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# The Demand for Housing: Integrating the Roles of Journey-to-Work, Neighborhood Quality, and Prices *

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## I. INTRODUCTION

THE household must resolve a number of interrelated questions when purchasing a dwelling. Ignoring problems of financing—what down payment, what interest rate, what mortgage life, and the like—the questions directly relevant to the dwelling are of three types: first, what characteristics should the dwelling have? That is, how much space, how many rooms, and what lot size? Second, where should the dwelling be located? Clearly, location will determine neighborhood crime rates, air pollution, public school quality, and the necessary commute to work. Third, what should be spent?

There is no lack of empirical studies of the "demand for housing," [1] but oddly, with only few and partial exceptions, they are all concerned with the third of these questions only, and fail to treat either of the first two.[2] The diversity encompassed by the term housing is ignored; instead, housing is treated as though it were a homogeneous good like milk, which households buy more or less of as their incomes, family characteristics, and the prices they face change. On the assump-

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[1] Paldam (1970) lists some 50 recent studies and this is by no means exhaustive.

[2] Winger (1962) and Kain and Quigley (1975) examine some aspects of the demand for special characteristics, such as number of rooms purchased. Straszheim (1975) has studied demands for characteristics very grossly defined and some aspects of location choice. Quigley (1972) has examined locational choice and housing demand with a model somewhat similar to that proposed in this paper.

tion that expenditures equal price multiplied by quantity, it is customary to measure the quantity of housing purchased in uniform, quasiphysical units by dividing expenditures by a price index. These studies of housing as a homogeneous commodity may be justified by convenience or, more formally, by invoking separability in the utility function; nevertheless, the approach clearly precludes any examination of such questions as whether some kinds of families are especially concerned with interior space, others with exterior space, and others with quality.

The general suppression of the locational aspect of housing is much less defensible. Unlike milk which can be purchased in one place and consumed in another, the services of the housing unit must be consumed where the dwelling is located. Thus, location is an integral part of the commodity, with implications for commuting costs, neighborhood quality, and, as will be seen, for housing prices themselves.

The present study makes some progress toward ameliorating both of these long-standing deficiencies. Instead of treating housing as a single homogeneous good, I treat it as a bundle of distinct items, each having its own price, and each to be bought or not, depending as would any good, on the income, relative prices, and special family characteristics. The analysis at this level has a strong resemblance to the Lancastrian "New Demand Theory" (1966, 1971), since it assumes that households perceive dwellings as supplying specific characteristics which are desired for themselves. "Housing," in this view, refers to nothing more meaningful than the total value of the parts, and two households buying the same "housing" could purchase commodities that are quite unlike.

A more satisfactory treatment of location as an aspect of housing is important because the question: What quantity and type of housing shall I buy? is inseparable from the question: Where shall I buy it? This is evident in even the simplest theoretical models of urban structure (Alonso [1964], Muth [1969]) which have predicted the existence of housing price gradients for some years. As Muth (1969, Chapter 2) demonstrates, if the costs of commuting rise less rapidly with income and distance from the Central Business District (CBD) than do potential savings on housing, wealthy households desiring to purchase relatively much housing will locate in the edges of the urban area where housing prices are low. Similarly, if housing is treated as a bundle, it should be true that households wishing to purchase relatively much of some components will find it advantageous to locate where the items are relatively cheap. For this reason, it can be said that a satisfactory model of housing demand carries within it a model of residential location choice.

Abandoning the assumption that housing is a homogeneous good and incorporating the choice of location as a part of the bundle greatly complicates the analysis of housing demand. But in return, the approach substantially improves understanding of household behavior. The reader must be warned that this paper does not complete all that it might; much work still remains. However, I am able to provide a model of household behavior which treats the choice of location and the purchase of particular components as related decisions, and which possesses considerable intuitive appeal. Supporting evidence demonstrates that households behave as though they perceive "housing" to consist of specific items with individual prices which vary throughout the metropolitan area studied; in addition, some simple tests imply that households locate in a pattern which can be explained by considering work sites, neighborhood quality, and the variation in housing prices.

## II. MODELING THE HOUSEHOLD'S DECISIONS IN THE HOUSING MARKET

I have suggested that to purchase a dwelling, the household must decide not merely how many units of a homogeneous commodity to purchase, but rather what combination of particular attributes is most satisfying. In addition, the question of location cannot be ignored. Consider the following schema as a description of how these decisions are made.

