_i q_i \dfrac{\partial P_{Qi}}{\partial Q_j}}{P_{Qi} + \sum_j q_j \dfrac{\partial P_{Qj}}{\partial q_i}}. \tag{6}$$

Similarly, for the combination of attributes chosen, the optimum location t requires that the ratio of the price of other goods to the price of a longer work trip (cost savings in housing outlays less transport costs) just equal the marginal rate of substitution between all other goods and a longer work trip.

$$\frac{\partial z}{\partial t} = \frac{P_z}{\sum_i q_i \cdot \left(\dfrac{\partial P_{Qi}}{\partial t} \right) - \dfrac{\partial P_t(t)}{\partial t} = 0}. \tag{7}$$

Assuming each housing attribute has positive marginal utility, this model implies that households will commute away from the work site until the additional disutility of a longer work trip more than offsets the attendant savings in the price paid for the bundle of housing services consumed.

In order to assure that the first-order conditions yield a maximum, and to avoid problems of multiple solutions, strict concavity of the opportunity-cost surface is required.[2] Sufficient conditions under which the intersection of the many rent gradients or price surfaces for different quality attributes produces a concave set involve particular assumptions about transport costs and the housing-attribute price surfaces around the work site in question. While a continuous concave surface in t and q describing the opportunity-cost set must exist, it is not necessary that distance t be defined over the entire unit circle. Changes in the opportunity-cost surface, either through changes in housing prices, transport costs, or incomes, alters the optimal choice of housing and its location. As noted earlier, the effects of incremental changes in any parameter can be deduced by total differentiating the first-order conditions.

The assumptions necessary to obtain a continuous opportunity-cost surface are made for analytic and pedagogical convenience, so that the first-order conditions are equalities; discontinuities would introduce inequalities and corner solutions, and would require different optimization techniques. However, there are two additional limitations of a more fundamental sort implicit in the Alonso-type approach. First, accessibility and the prices of various housing attributes are the only characteristics of any given location which influence a household's valuation of that site vis-à-vis other possible sites. This ignores other considerations which may be important in household choices, particularly neighborhood characteristics. The nature of public services and taxes, racial or ethnic composition of the area, and aesthetic or environmental aspects of the neighborhood all may influence household choices. Neighborhood characteristics could easily be introduced into the household's utility functions. However, the assumptions of continuity and the use of the calculus to represent household choices would no longer be tenable, since neighborhood effects are associated with discrete geographic boundaries and hence are probably not well represented by continuous variables. If variables representing neighborhood effects are discontinuous, a household's equilibrium may involve corner solutions. Measurement of

2. Let $c(q_i, z, t, y)$ be the opportunity-cost surface. Assuming that $\partial u/\partial q_i$, $\partial u/\partial z > 0$ and $\partial u/\partial t < 0$, the second-order conditions require that the utility surface must be more convex than c in the region of the solution.

many neighborhood effects also poses problems, particularly those characteristics related to neighborhood homogeneity or loyalty. While racial or ethnic composition and turnover rates are readily measurable, these may be a poor proxy for what sociologists mean by "neighborhood spirit," "cohesiveness," or "pride of community."

The second limitation implicit in the static Alonso-type model and in the use of the cross-section data below is the neglect of relocation costs. For owners, the monetary costs of relocation can be substantial. Psychic costs associated with moving may also be high, especially for families with school-age children or strong ties to their current neighborhood. A household's decision to relocate when its job site, income, or tastes change will therefore depend on the magnitude of the associated increase in utility relative to the cost of moving.

There are several possible approaches which might be employed in introducing relocation costs. Perhaps the simplest would assume income, tastes, and work site exogenous—each changing over time in an unpredictable fashion; and would further assume that moving costs are a constant amount, irrespective of previous housing consumption, income, and tastes. Preferences would be represented as in the Alonso model. These assumptions imply that households would relocate only periodically, when changes in income, tastes, housing prices, or work sites were sufficiently large so that the associated gain in utility from moving would offset the cost of doing so. In this model, only those households who have just moved can be considered to be at their highest utility level among available options. Other households may have experienced changes in the exogenous variables too small to induce relocation.

A more realistic but more complicated model would introduce expectations inasmuch as households presumably form expectations regarding their future tastes, income levels, and housing-market opportunities. In such a model, household moves would be made in anticipation of future outcomes. For example, expected increases in income or family size might lead households to choose larger structures and higher-quality living space early in their life cycle, thereby eliminating the costs of a subsequent move. Work site changes could also be anticipated. How households act in the face of uncertainty and how they discount the future must also be specified.

Another extension, and one which would add additional realism to the analysis, would treat household income (or wealth) as endogenous. Housing investment constitutes a large portion of the financial holdings of all but the highest-income households. Viewing housing choices as both a consumption good and a financial investment converts the problems of when to move, what to buy, and where to locate into a standard exercise in control theory, with current housing choices influencing future levels of utility. This same conceptual approach is required if current housing-location choices affect future income and, hence, utility levels (for example, by providing more information about employment opportunities). Finally, relocation costs are likely to be dependent on current housing consumption (tenure and the size of house affect the costs of moving). Again, a control-theory approach is dictated.

The purpose of this sketch of possible models which incorporate moving costs is to provide some insight into the implications of using a cross-section sample which does not distinguish whether or not a household has recently moved. No dynamic model of the type outlined above has been specified or estimated and, hence, there is no means of formally relating static cross-section demand estimates to the parameters of a dynamic model. However, some simple inferences can be drawn. First, if households cannot anticipate future changes, and moving costs are substantial, then only those households who have recently moved provide good estimates of the effects of income and other exogenous variables on housing choices. This is the implicit rationale for the emphasis on recent movers in some empirical studies.

However, it seems likely that expectations are important in households' decisions to relocate. Under this assumption, the differences in estimates using separate cross-section equations for movers and nonmovers are not so easily interpreted. It is likely that a household's expectations and its adaptations in view of those expectations will not be invariant vis-à-vis its position in the life cycle, since the time profile of changes in those factors affecting households' demands for housing and households' expectations will differ across households of different ages. For example, all those households with younger heads, growing families, and rising incomes will probably make choices which anticipate their future status (perhaps "extending" themselves in their housing purchase at the time of moving). Some years after the move they will most likely be spending less of their income on housing. In dealing with older households (where the children have left home), the opposite situation may be observed. Thus, given the complexity of the proper specification, estimates based on *any* particular cross section (e.g., recent movers) provide virtually no insight into the dynamic aspects of the moving process: how expectations are formed, the lags in households' adjustments, and so on. Estimating the parameters of these dynamic models will require a rather sizable panel survey, covering a long time span. In short, while mover and nonmover cross-section samples lead to different results, it is not clear that a sample based only on recent moves provides more information or is the preferred specification, *if* expectations and relocation costs are both significant in household choices. There is little basis for choosing one cross-section sample over another; estimates based on an average of all households are likely to provide the most useful description of the characteristics of household choices in a *static* context.

These difficulties in interpreting cross-section results which arise because of relocation costs can easily be overstated. Households often move every few years. In San Francisco, 60 percent of all households in the 1960 Census reported that they lived in a different house in 1955.[3] Two studies of a panel survey of 3,185 San Francisco households over the period 1955 to 1965 reveal high moving rates. Goldstein's study of choices made in an eighteen-month period—January, 1964, to June, 1965—revealed that 30.7 percent moved during that time. Length of time at one's current job was negatively related to the probability of moving, indicating that job location changes do induce relocation.[4] Kain and Brown's analysis of moving behavior by these same households over the period 1955-65 also reveals high moving rates. They, too, found that job changes had a significant effect on moving rates. Of those households whose job moved to another geographic zone (the zones comprise several Census tracts), 28.1 percent moved their residence within a year; for households with no job change, the moving rate was 11.1 percent.[5]

3. ANALYSIS OF VARIANCE TESTS OF INCOME AND WORK-SITE EFFECTS

This model predicts that differences in work site and income affect the amount of housing consumed and the choice of location. For any plausible utility and rent surfaces, more centrally employed workers facing steeper prices will make longer commuting trips but consume less housing relative to workers employed in the suburbs.

Housing Consumption

In Table 4.1, households in the Bay Area are stratified by three income classes and two work sites. Analysis of variance tests reveal

3. U.S. Department of Commerce, Bureau of the Census, 1960 *Census of Population and Housing, Census Tracts*, Final Report PHC (1)-137 (Washington, D.C.: Government Printing Office, 1962), p. 14.
4. Gerald Goldstein, "Household Behavior in the Housing Market: The Decision to Move and the Decision to Buy or Rent Housing," 1972, processed (based on "A Cross-Section Study of Households in the San Francisco Bay Area, 1965" [Ph.D diss., Princeton University, 1970]).
5. James Brown and John Kain, "The Moving Behavior of San Francisco Households," NBER, 1971, processed.

TABLE 4.1
HOUSING CONSUMPTION BY WORK SITE AND INCOME

	Less Than $7,000		$7,000–12,000		More Than $12,000	
	CBD[a]	Suburb[b]	CBD[a]	Suburb[b]	CBD[a]	Suburb[b]
			A. Owners			
Average value of housing ($)	$22,750[c]	23,200	25,451[c]	22,285	37,222[c]	34,952
Average commuting time (hrs.)	.62[c]	.34	.59[c]	.35	.54[c]	.45
Percent owner-occupants	29[c]	42	53[c]	61	68[c]	81
Average number of rooms	5.2	5.5	5.7	5.8	6.3	6.4
Structure age						
% built before 1940	78[c]	51	47[c]	38	40	43
% built 1940–60	22[c]	45	39[c]	45	39[c]	38
% built after 1960	0[c]	4	14[c]	17	21	19
Lot size						
% less than .2 acre	41[c]	23	28	27	24[c]	16
% .3–.5 acre	59[c]	71	65	66	54[c]	67
% greater than .5 acre	0[c]	6	7	6	22	17
			B. Renters			
Average rent (month, $)	$103[c]	81	117[c]	100	193[c]	139
Average commuting time (hrs.)	.39[c]	.34	.45[c]	.37	.55[c]	.32
Average number of rooms	3.8	3.8	4.0	4.2	4.7	4.6
Structure age						
% built before 1940	93[c]	75	72[c]	65	56[c]	32
% built 1940–60	5[c]	11	11[c]	13	21[c]	28
% built after 1960	2[c]	14	17[c]	22	23[c]	35

[a] Average in geographic zones defined by Census Tracts A-14 to A-17 and K-2 to K-4 in downtown San Francisco.

[b] Average for geographic zones located 5 to 8 miles from the San Francisco CBD.

[c] CBD-suburb difference in means significant at the 5 percent level.

that the work-site classification affects the probability of home ownership, age of structure, lot size, and commuting time. Only dwelling-unit size (number of rooms) seems invariant to work-site location. As has been noted in Chapter 3, the spatial variation in prices for housing of like quality confronting households at different work sites is dramatic; centrally employed households may have to pay twice as much for housing of a given quality as workers employed in the ring if the location choices of each entail equal commuting time from place of work. As a means of reducing the dollar costs for housing of any given quality, households employed in central locations and facing steep rent gradients travel considerably farther than households who are employed in the suburbs. Because of this twofold adjustment by centrally employed workers—commuting farther and consuming older units on smaller lots—centrally employed households actually spend only marginally more for housing (for homeowners about 10 to 15 percent) than households with the same income who are employed in the suburbs.

Income also affects the tradeoffs between housing costs, transport time, and housing consumption. Table 4.1 reveals that a central work site poses especially difficult problems for the poor. Of those households with annual incomes of less than $7,000 and central work sites, only 29 percent are homeowners, versus 42 percent for the same income group when employed in the ring. In this income strata, centrally employed workers who own their homes also make very long commuting trips, .62 hour versus .34 hour for homeowners of similar income employed in the ring. Centrally employed low-income homeowners also travel farther than higher-income households working in the center; by traveling further down the rent gradient, they are able to buy housing at a lower price. (The observed differences in housing expenditures across income levels involve differences in both the location and the quality of housing purchased.) The majority of households in this lowest income class who are employed in the center are renters and commute relatively short distances to work.

For higher-income households (income exceeding $12,000), a somewhat different housing pattern emerges. Place of work again affects home-ownership rates, with 68 percent of centrally employed households owning versus 81 percent for those employed in the ring. Those households who are employed in the core and are renters make substantial commuting trips—.55 hour versus .39 hour for those renters with the same income working in the ring. Much of this commuting is away from the core. The substantial commuting trips by high-income households who are renters and employed in the core suggests that a shortage of good-quality rental units (or satisfactory neighborhoods) exists in the city center.

Commuting Patterns

The details of the geographic pattern of workplace-residence site pairings are voluminous and enumerating them here would be an unnecessary digression. For present purposes, the important issue is whether commuting patterns generally support the inferences of the static utility-maximization model of household choice. Since neighborhood effects are excluded from the model, accessibility to the household's work site and the prices of available housing are the only characteristics of neighborhoods affecting the choices of households. Perhaps the simplest and most straightforward test of the validity of the model involves the number of cases in which households chose a given neighborhood when there are other areas *both* more accessible *and* containing comparable housing at a lower price. For households employed at a point from which rents decrease in some directions and increase in others, none should commute up the rent gradient; if rent surfaces assume less regular shapes, households should avoid residing in areas representing a local maximum in rents. In the context of the Alonso-type model, disregarding these strictures would be regarded as "irrational." However, as has been noted earlier, in a more complete specification of the determinants of household behavior, such choices need not be "irrational," since they may reflect neighborhood effects or relocation costs. The question being raised here is whether such cases are so frequent as to seriously undermine the simplifying assumptions implicit in the Alonso-type approach.

Determining the incidence of "irrational" choices in the context of the Alonso-type model is somewhat complicated when housing services are multidimensional. When making utility comparisons in circumstances in which prices of several goods are different, familiar index-number problems are introduced. There is no unique set of price weights to provide an index ranking the desirability of all potential consumption bundles (in this instance, a set of housing attributes and a location) for all households if households' incomes and tastes differ *and* prices vary across housing types. The procedure followed below abstracts from these complications; the measure of neighborhood desirability used was based on only two dimensions—accessibility to the work site and the price for a single type of housing, a standard-sized owner unit built on a .2 to .3 acre lot, in 1950–59. Using this criterion, an "irrational" choice of location was one in which the household located in a zone in which the price of this housing type was higher than zones *more* accessible to the work site. Some households will, of course, be acquiring other types of units, and hence this particular two-dimensional measure of the desirability of different submarkets will result in an overestimate of the number of households who reside in a location which is "less desirable" than other possible sites, as compared with the figure that would be obtained *if* their tastes and all dimensions of housing were properly taken into account.

Even using this simple criterion for rationality, examining all possible residential options and the location choice actually made for each

TABLE 4.2
RESIDENCE SITE-EMPLOYMENT SITE FREQUENCY DISTRIBUTIONS, SELECTED SITES

A. Frequency Distribution of Residential Location Choices, for Selected Work Sites

Work Site	Residential Locations Where Housing Prices Higher Than at Work Site	Number of Households	Residential Locations Where Housing Prices Comparable or Below Work Site	Number of Households
1. Suburbs to south of San Francisco[a]	Nearly neighborhood (6-mile commuting)	38	Within area of work site	253
	Palo Alto suburbs (16-mile commuting)	10	Surrounding suburbs not listed	123
	City of San Francisco	79	More distant suburbs	84
	Marin City	6	Oakland suburbs	45
	Central Oakland	3		505
	Berkeley	2		
		138		
2. Suburbs to south of Oakland[b]	Nearly neighborhood	19	Within area of work site	501
	Central Oakland	13	Surrounding suburbs not listed	20
	Berkeley	2	Northern Oakland suburbs	18
		34		539
3. Marin City (northern suburbs)	City of San Francisco	7	Within area of work site	408
	Berkeley	2	Suburbs to south of San Francisco	1
		9	Oakland and surrounding suburbs	12
				421
4. Central Oakland[c]	Berkeley	18	Within area of work site	195
	City of San Francisco	9	Remainder of Oakland and surrounding suburbs	320
		27	Suburbs to south of San Francisco	10
				525