### *A. A General Model of Location Choice and Housing Demand*

The location problem for the household is that a dwelling close to work will minimize commuting costs but may limit the household to neighborhoods with unsatisfactory sets of amenities, since there is no presumption that all varieties of neighborhoods are available at all distances from the work site. Consequently, there will usually be some tradeoff between the goals of low commuting costs and a high quality neighborhood. Moreover, a third goal exists: an optimal set of prices for the housing components. Even if all households have the same utility function and face the same prices, if they have different incomes the desired proportional composition of the housing bundle will change among, for example, interior space, exterior space, and quality if these have different income elasticities of demand. Given that prices for housing components can vary in different parts of a metropolitan region,[3] it will be advantageous for the household to locate in that submarket where the goods it wishes to buy relatively much of will be relatively cheap. Consequently, even if all households work in the same place and all neighborhoods offer the same amenities, one would expect to find households of different incomes selecting different submarkets in which to purchase their dwellings. More generally, since neighborhoods and work sites do differ, one would expect the household to choose its location in a three-way tradeoff: commuting costs against neighborhood quality against advantageous housing prices.

The demand problem for the house-hunting household is not merely how much to spend, but also what type of dwelling to buy. Since the prices for individual characteristics vary among submarkets, what is bought should depend, as with any good, not just on preferences, but also on relative prices. However, as argued above, the set of prices will depend on the resolution of the location choice. Let me suggest the following as a reasonable description of how these interrelated decisions are made.

Suppose that the household begins its search process knowing three things: (1) the place of work for each worker, which is not necessarily or even usually the CBD, (2) the division of the metropolitan area into housing submarkets with differing sets of relative prices for housing bundle components, and (3) the division of the area into neighborhoods with different public services and natural amenities in each. Imagine the household to go now from submarket to submarket considering what dwelling it would purchase in each and what its utility would be. In each place, the commuting costs—both monetary and in terms of time—are known. This permits the calculation of an adjusted income with the wages received reduced by commuting costs. Assume now that the adjusted income is apportioned among groups of commodities, "food," "clothing," "housing," and the like. Then, given the amount to be spent on the housing bundle and the set of prices for commodities in the bundle, the household selects that particular dwelling it most prefers. At this point, the household can determine its utility level were it to locate in this place.[4]

Moving on then in the search process, the household can consider

[3] Why this occurs is discussed in Section III.

[4] Formally, the assumption made here is that the household's utility function is weakly separable, a "tree" with housing as one "branch." It can be shown (Pollak, 1970) that demand functions derived from such a function can be written in a simplified form. Instead of

$$q_i = f_i(p_1, p_2, \ldots, p_n, Y) \qquad i = 1, n$$

locating in another submarket with another set of relative prices, neighborhood quality, and commuting costs. Each site can be assigned a utility level by this procedure,[5] and the household is predicted to choose that location where its satisfaction is greatest.

One particularly significant implication of this schema is that certain decisions are made sequentially rather than simultaneously. In particular, the choice of components within the housing bundle is dependent only on the allocation to it and the relative prices within. This permits an empirical study of demand parameters to proceed in isolation from the complete model. Later, when the characteristics of the demand functions are understood, it will be possible to examine how prices, work site, and neighborhood quality interact to determine location.[6]

one has

$$q_i = g_i(p_1^\theta, p_2^\theta, \ldots, p_m^\theta, \alpha^\theta(p_1, p_2, \ldots, p_n, Y)) \qquad i = 1, n$$

where

$\theta$ is the branch designation;
$m$ is the number of goods in branch $\theta$;
$p_1^\theta$, $p_2^\theta$, $p_m^\theta$ are the prices of goods in the $\theta$th branch; and

$$\alpha^\theta(p_1, p_2, \ldots, p_n, Y) = Y - \sum_{k \epsilon \bar{\theta}} p_k q_k(p_1, \ldots, p_n, Y).$$

The decision process is consequently in two stages: first, income is allocated among branches; second, commodities within a branch are purchased in response to prices in that branch only and to the total allocation to the branch. This behavior is both plausible and highly desirable from the standpoint of empirical estimation, since the number of prices in each demand function is greatly reduced.

[5] Of course, it is unnecessary that all potential locations be examined in the same detail. Those offering clearly unacceptable neighborhood quality or requiring "excessive" commuting can be excluded immediately.

[6] It is useful at this point to compare the model just developed to other work. Of the previous studies of household behavior in housing markets, the work of Quigley (1972), (1973) most closely resembles the present model. There are important differences, however. Quigley does not introduce the tradeoff of commuting costs, housing prices, and neighborhood quality; instead, he defines what he calls a "gross price surface" for each type of housing, which is created by adding commuting costs to the "on site" cost of the dwelling. The hypothesis, then, is that the household buying a particular type of housing will locate where the "gross price" is lowest. One of the difficulties of this approach is the need to specify types of dwellings, e.g., a two-bedroom, single-family home, constructed between 1940 and 1950. In order to examine the tradeoffs between different types of dwellings, a very great number of different types must be specified. Since the "gross price" will differ for each income level and work site, the data base rapidly becomes exceedingly cumbersome to manipulate.