B. Work-Site Origins of Households Residing in Selected Residential Areas

Residence Site	Work-Site Locations Where Housing Prices Below Those at the Residence Site	Number of Households	Work-Site Locations Where Prices Equal to or Above Those of the Residence Site	Number of Households
1. Berkeley[d]	Central Oakland (excluding areas with more than 15% black population)	23	Within area of residence site	112
	Black residential areas of Oakland	27	City of San Francisco	42
	Suburbs to north of Oakland	19		154
	Suburbs to south of Oakland	9		
		78		
2. Suburb to south of Oakland[e]	Central Oakland (excluding areas with more than 15% black population)	46	Within area of residence site	34
	Black residential areas of Oakland	41	Berkeley	5
	Adjacent suburb to north, toward Oakland	33	City of San Francisco	15
	Surrounding suburbs to south, away from Oakland	129		54
		249		
3. Suburb to south of San Francisco[f]	Surrounding suburbs	36	Within area of residence site	69
	San Jose	46	City of San Francisco	39
		82		108

[a] San Mateo County, Census Tracts 1-29.
[b] Alameda County, Census Tracts FR 70-75, HA 46-68, CV22-CV28.
[c] Census Tract, Oakland, OK39A-OK58.
[d] City of Berkeley.
[e] Alameda County, Census Tracts SL29-SL37.
[f] San Mateo County, Census Tracts 30-38.

household in the sample would be a large task.[6] Consequently, a selected subsample of households' location choices was analyzed in order to explore the extent to which the Alonso-type model's assumptions hold up. The first test considered the residential location choices of households employed at one central and three suburban work sites, each representing a work site where housing prices are neither the highest nor lowest in the entire Bay Area. Examining location choices of households employed at these sites will reveal how frequently households commute to higher-priced submarkets. In the case of workers employed in the central work site, in this case central Oakland (Table 4.2, Part A, Case 4), 4.8 percent commute to San Francisco City or Berkeley, where housing prices are substantially higher. In the case of those employed in the three suburban work sites, a small percentage of households also commute up the rent gradient. Of those employed in the most centrally located of the three suburban work sites, a zone adjacent to the City of San Francisco (see Table 4.2, Part A, Case 1), 21.4 percent of the workers chose a residence site where prices are higher than in the area in which they work; 12.3 percent located in nearby San Francisco, while 7.6 percent reside in two nearby surburbs where housing prices are distinctly higher. In the case of the two more distant suburban work sites (see Table 4.2, Part A, Cases 2 and 3), 9.2 percent and 2.4 percent, respectively, of households employed in these areas commute to zones where housing prices are higher (generally toward the central cities of San Francisco and Oakland). Thus, in each of these four cases, only a relatively small percentage of households chose to reside in areas in which prices at their place of residence were significantly higher (in some instances, 50 percent higher) than prices at their place of work. However, the majority of households working at these four work sites live in the immediate area of their work or in surrounding areas where prices are lower (or not significantly different from those prevailing at their work site)

An alternative view of the same phenomenon of commuting up

6. A more elaborate test of household location choices has been made by Quigley. Quigley calculated the total cost of housing for each household, defined as the cost of the housing unit chosen in the zone of residence plus transport costs from the work site to the residence site, with time valued at the wage rate. He then calculated the same costs for *all* possible zones of residence. He found that for most households, the costs associated with the households' actual place of residence was less than 10 percent above what was hypothetically their "least cost" choice of neighborhood (John Quigley, "The Influence of Workplace and Housing Stocks upon Residential Choice," paper presented at the Toronto Meetings of the Econometric Society, December 30, 1972, processed).

the rent gradient can be seen by analyzing the work-site origins of households residing in suburban submarkets which constitute distinct local peaks in the rent surface.[7] There are three distinct local peaks in the rent surface in the San Francisco Bay Area. The most pronounced local peak was for the City of Berkeley, where housing prices are one-third to two-thirds higher than those in immediately surrounding areas, holding the type of dwelling unit constant. Examination of the work-site origins of Berkeley residents reveals that they can be classified into three groups: 33.7 percent work in surrounding areas where prices are lower, 18.4 percent work in San Francisco, where prices are roughly comparable, and 47.9 percent work in the area of residence (see Table 4.2, Part B, Case 1). In the case of the other two suburban areas (where prices are above surrounding areas by about one-third), the percentages of workers who work in other zones where prices are *lower* are 53.2 percent and 18.9 percent, respectively. Thus, in all three cases, a significant proportion of residents commute to work sites where prices are lower. In addition, many of these commuters bypass other potential areas of residence where prices are lower. Apparently the peak-price neighborhoods have special attractions which have resulted in housing prices there being bid up sharply.

Taken together, these results suggest that the basic insight of the Alonso model—that households commute away from their place of work to obtain housing at lower prices—is substantiated. At the same time, there is evidence that certain neighborhood characteristics are important, and that selected neighborhoods attract households with widely dispersed work sites. A complete explanation of household residential choices must necessarily address these neighborhood effects.

4. ESTIMATION OF DEMAND FUNCTIONS

The comparisons of mean levels of housing attributes consumed by households stratified by work site and income constitute only the simplest empirical representation of the inferences to be derived from the model discussed above. If simplifying assumptions are made about the shape of price surfaces, the utility maximization model can be used to derive demand functions for the several housing attributes; the elements of these demand functions are income and the parameters of the utility and rent surfaces.

7. There are other irregularities in rent surfaces, but the differences in prices between contiguous zones or zones near each other are much smaller than for the three cases selected.

As noted, while households employed at any work site actually confront a set of housing submarkets with discrete boundaries and discontinuities in price tradeoffs through space, the demand model disregards much of this spatial variation in prices, since space is treated in one dimension.[8] Actual prices confronting a household at any given work site must be condensed into single-dimension rent gradients, indexed by accessibility, t, to the work site in question. If one does not specify a complete model of household search and bidding for the available housing stock, a formidable task, somewhat ad hoc procedures must be employed.[9] To exclude households considering traveling up the rent surface, only surrounding areas in which rents were below rents at the work site were considered. Zones where the price of housing achieved a local maximum—i.e., were above prices in all immediately surrounding areas—were also excluded. As noted earlier, unless unusual restrictions are put on the extent of convexity in utility and price surfaces, households will always commute down the rent gradient and around or beyond areas which represent a local maximum in the rent surface.

Prevailing prices in all other zones were deemed relevant to a household's perception of the rent surface. The rent surface confronting households employed at any given site will be determined by prevailing prices, the availability of housing at different sites, and the length of the commuting trip to each site. As a continuous approximation to housing price-transport time options in all other zones, a negative exponen-

8. Irregular price surfaces also increase the likelihood that corner solutions will emerge, and that multiple local solutions exist. The second-order conditions involving concavity must be met for households employed at different work sites and confronting different prices. However, these many different households are in fact viewing only a single set of urban housing submarkets from different viewpoints (i.e., different work sites); a spatial pattern of housing prices which yields a concave opportunity-cost surface required by the second-order conditions for households at a particular work site may not yield the same-shaped surface for households employed at other sites. One set of assumptions which will meet the second-order conditions for households employed throughout the city is for prices of all housing attributes to decline at a decreasing rate as distance to the center increases. Other less restrictive assumptions (e.g., a continuous rent surface with two local maxima) may also yield a set of continuous price surfaces such that households employed at any work site in the city confront an opportunity-cost surface that is concave in some direction from their work site.
9. There is no empirical evidence indicating how households conduct this search, or how they perceive the rent surface which confronts them.

tial was assumed, $P_{jk} = A_{ik} e^{\beta_{ik} t_{ij}}$, where P_{jk} is the price of house type k at location j, t_{ij} is the transport time from work site i to j, and A_{ik} and β_{ik} are parameters defined for each work site and house type. It was assumed that any household regarded the probability of obtaining a house at the prevailing price at any given site as proportional to the share of the housing stock with those quality characteristics located at that site. The expected price of house type k is therefore $\Sigma n_{jk} P_{jk}$, where n_{jk} is the proportion of units of type k in zone j. Under these assumptions, the minimum variance estimators of A_{ik} and β_{ik} will be nonlinear. A_{ik} and β_{ik} must be estimated for each *work site* and *house type*, as denoted by the subscripts i and k. Those employed in or near work-site concentrations generally face a steeper rent gradient.

Alternative assumptions might be made about how households form expectations about the shape of the rent gradients. Strict "rationality" would suggest that any single household confronting various housing price–transport time choices at different sites would consider only those zones which define the lower "envelope" (or least-cost possibilities) among these options. Under this assumption, the relevant opportunity-cost surface is often a few discrete points rather than a continuous surface. However, prices in these same few zones may often appear as part of the envelope for those employed at other work sites. Clearly, all households collectively cannot expect to obtain housing in a few zones which represent only a portion of the stock. There may also be other still unspecified housing quality characteristics which account for the existence of these few apparently most favorable cost-accessibility options.

The estimated parameters A_{ik} and β_{ik} describing the opportunity-cost surface for each housing attribute for those employed at any work site are included in the demand functions along with incomes. It is inappropriate to include prices which households *actually* pay as independent variables in demand estimation when using individual household data. Prices paid are choice variables which households alter by changing their work trip. Those with a preference for more housing will travel farther to buy housing at a lower unit price. Since households with different tastes for housing or commuting time will alter their work trip, and hence the actual prices at which housing is purchased, such prices will reflect variation in tastes as well. Inclusion of the actual price paid by the household at the residence site chosen in statistical demand equations using individual household data will therefore result in biased estimates. Similarly, the market prices included in the demand equations for each attribute should *not* be indexed by the household type, its preferences, or income level. Price options confronted (as parameterized above, or in any other form) are invariant across all households employed at any *one* work site (though actual prices *paid* will reflect income and tastes).

In the estimation below, price gradients for each attribute confronting households employed at different work sites were characterized by the level of prices of that attribute at a specified trip distance down the rent gradient (the mean travel time for the entire sample). These prices depend on both parameters of the estimated rent surfaces and vary substantially for households employed at different work sites. This is the simplest parameterization of differences in the set of price options confronting households employed at different work sites. More complex measures of differences in price options did not significantly improve the fits. Since the model's treatment of the spatial dimension of households' choices in one dimension is a substantial abstraction, it is unlikely that any more complex parameterization of these empirical approximations to rent surfaces would prove useful.

The functional form for demand equations will depend on the form of utility functions. While the shape of price surfaces can be approximated empirically, there is little basis for choosing a particular utility function. The nonlinearity in the opportunity-cost surfaces requires judicious choice of a utility function to yield manageable demand functions, in particular, linear in the important parameters. The simplest cases are generally uninteresting.[10]

Since there is little basis for choosing among several different utility functions, and all produced nonlinear demand relationships when rent gradients were represented by a negative exponential or other suitable nonlinear forms, linear forms of the demand equations were used, including as independent variables, income and prices as described above. The object of the estimation is to provide insight regarding the effects of important independent variables in the region around the sample mean. With this purpose in mind, it hardly seems fruitful to complicate the estimation process so as to take into account speculation about the

10. A simple example in which housing is treated as a one-dimensional commodity, the housing gradient is assumed to be a negative exponential $P = Ae^{-\beta t}$, and the utility function is a Cobb-Douglas form, $U = \alpha_0 Q^{\alpha_1} Z^{\alpha_2} t^{\alpha_3}$, will illustrate the problem. The solution to Equations 3, 4, and 5 in this case yields the following demand function for housing: $q = k(Y/A)$. Unfortunately, the data do not support this result; for fixed prices, A, q is not linear with Y. Specifying a utility function leading to tractable but interesting demand functions is much complicated in the many-dimensional case and if relative prices of several quality attributes are to be included in the demand equations for any single housing attribute.

shape of the utility function or price gradients. As has been noted, the model itself is a considerable simplification, neglecting neighborhood effects and spatial discontinuities in housing prices. In view of these limitations of the model, deriving explicit demand functions (linear or otherwise) in the context of an Alonso-type model is, in my judgment, largely a pedagogical exercise. The more important avenue for research is the inclusion of neighborhood characteristics in the utility function and a recognition of the discontinuities in housing options. (As previously noted, this extension requires a fundamental revision of the basic model of household choice.)

Most other studies have attempted to explain either total housing expenditures or the probability of ownership, focusing on income and generally not including prices as independent variables.[11] Cross-section samples across cities include little price variation, and efforts to interpret price effects in aggregate time-series demand equations have generally been plagued by the fact that most price variation is trend dominated. Variation in work sites is the source of variation in prices in the sample below; estimates are made by pooling data across work sites for a given life-cycle class.

The estimation of income elasticities must be interpreted with the reservation usual in studies of durable consumer purchases—a reservation arising from the fact that reported income is only a first approximation to permanent income. Permanent income has been shown to be the more relevant variable in consumers' housing decisions.[12] Several studies have been made of the relationship between the estimated income elasticity in cross-section housing demand regressions when measured income is used and the results obtained when using permanent income.[13]

11. Margaret Reid, *Housing and Income* (Chicago: University of Chicago Press, 1962); Richard Muth, "The Demand for Nonfarm Housing," in *The Demand for Durable Goods*, ed. Arnold C. Harberger (Chicago: University of Chicago Press, 1960), pp. 29-96; Tong Hun Lee, "Housing and Permanent Income: Tests Based on a Three-Year Reinterview Study," *Review of Economics and Statistics* (November 1968), pp. 480-90; Alan R. Winger, "Housing and Income," *Western Economic Journal* (June 1968), pp. 226-32; Frank de Leeuw, "The Demand for Housing: A Review of the Cross Section Evidence," *Review of Economics and Statistics* (February 1971), pp. 1-10.
12. Milton Friedman, *A Theory of the Consumption Function* (Princeton: Princeton University Press, 1957).
13. Margaret Reid, *Housing and Income;* Sherman Maisel and Louis Winnick, "Family Housing Expenditures: Elusive Laws and Intrinsic Variances," in *Consumption and Savings*, ed. Irwin Friend and Robert Jones (Philadelphia: Wharton School of Finance and Commerce, University of Pennsylvania, 1960), pp. 359-435.

Lee's study reconciles these several estimates. His figures indicate that in equations explaining house value, the permanent income elasticity may be as much as one-third higher than the elasticity when using measured income. The former was as much as 15 percent higher in equations explaining monthly rent.[14] A downward bias of this general magnitude in the estimated income elasticities for the several components of housing quality presented below is likely.

In order to control for variations in tastes, the data were stratified by family life cycle. The large sample permits a rather detailed life-cycle stratification. The life-cycle classification was based on marital status, the age of the head of the household, and the number of children under fifteen. Single individuals who identified themselves as heads of households were grouped into those living alone and those living with others. Two life-cycle groups were defined for households in which the head was separated or divorced: those households with children present and those without them. Most families with a separated head and children present were female-headed households. The remaining twelve life-cycle groups were for married households with both parents present; these households were classified by four age classes and three family sizes. The open-ended classification of married households with the head over fifty included very few households with a head older than sixty-five, since the sample used in the demand estimation includes only those households in which the head is employed. This stratification allows for the testing of a variety of hypotheses about life-cycle effects, although the classification by no means resolves all ambiguities. For example, older heads of household (over forty) without children may never have had children or their children may have moved away. In the above classification, no consideration is given to the presence of adults other than the parents (either related or unrelated to the household head) in the household.

The attributes of housing analyzed included choice of tenure, dwelling-unit size, age of structure, lot size, travel time, and total housing expenditures.[15] Separate equations were estimated for owners and renters.

14. Lee, "Housing and Permanent Income."

15. There are many characteristics of individual dwelling units which are not included in the sample below. In some cases, of course, the characteristics of the stock provide only a first approximation of any meaningful description of the type or level of services being consumed. Structure age, for example, often serves as a proxy for the layout or size of rooms, whether there are high ceilings, the quality of plumbing and utilities, the style of the structure, its general condition, and so on. Those attributes of residential services which are unrelated to the capital stock, presumably because the price of securing that attribute is independent of the type of structure chosen, are excluded from the discussion.

Age and lot size were represented both in continuous and discrete forms.[16] The dependent variables were:

Q_1 = probability of ownership (1 if owner, 0 if renter);
Q_2 = number of rooms in dwelling unit;
Q_3 = structure age (years);
Q_4 = 1 if unit built prior to 1939, 0 otherwise;
Q_5 = 1 if unit built 1960-65, 0 otherwise;
Q_6 = lot size (acres);
Q_7 = 1 if unit built on lot less than .2 acre, 0 otherwise;
Q_8 = 1 if unit built on lot greater than .3 acre, 0 otherwise;
Q_9 = 1 if unit built on lot greater than .5 acre, 0 otherwise;
p^* = price of total bundle of housing services;
t = travel time to work.