The model in this paper assumes, in contrast, that households distinguish travel costs from housing costs. The journey-to-work becomes in effect the price paid for obtaining particular locational advantages; consequently, prices for housing characteristics in a

*B. Housing as a Bundle of Characteristics: A Lancastrian View*

Up to this point, "housing" has been treated as a convenient term referring to a bundle of complex makeup, but there has been little discussion of what constitutes the bundle. It is clear, of course, that "housing" consists actually of a great many very specific items: copper pipes, forced air heating, brick facing, a dining room of particular size, and the like, but it is not clear that these are the features which concern households when deciding whether or not to purchase. It is quite plausible to suppose instead that households regard "housing" as producing certain kinds of general satisfaction, and individual items like doorknobs and chandeliers merely contribute to one or more of these general commodities.

The view that goods possess certain characteristics and that these characteristics—rather than the goods themselves—are the arguments of the utility function has been developed by Lancaster as his "New Theory of Demand" (1966, 1971). This theory can be expressed simply in the following propositions: define $b_{ij}$ as the quantity of the $i$th characteristic supplied by a unit of the $j$th good. Then a quasi-production function B exists which "transforms" the goods purchased $x$'s into characteristics $z$'s; that is, $Z = BX$ where $Z$ and $X$ are vectors of characteristics and goods. The utility function is $U = U(z_1, z_2, \ldots, z_n)$ and is to be maximized subject to the two constraints $y = \sum_{i=1}^{m} p_i x_i$ and $Z = BX$.

The view that households are directly concerned with characteristics rather than goods is particularly satisfying when dealing with "housing." It is plausible and permits further simplification in the demand analysis, since there is no need to consider separately the interrelated demands for an enormous number of specific items. Accordingly, I shall adopt this approach in what follows and distinguish between "housing components," which are the specific items purchased, and "housing characteristics," which are what the household

given market are constant for all buyers and do not vary with income or work place. Another distinction is that I assume implicitly that any desired combination of housing characteristics can be obtained in a market at the prices prevailing there, whereas Quigley attempts to define a limited number of dwelling types (that is, combinations of characteristics) for households to choose among. The contrast between the models in this respect is that between variable and fixed-proportion models.

One important advantage of Quigley's approach is the explicit attention given to the choice between types of dwellings: apartments, multi-family units, and single-family; the present model considers only single-family housing purchases, but with a more extensive data base, this limitation could be removed.

gains utility from. One difficulty raised by this approach is how to distinguish and measure the quantities of housing characteristics embodied in each bundle. The solution to this is described briefly in the next section and more fully in Section VI.

### *C. An Informal Description of Housing Demand: A Postscript*

The model of household behavior in the choice of location and purchase of particular dwellings has, I believe, considerable intuitive appeal; interestingly, it is possible to cite some simple informal evidence that households do behave in this way. Consider, for example, this advice from a leading consumer magazine to persons buying housing:

Step 1: Analyze your needs. Taking into account your age, family prospects and way of life, you can probably tick off your basic demands without any trouble. Do it . . . before you start those weekend wanderings. . . . notice that you can deal with any of these questions without getting into matters of price or plan or style or type of construction.

Step 2: Figure what you can pay. . . . two figures tell the tale . . . the amount of cash . . . for a down payment . . . (and) how much of your monthly income you can allocate to a monthly mortgage payment. How much can you spend? . . . First determine your net average monthly take-home pay. . . . Next, add up your monthly expenses for non-housing items. . . . Subtract. . . . What's left is your average monthly income available for *housing* expenses. Add the size of the mortgage your monthly payment will support to the amount of your down payment and . . . you've got the magic number, . . . the price category for you to shop.

Step 3: Now Hunt and Pick.[7]

The advice certainly suggests that the separation of decisions implied by the formal model is quite reasonable.

## III. PRICING IN THE HOUSING MARKET

The housing market has a long-standing reputation for inscrutable workings:

> The absence of a market place, the private and secret nature of transactions, the want of comprehensive market data, all combine to deprive the housing market of the benefits of a visible price structure. Both buyers and sellers, in varying degree, operate in the dark. . . . The ultimate uniqueness of every house makes it impossible to establish uniform sales units or standards of values (Twentieth Century Fund, 1944, p. 209.).

[7] "How to Buy a House in Five Easy Steps," *Changing Times* 27 (February 1973): 6–11.

Recent empirical research has demonstrated, however, that pricing in the housing market is not the capricious process long assumed but exhibits quite strong regularities of a very reasonable sort. What might superficially appear to be the quirks can generally be explained as the consequences of special housing characteristics or of circumstances involved in the transactions (Musgrave [1969], Kain and Quigley [1970], King and Mieszkowski [1973], King [1973a]).