Q_2 through Q_5 were defined both for rental and owner units. Independent variables included income and a series of price variables—the price of a composite bundle of housing characteristics and the incremental price associated with the several particular attributes:

Y = Income.
P = Price of standardized owner-occupied unit—5.5 rooms, built since 1960, on .2 to .3 acre lot, in sound condition.
$POWN$ = Monthly costs of owning standardized unit. Mortgage amortization costs assume 20-year mortgages at 5 percent. Maintenance and property taxes assumed to be 4 percent of housing price.[17]
$PRENT$ = Monthly rent of standardized unit—4 rooms, built since 1960, in sound condition.
PR = Price of additional room in owner unit.
PA_1 = Incremental price of a newer owner unit. Ratio of price of standardized unit built since 1960 to price of a standardized unit built in 1950-60.
PA_2 = Incremental price of a newer owner unit. Ratio of price of standardized unit built 1940-50 to price of unit built before 1940

16. The several dichotomous dependent variables describing the structure-age (or lot-size) choice are alternative measures of certain characteristics of the single frequency distribution describing choices regarding structure age (or lot size) for any given underlying population. Accordingly, the parameters of the equation for these several dichotomous variables denoting age will be related.
17. Richard Muth, *Cities and Housing* (Chicago: University of Chicago Press, 1969), pp. 103-4. A range of alternative assumptions used to define the monthly cost of owning, including the tax savings associated with owning, led to the same qualitative conclusions about price and income elasticities as those reported below.

PL_1 = Incremental price of large lot. Ratio of price of standardized unit with lot .2 to .3 acre to price of standardized unit on lot < .2 acre.
PL_2 = Incremental price of larger lot. Ratio of price of standardized unit built on .3 to .5 acre to price of standardized unit on .2 to .3 acre.
PL_3 = Incremental price of very large lot. Ratio of price of standardized unit built on more than .5 acre to price of standardized unit built on .3 to .5 acre.
RR = Rental cost of additional room in rental unit.
RA_1 = Incremental rent of newer unit. Ratio of rent of standardized unit built since 1960 to rent of standardized unit built 1950–60.
RA_2 = Incremental rent of newer unit. Ratio of rent of standardized unit built 1940–50 to rent of unit built before 1940.

The definitions of the incremental prices associated with acquiring more of any particular attribute are the best available approximations based on the information contained in the hedonic price indexes. In each case, the incremental price of a unit of higher quality was defined as the ratio of prices of units different with respect to the quality dimension of interest but comparable in all other dimensions of quality. This method of describing price differences avoids the specification bias which would arise if actual expenditures were used. Actual expenditures confound many quality dimensions. In the equation for choice of tenure, only the price of owning relative to renting is included. In the equations for the other housing attributes, both the price of the standardized bundle of services and the incremental price of several selected housing attributes were included. Coefficients for the incremental prices of particular attributes in the demand equation for any one attribute will reflect substitute or complementary relationships.[18]

A logarithmic form was employed if the dependent variable was continuous and a semilog form was used if the dependent variable was a zero-one dummy. Because of the wide variation in income in the sample, these nonlinear forms proved superior to linear equations. The equations were estimated by ordinary least squares. In the case where the dependent variables were dichotomous, the error term was no longer homoscedastic. Fortunately, the loss of efficiency associated with using ordinary least squares is probably very small when dealing with samples of the size employed here. A more precise treatment of such equations—

18. Other demand studies have used only the price of some composite bundle of housing services and have generally found demand to be inelastic. It is plausible to expect particular attributes of the bundle of services to exhibit a greater elasticity with respect to the incremental cost of that attribute.

assuming, for example, that a linear probability function is being estimated, with the expected value of the dependent variable linearly related to the independent variables—is complex and involves nonlinear estimation.

A. Results: Preferences for Particular Housing Attributes

The specification of the equations and the results for the life-cycle class "married households, with one child and with age of head 30-39" are shown in Table 4.3. Among the several housing attributes, tenure and lot size are the two characteristics exhibiting the highest income elasticities, with the income elasticity very high in the equation for the decision to choose very large lots (in excess of .5 acre), 3.127. Income elasticities for structure age and number of rooms are well below unity. The income elasticity for rooms is only .120. Previous studies have generally found a high relationship between overcrowding (persons per room) and income.

Price variables also prove significant in the demand equations. The price elasticity for the composite bundle of housing services is well below one in most equations, while the elasticity with respect to the incremental price of any particular attribute is often substantially higher. This suggests that the most important substitutions that households make when confronting different housing prices are among quality attributes, and that these incremental prices are important in explaining housing consumption.

In the tenure equation, the price elasticity is −.462. Previous studies of home ownership have generally stressed income and family characteristics as the key explanatory variables, particularly age of head and family size,[19] but none have addressed the role of price in the decision to own. As has been pointed out, the price of owning versus renting varies substantially throughout the city, with the price gradient for owner-occupied housing much steeper than the rental-housing price gradient.

Choices with respect to structure size and age exhibit the lowest price elasticities, with most of the estimated price elasticities below

19. Sherman Maisel and Louis Winnick in *Proceedings of the Conference on Consumption and Savings*, vol. 1 (Philadelphia: University of Pennsylvania Press, 1960), p. 397; Sherman Maisel, "Rates of Ownership, Mobility and Purchase," in *Essays in Urban Land Economics* (Berkeley and Los Angeles: University of California Press, 1966), p. 94; Martin David, *Family Composition and Consumption* (Amsterdam: North-Holland, 1962), pp. 55-57; James Morgan, "Housing and the Ability to Pay," *Econometrica* (April 1965), pp. 289-306.

TABLE 4.3
DEMAND ESTIMATES: MARRIED HOUSEHOLDS WITH ONE CHILD, AGE OF HEAD 30-39

Dependent Variable		Independent Variable (Logs)					Elasticities (at Mean)[h]				
A. Probability of ownership		Y	$(POWN)/PRENT$				Y	$(POWN)/PRENT$			
	Q_1	.396	−.462[a]				.396	−.462			
B. Owner-occupants: housing attributes		Y	P	PR	PA_1	PL_1	Y	P	PR	PA_1	PL_1
Rooms	Q_2	.120[a]	.208	−.078[a]	.215	.045	.120	.0	−.078	.0	.0
Structure age: years	Q_3	−.172[a]	.270[a]	c	1.439[a]	.879[a]	−.172	.270	c	1.439	.879
Since 1939	Q_4	.030[b]	−.142[a]	c	−.474[b,d]	−.309[b]	.033	−.158	c	−.528	−.344
Since 1960	Q_5	.054[a]	−.081[b]	c	−.414[b]	−.399[b]	.179	−.269	c	−1.375	−1.326
Lot size: acres	Q_6	.345[a]	−.182[a]	c	−.457[b]	−1.072[a]	.345	−.182	c	−.457	−1.072
Less than .2 acre	Q_7	−.061[a]	.152[a]	c	.231[b]	.238[b]	−.709	1.767	c	2.686	2.767
Greater than .3 acre	Q_8	.065[a]	−.137[b]	c	−.496[b]	−.294[b,e]	.299	−.646	c	−2.339	−1.387
Greater than .5 acre	Q_9	.172[a]	−.045[b]	c	.051	.197[f]	3.127	−.818	c	.0	.0
Expenditures	P^*	.419[a]	.472[a]	c	c	c	.419	.472	c	c	c
Travel time	t	.015	.411[a]	c	c	c	.0	.411	c	c	c

C. Renter-occupants: housing attributes		Y	R	RR	RA_1	Y	R	RR	RA_1
Rooms	Q_2	.063[a]	.104	.092	.215	.063	.0	.0	.0
Structure age: years	Q_3	−.194[a]	.828[a]	[c]	1.264[a]	−.194	.828	[c]	1.264
Since 1939	Q_4	.161[a]	−.387[a]	[c]	−.281[g]	.266	−.640	[c]	−.464
Since 1960	Q_5	.125[a]	−.277[b]	[c]	−.613[b]	.464	−1.031	[c]	−2.280

[a] = Coefficient significant at .05 level.
[b] = Coefficient has t-ratio exceeding one.
[c] = Variable not included in equation.
[d] = Coefficient for PA_2.
[e] = Coefficient for PL_2.
[f] = Coefficient for PL_3.
[g] = Coefficient for RA_2.
[h] = Elasticities presented for coefficients with t-ratio exceeding one.

unity. Conversely, lot-size decisions are more price elastic. The elasticity for the price of the composite bundle of services is higher than that in the structure-age equations; the elasticity associated with the incremental price of a larger lot is 2.767 in the equation denoting the likelihood of a household residing in a unit on the smallest lot size, and −1.387 in the equation denoting the likelihood of an above-average-size lot. Finally, lot size and structure age are complementary commodities, as evidenced by the significant coefficients for both age and lot-size prices in the lot-size and structure-age equations. These cross price elasticities are well above unity in most of the equations.

Equations for aggregate expenditures on housing and travel time to work complete the set of demand equations. As has been previously noted, households employed in central locations and facing steep rent gradients travel considerably farther than households who are employed in the suburbs; this is a way of reducing the dollar costs for housing of any given quality. The travel-time equation exhibits statistically significant elasticities with respect to both the level of prices and incomes. Richer households are more disposed to commute long distances in the face of any given rent surface than poorer households, implying that the savings in expenditures associated with richer households' much higher levels of consumption outweighs the disutility of a longer commuting trip. The elasticity of housing values or rent with respect to both prices and incomes is less than one.[20] However, as has been noted, despite households' substitution of longer commuting trips to reduce housing costs, and the consumption of lower-quality housing, those with central-city work sites do spend somewhat more for housing than similar households employed in the ring.

20. Inclusion of housing attributes in the equations for expenditures and travel time provides a summary description of the combined effects of income, work site, and differences in tastes on decisions regarding housing expenditure and commuting time. It must be stressed that this is purely descriptive, and beyond the spirit of the estimation above, which includes only incomes and parameters describing prices in the equations. Housing expenditures independent of the quality of housing purchased are positively related to the level of housing prices arising from work-site differences, and are inversely related to transport time. Despite households' substitution of longer trips to reduce housing prices, those with central-city work sites pay more for housing of comparable quality. The elasticity of *actual* prices paid with respect to the level of prices at a *given* trip distance P_0, holding housing quality constant, is about .80. In the equation for travel time, income proves insignificant when housing quality and price are held constant. The fact that higher-income families make the longest commuting trips reflects their desire to reduce the costs of consuming substantially larger amounts of housing.

B. *Results: Life-Cycle Differences*

A substantial variation exists in both preferences for housing and ability to pay across the sixteen life-cycle classes. Table 4.4 presents mean levels of income and housing consumption for these groups. The most dramatic life-cycle effects appear in comparisons of home-ownership rates. Only 16 percent of single households are homeowners. For married families whose head is under 30, ownership rates are 16 percent, 36 percent, and 54 percent, respectively, for none, one, and two or more children. Ownership rates increase sharply with age.

Among homeowners, age and lot-size characteristics of housing consumed by households classified as "single," "single with others," and "separated without children" are indistinguishable from one another in this sample. (Households in the group "single with others" occupy larger units.) Households classified as "separated with children" which are homeowners occupy housing which is roughly comparable with that of married households. Among married households who are homeowners, structure age rises with age of head. With regard to lot-size differences, the proportion of households occupying both the largest (over .3 acre) and smallest (less than .2 acre) lot sizes rises with the age of head. That older households (of a given family size) occupy smaller lots and older units probably reflects their tendency to move less often. Household size or number of children has been hypothesized to be positively related both to dwelling-unit size and lot size. Dwelling-unit size increases significantly with number of children, but the effects of family size on lot-size appear only for households with heads over forty. For these older households, the presence of children raises the proportion of households with above-average-size lots.

Among renters, life-cycle differences are much less pronounced than is the case for owners. This probably reflects the greater mobility of renters, arising from lower moving costs. Household size affects dwelling-unit size; households with children rent larger units. With respect to structure size, married households with head under forty occupy significantly newer units than single and separated households. As with renters, structure age of owner-occupied units is positively related to the age of head.[21] The presence of children has little or no effect on structure age with the exception of the oldest age group; renters over fifty without children occupy a significantly higher proportion of newer units (built since 1960) than households of the same age with children.

21. Sixty-nine percent of married renters whose head of household is under forty occupy units built after 1940 versus 54 percent for married families whose head of household is over fifty; the same comparisons for owners yield 90 percent for younger households versus 70 percent for older households.

TABLE
DIFFERENCES IN INCOME AND

Life-Cycle Class	Mean Income	Probability of Ownership	Number of Rooms	Proportion with Lot Less Than .2 Acre	Proportion with Lot Greater Than .3 Acre
Single, alone	$7,651	.161	5.04	.229	.183
Single, with others	12,323	.247	5.91	.269	.099
Separated, no children	7,912	.450	5.50	.225	.227
Separated, children	7,050	.455	5.86	.137	.216
Married, head <30, no children	9,272	.164	5.57	.080	.248
Married, head <30, 1 child	8,160	.356	5.58	.104	.249
Married, head <30, 2+ children	8,859	.538	5.76	.083	.221
Married, head 30–39, no children	12,842	.539	5.67	.079	.267
Married, head 30–39, 1 child	11,310	.677	5.77	.086	.272
Married, head 30–39, 2+ children	11,573	.802	6.32	.076	.283
Married, head 40–49, no children	14,315	.812	5.98	.118	.279
Married, head 40–49, 1 child	13,434	.856	6.27	.092	.326
Married, head 40–49, 2+ children	13,817	.872	6.71	.083	.330
Married, head 50+, no children	13,521	.821	5.85	.155	.318
Married, head 50+, 1 child	14,058	.876	6.28	.122	.333
Married, head 50+, 2+ children	14,838	.898	6.63	.127	.367

This suggests that households often move to newer units after their children have grown.

This cross section permits some simple hypothesis-testing regarding the source of these housing differences by life-cycle group. By estimating demand functions for each life-cycle group, tests can be made for differences in income and price elasticities. If the tests reveal no significant

4.4
HOUSING CONSUMPTION BY LIFE CYCLE

Owners			Renters		
Proportion with Lot Greater Than .5 Acre	Proportion with Structure 1960-65	Proportion with Structure Pre-1939	Proportion in Structure Pre-1939	Proportion in Structure 1960-65	Proportion in Structure in Sound Condition
.049	.065	.443	.275	.463	.961
.086	.165	.400	.315	.544	.962
.083	.067	.415	.227	.522	.935
.044	.132	.196	.242	.545	.922
.056	.360	.136	.398	.696	.962
.055	.373	.097	.367	.711	.965
.040	.354	.094	.257	.680	.899
.070	.267	.127	.335	.632	.962
.055	.301	.103	.269	.604	.956
.071	.343	.104	.245	.644	.902
.077	.192	.154	.225	.578	.959
.086	.175	.138	.293	.654	.947
.109	.262	.124	.226	.644	.926
.114	.119	.317	.265	.551	.959
.101	.153	.200	.143	.551	.918
.113	.179	.241	.167	.500	.875

differences, housing differences across life-cycle groups can only be traced to differences in the intercept terms in the demand equations. The complete set of equations for the sixteen life-cycle classes appears in Appendix A. A summary of the elasticities (evaluated at the sample mean) with respect to income, the price of the aggregate bundle of housing services, and the incremental price of the attribute in question

TABLE
INCOME ELASTICITIES BY HOUSING

	Dependent Variable				
		Owners			
Life-Cycle Class	Probability of Ownership	Rooms	Structure Age (Years)	Probability Structure Pre-1939	Probability Structure 1960-65
Single, alone	.762	-	−.352	.446	1.384
Single, with others	-	.076	−.346	.198	.538
Separated, no children	.175	.086	−.131	.088	.667
Separated, children	.545	.042	-	-	-
Married, head <30, no children	1.189	.103	-	-	-
Married, head <30, 1 child	.848	.076	-	-	-
Married, head <30, 2+ children	.701	.100	−.283	-	.465
Married, head 30-39, no children	.487	.063	−.306	-	.587
Married, head 30-39, 1 child	.396	.119	−.172	.033	.179
Married, head 30-39, 2+ children	.232	.165	−.220	-	.401
Married, head 40-49, no children	.158	.144	−.167	.036	.253
Married, head 40-49, 1 child	.117	.136	−.173	.038	.360
Married, head 40-49, 2+ children	.114	.184	−.184	-	.381
Married, head 50+, no children	.147	.168	−.204	.109	.497
Married, head 50+, 1 child	.060	.157	−.190	.064	.379
Married, head 50+, 2+ children	.132	.257	−.055	-	-

Note: Elasticities calculated at the mean of the dependent variable. An omission in the table indicates that the estimated coefficient has a *t*-ratio less than one.

for each equation appear in Tables 4.5, 4.6, and 4.7. The following discussion summarizes the principal differences in the demand equation by life cycle.

With regard to tenure, the income elasticity varies significantly by household type, ranging from .05 for older households with children

4.5
ATTRIBUTES AND LIFE CYCLE

Dependent Variable						
			Renters			
Lot Size (Acres)	Probability Lot .2 Acre	Probability Lot > .5 Acre	Rooms	Structure Age (Years)	Probability Structure 1960-65	Probability Structure Pre-1939
.201	-	1.755	.186	−.268	.322	.353
.309	−.307	1.360	.093	−.302	.372	.242
.133	−.144	.716	.060	−.414	.650	.301
-	−.466	-	.076	−.255	.423	.136
.264	−1.209	1.482	.095	−.441	.493	.212
-	-	-	.069	−.340	.372	.214
.139	−.424	1.455	.102	−.175	-	.172
.135	-	.640	.093	−.247	.343	-
.345	−.709	3.127	.063	−.194	.464	.266
.294	−.634	1.729	.113	−.377	.446	.281
.307	−.488	1.728	.061	−.510	.901	.208
.354	−.533	1.875	.222	−.515	.451	.315
.402	−.693	1.519	.150	−.553	.835	.478
.316	−.377	1.041	.144	−.317	.414	.228
.451	−.820	1.687	.180	−.145	-	-
.464	−.661	1.346	.088	−.103	-	1.073

to almost unity for single people and young married couples. For both separated and married families, the presence of children reduces the income elasticity. The price of owning relative to renting also varies across life-cycle groups, assuming values from −.37 to −1.25 for single people, separated families, and married households with head under thirty, and declining to zero for families with an older head of household. The relative absence of price effects on home-ownership rates for those

TABLE
ELASTICITIES FOR PRICE OF STANDARD BUNDLE OF

	Dependent Variable				
					Owners
Life-Cycle Class	Probability of Ownership	Rooms	Structure Age (Years)	Probability Structure Pre-1939	Probability Structure 1960-65
Single, alone	[a]	[a]	.482	−.508	−1.946
Single, with others	[a]	[a]	.397	−.399	-
Separated, no children	[a]	[a]	.247	−.329	-
Separated, children	[a]	[a]	.698	−.502	−1.348
Married, head <30, no children	[a]	[a]	.0	−.268	-
Married, head <30, 1 child	[a]	[a]	.218	−.062	−.284
Married, head <30, 2+ children	[a]	[a]	.239	−.041	−.279
Married, head 30-39, no children	[a]	[a]	.491	−.149	−.613
Married, head 30-39, 1 child	[a]	[a]	.270	−.158	−.269
Married, head 30-39, 2+ children	[a]	[a]	.417	−.174	−.443
Married, head 40-49, no children	[a]	[a]	.232	−.181	-
Married, head 40-49, 1 child	[a]	[a]	.100	−.083	-
Married, head 40-49, 2+ children	[a]	[a]	.280	−.145	−.399
Married, head 50+, no children	[a]	[a]	.252	−.244	−.505
Married, head 50+, 1 child	[a]	[a]	.237	−.138	−.453
Married, head 50+, 2+ children	[a]	[a]	.475	−.261	−.935

Note: Elasticities calculated at the mean of the dependent variable.
An omission in the table indicates that the estimated coefficient has a t-ratio less than one.

[a]Price of standardized bundle of services not included in the equation for this attribute.

over thirty is hardly surprising, given the tax advantages of ownership and inflation in the postwar period. These factors accrue such an advantage to home ownership that, except for younger households who wish to retain greater mobility and households with lower incomes, price

4.6
HOUSING SERVICES BY HOUSING ATTRIBUTES AND LIFE CYCLE

Dependent Variable						
			Renters			
Lot Size (Acres)	Probability Lot .2 Acre	Probability Lot > .5 Acre	Rooms	Structure Age (Years)	Probability Structure 1960-65	Probability Structure Pre-1939
−.264	.913	-	a	1.315	−1.882	−1.626
−.814	1.207	−2.766	a	1.629	−1.775	−2.038
−.375	1.441	-	a	.0	-	−.884
−.262	1.578	-	a	.765	−1.071	−1.006
−.378	1.804	-	a	.0	-	−.489
−.109	2.105	-	a	.902	−.648	−.777
−.118	.977	-	a	.0	-	−.607
−.212	-	−.891	a	.817	-	−1.147
−.182	1.767	−.818	a	.828	−1.031	−.640
−.100	1.589	-	a	.640	−1.056	−.193
−.225	1.564	−.606	a	1.608	−3.020	−.396
−.179	.671	−.619	a	.0	−2.325	-
−.070	1.190	−.441	a	.989	−2.295	−.557
−.215	1.164	−.108	a	.844	−1.713	−1.345
−.351	2.407	-	a	.0	-	−2.699
−.472	2.084	-	a	.0	-	−1.510

differences arising from the household's work-site location have little impact on ownership.

The dwelling-unit-size equations exhibit very low income and price elasticities for all life-cycle groups. The income elasticity for rooms is quite low, ranging from .05 for single persons to .20 for married heads of household with children. The income elasticity for married households is positively related to the age of the head of the household and to the number of children. There are no significant differences

TABLE
ELASTICITIES FOR INCREMENTAL PRICES

Life-Cycle Class	Probability of Ownership	Rooms	Structure Age (Years)	Probability Structure Pre-1939	Probability Structure 1960-65
	Dependent Variable				
		Owners			
Single, alone	−.372	.0	.0	−2.663	−5.522
Single, with others	−.889	.0	.0	−1.104	−4.500
Separated, no children	−.721	−.088	.759	−.657	-
Separated, children	−.564	.0	.0	−.985	-
Married, head <30, no children	−1.257	−.121	.0	-	-
Married, head <30, 1 child	−.606	−.121	2.475	-	−3.593
Married, head <30, 2+ children	−.501	−.121	.0	−.422	-
Married, head 30–39, no children	−.517	−.121	.0	−.401	-
Married, head 30–39, 1 child	−.462	−.121	1.439	−.528	−1.375
Married, head 30–39, 2+ children	−.209	−.121	.720	−.208	−.773
Married, head 40–49, no children	−.103	−.121	1.415	−.388	−2.640
Married, head 40–49, 1 child	−.109	−.121	1.450	−.409	−4.100
Married, head 40–49, 2+ children	.0	−.121	1.545	−.389	−2.084
Married, head 50+, no children	−.240	−.121	1.087	−.746	−2.597
Married, head 50+, 1 child	−.105	−.121	.0	−.694	−1.370
Married, head 50+, 2+ children	.0	−.121	.0	-	-

Note: Elasticities calculated at the mean of the dependent variable.
An omission in the table indicates that the estimated coefficient has a *t*-ratio less than one.

in the coefficients for the price of rooms across life-cycle groups. For renters, the income elasticity does not vary across household groups; the price elasticity for married households is insignificant for most age and family-size groups, whereas it proves significant—from −.104 to −.150—for single and separated households.

4.7
BY HOUSING ATTRIBUTES AND LIFE CYCLE.

Dependent Variable						
			Renters			
Lot Size (Acres)	Probability Lot .2 Acre	Probability Lot > .5 Acre	Rooms	Structure Age (Years)	Probability Structure 1960–65	Probability Structure Pre-1939
−1.020	6.880	-	−.139	3.605	−3.319	−1.797
−1.382	7.961	-	−.150	3.297	−3.548	−.677
−1.807	2.575	−1.695	−.104	6.297	−10.315	−.986
−2.198	-	-	.0	2.771	−3.816	-
−2.964	-	-	−.221	2.714	−1.518	-
−.554	-	-	.0	2.353	−1.977	−.691
−1.232	4.855	-	−.109	2.862	−3.029	−.859
−.528	9.370	-	.0	2.056	-	-
−1.072	2.686	-	.0	1.264	−2.280	−.464
−.532	-	−1.021	.0	1.914	-	−.640
−.405	-	-	.0	.0	−4.415	-
−1.068	-	-	.0	6.596	−6.893	-
−1.402	2.879	-	.0	.0	−2.460	-
−1.236	2.661	−.670	−.084	2.558	-	1.534
−1.372	3.422	-	−.085	4.243	-	4.636
.0	3.944	-	.0	10.168	−17.354	5.168

In the equations for structure age, the principal life-cycle differences in the slope coefficients arise from the classification by marital status. Households comprised of single and separated individuals without children (life-cycle groups 1 to 3) exhibit significantly higher income and price coefficients than is the case for married households; income and price elasticities for the several structure-age decisions are approximately twice as high for these three types of households made up of single individuals than for married households. For example, the income elasticity in the structure-age demand equation for single individuals is −.352, versus values ranging from −.055 to −.306 for married households of different ages. The income elasticity in the equation denoting the likelihood a household occupies a unit built since 1960 is 1.384 for single individuals, versus values ranging from .179 to .587 for married households. (See Table 4.5, columns 3 to 5.) The elasticity associated with the price of the standardized bundle of housing services in the equation for the decision to acquire the newest units is −1.946 for single individuals, versus values ranging from −.269 to −.935 for married households. The cross-price-elasticity term defined by the price of a larger lot in the structure-age equations is significant; again, the size of this cross elasticity is less for married than for single households.

Among married households, there are no significant life-cycle differences in slope coefficients for income or price effects. It was noted earlier that older households have higher average incomes but live in older structures. Since the income elasticity with respect to structure age is negative, the higher incomes of households with an older age of head implies that older households should occupy newer units, all other things being equal. The finding that older households live in older units (a difference which appears in the intercept terms) reflects the fact that older households are less willing to move. This more than offsets the income effect, which is positively related to age.

Life-cycle differences among renters are less pronounced. The principal difference appears in the structure-size equations; single and separated households exhibit a significant negative price elasticity, ranging from 10 to 15, while for most married households the estimated price elasticity proves insignificant. No significant life-cycle differences appear in the slopes of the structure-age equations, though the intercepts differ.

This discussion of life-cycle effects is hardly satisfactory, largely because the most critical dimension of the problem cannot be addressed with a single cross-section sample. Analyzing the dynamic aspects of the process of life-cycle change, particularly how households form expectations regarding such changes and act given these expectations, cannot be analyzed without a panel survey and a more elaborate theory of household behavior. Many of the earlier remarks regarding the effects of relocation costs are again relevant. The above cross-section demand estimates are essentially an analysis of variance which suggests those elements likely to be most important in a more complete dynamic model of household location.

C. Neighborhood Choice

As has been previously noted, households' preferences for particular

TABLE 4.8
INCOME AND LIFE-CYCLE EFFECTS ON CHOICE OF RACIAL COMPOSITION IN THE NEIGHBORHOOD OF RESIDENCE

Life-Cycle Class	Owners: Mean of Dependent Variable[a]	Owners: α	Owners: β	Owners: t-ratio for β	Owners: Income Elasticity	Renters: Mean of Dependent Variable[a]	Renters: α	Renters: β	Renters: t-ratio for β	Renters: Income Elasticity
Single, alone	.1639	.1461	−.0199	.3613	-	.1430	.6852	−.0591	2.2543	−.413
Single, with others	.1826	.6253	.0647	1.2180	.354	.1117	.0131	−.0015	.0604	-
Separated, no children	.1842	.1860	−.0098	.3812	-	.1402	.5884	−.0598	2.9305	−.426
Separated, children	.1225	.2680	−.0297	.7360	-	.1551	.5322	−.0329	.8376	-
Married, <30, no children	.1280	.1336	−.0144	.1980	-	.1132	.4086	−.0461	1.7129	−.407
Married, <30, 1 child	.0522	.3654	+.0411	.9603	-	.1134	.0262	.0098	.3037	-
Married, <30, 2+ children	.0535	.1825	−.0202	.7577	-	.1588	.3910	−.0436	1.0603	−.275
Married, 30–39, no child	.1173	.3243	−.0358	.7313	-	.1428	.9661	−.1040	2.0325	−.728
Married, 39–39, 1 child	.0837	.6327	−.0650	2.0030	−.777	.1318	.2907	−.0331	.4660	-
Married, 30–39, 2+ children	.0562	.1684	−.0186	1.5823	−.331	.1002	.6768	−.0769	2.6593	−.767
Married, 40–49, no child	.1148	.3554	−.0275	1.4693	−.239	.1605	1.1177	−.1262	2.3464	−.786
Married, 40–49, 1 child	.0746	.3069	−.0320	1.6051	−.429	.1127	.0375	−.0039	.0645	-
Married, 40–49, 2+ children	.0587	.0962	−.0102	.7812	-	.1186	.2912	−.0730	1.5909	−.616
Married, 50+, no child	.1386	.6830	−.0721	5.9771	−.520	.1513	.6589	−.0564	2.1608	−.372
Married, 50+, 1 child	.0867	.7539	−.0831	3.1037	−.959	.1612	.4200	−.0103	.0208	-
Married, 50+, 2+ children	.1226	.1936	−.0202	.5277	-	.2083	−.8953	.1010	.5942	-

[a]Dependent variable Y is 1 if neighborhood is racially mixed, 0 otherwise. $Y = \alpha + \beta \ln (Y)$.

neighborhoods are also likely to be important, with the choice of neighborhood being made jointly with the decision regarding the type of housing. Satisfactory measurement of neighborhood effects and a specification of how households make tradeoffs must take into account the discontinuities in options available to households arising from discrete municipal and ethnic boundaries. However, a few simple hypotheses concerning neighborhood choice can be tested with the Bay Area data. One important neighborhood characteristic can be measured, racial composition. Comparisons of neighborhood-income data by race in Chapter 3 revealed that the white exodus from mixed neighborhoods is not random; only the poorer white households remain. A simple test showing the effect of income and life-cycle on white households' choice of neighborhoods can be performed: stratifying by life-cycle and then regressing a dummy variable denoting racial composition in the neighborhood of residence on income reveals the income effect on choice of neighborhood.[22] A mixed neighborhood is one in which black households comprise more than 15 percent of the population.

The results appear in Table 4.8. The differences across household life-cycle groups in the mean number of households who choose to reside in a mixed neighborhood are statistically significant. A higher percentage of single individuals reside in mixed neighborhoods than married households. Among married households, the presence of children reduces the likelihood of choosing a mixed neighborhood by about one-third. (Age of head of household appears to have no significant effect on choices.) Within any given life-cycle class, renters tend to be approximately twice as likely to live in mixed neighborhoods as owners. The income elasticity is generally significant, with the elasticities ranging from −.2 to −.7. The goodness of fit is not high, however, suggesting that there are other sources of variation in white households' preferences regarding neighborhood racial composition which are independent of income and life cycle.

5. CONCLUSIONS

Work site, income, and life cycle all have significant effects on households' choice of location and the amount of housing consumed.

22. Individual households' decisions represented above reflect choices based on an opportunity set which includes a wide range of options available in the Bay Area. This is to distinguish the results from an analysis which considered the type of housing, or the type of neighborhood, chosen by households confined to living in a very limited geographic submarket.

Despite households' willingness to alter their work trip when confronting different prices, residential location choices are significantly affected by the spatial distribution of employment.

Households also exhibit distinct preferences for certain quality characteristics closely related to the capital stock, with both income and life-cycle affecting the demand for particular attributes. Accordingly, the socioeconomic composition of any neighborhood's residents (both income and position in the life cycle) will be affected by the nature of available housing. The latter changes only very slowly in neighborhoods which have little land for new construction. This suggests that, where data permit it,[23] analyses of changing neighborhood and housing patterns in metropolitan areas must disaggregate both by life cycle on the demand side and by housing type on the supply side.

The location and type of housing consumed also vary substantially, depending on the structure of prices of particular types of housing. While the price elasticity for the composite bundle of services is below one in virtually all equations, the direct- and cross-price elasticities associated with the price of particular age and lot-size housing quality attributes are quite high. Attention must therefore be directed to the detailed characteristics of available housing services and to their prices in order to understand the evolving pattern of housing demand. It appears that many kinds of housing services which were in increasing demand in the postwar period—particularly, large lots and newer structures—could be made available in the suburbs at much lower prices than in the central city; conversely, the demand for the quality attributes which characterize the central-city stock has been declining. The existence of high price elasticities implies that the sharp rise in the consumption of newer housing and larger lots in the suburbs which occurred would only have been possible if relative price differentials of new over older housing remained small. This in fact was the case. During this period, new housing on larger lots was available at modest price differentials.

23. This is the rationale for the high level of disaggregation in the description of the housing market in the NBER urban simulation model. The model employs 96 household types and 40 housing and neighborhood types.