When the housing bundle is well specified, it is possible to estimate the price relationships in a single housing market by applying a "hedonic price" equation of the following sort to observed housing transactions

$$\text{Sales Price (or rent)} = \sum_{i=1}^{m} \alpha_i SC_i + \sum_{j=1}^{n} \beta_j LC_j + \gamma L \qquad (3.1)$$

where

$SC_i$ is the *i*th structural component (number of rooms, quantity of insulation) and $\alpha_i$ the price per unit;

$LC_j$ is the *j*th location component (accessibility to the CBD, neighborhood quality) and $\beta_j$ the price per unit;

$L$ is the quantity of land purchased and $\gamma$ the price per unit.

Provided that the transactions are genuine "arms-length" transactions and the components of the bundle known in detail, such an equation will explain a large fraction of the observed variation in sales prices as a function of the individual items purchased.[8] Moreover, the individual hedonic prices are often quite reasonable. In Section VI, for example, fireplaces will be found to add about $1,000 to the sales price of a dwelling, an amount approximating construction cost, and municipally provided garbage collection to increase the value of a house by about $300, a reasonable capitalization of the cost of privately contracted services in the area studied.

It is not to be expected, of course, that a single hedonic equation will describe all housing markets, for the prices in each will naturally reflect the interplay of supply and demand for the various bundle components. What is important for the present study is to observe that a metropolitan area of even moderate size may well consist of a number of linked but distinct submarkets, each needing its own hedonic price equation to describe the price patterns.[9] The subdivision of the metro-

[8] Typically, the $R^2$ of these equations exceeds 0.60.

[9] This is emphasized by Straszheim (1975).

politan area reflects fundamental characteristics of the supply and demand conditions for housing; and because of the importance of the resulting price variations for this study, it is useful to set these out clearly.

If the housing in a metropolitan area were built anew each year in accordance with the latest technology and prevailing wages and prices for material inputs, and if the composition of the bundles reflected a uniform pattern of demand throughout the area, there should be no reason for similar housing bundles to sell for dissimilar amounts. But in few areas is this a good description of either the supply or the demand functions for housing. Instead, on the supply side, the housing stock is built little by little over many years, during which input prices and technology both change. Once constructed, the housing remains, subject always to remodeling and somewhat limited possibilities for new construction, but with the essential characteristics of the stock in each area fixed by the nature of the original construction.

On the demand side there are essentially two problems. First, relative preferences for components of the housing bundle will change over time, so that a housing bundle of 1910 would not be judged an optimum bundle today, even at the old set of relative prices. In general, some components of the 1910 bundle have little value as a part of the 1910 bundle, though they might be valued as components of a different, more modern bundle. The consequence, of course, is that component prices which clear the market in the 1910 part of town will differ from the prices in the newly constructed sections. Second, the tendency toward such price differences will be strengthened to the extent that purchasers examine only the bundles in a limited geographic area. Reasons for this are manifold: reluctance to move from an ethnic neighborhood, racial discrimination, desire to be close to friends or work, a wish to live in a particular school district. Whatever the cause, such behavior eliminates the competitive pressure for price uniformity throughout the metropolitan area.

The consequence of inflexible, unadjustable supply within limited geographical areas and of fragmented demands will be the division of the large metropolitan area into discrete submarkets for housing bundles. Within each, there should be a regular relationship of sales price to bundle composition, but the relationship may differ from one submarket to another.

The variation of prices for identical components throughout a metropolitan area is critically important to this study because it provides the setting and means required to implement the model of household behavior set out. First, the model of housing purchase contained as a primary element the proposition that households would tend to search out and locate in those places with particularly advantageous sets of relative prices. Obviously, for this to happen, it is necessary that price variation occur and be discernible. Second, the model predicted that wherever they actually locate, households will alter their purchases in response to the housing prices in that place; consequently, by observing what consumers purchase in the different submarkets it should be possible to deduce how they respond to price variations in the usual sense. Third, the hedonic prices provide the means to treat housing as a bundle of Lancastrian characteristics. If one is able to determine which characteristics each component supplies (that is, the $b_{ij}$), the hedonic price for that component permits one to measure the expenditure on each characteristic by adding together the expenditures on appropriate components.

## IV. DATA SOURCES

The data used in this study were obtained from two sources. First, the basic data are a set of detailed physical descriptions,[10] and the prices of some 1,800 single-family houses sold in the New Haven, Connecticut, metropolitan region from 1967 to 1970.[11] With a few exceptions, these 1,800 houses include all the single-family houses sold through the Multiple Listing Service (MLS) of the Greater New Haven Board of Realtors during this period.[12] These data plus additional information on neighborhood amenities and services, described below, provide the base for estimation of hedonic price equations like (3.1) for each housing submarket.[13]

The second data set, needed to examine choice of location and demand functions, was obtained as the responses to a mail survey di-

[10] The exact physical details used in this study are discussed in Table 3 below.

[11] This is defined to include New Haven, Hamden, North Haven, West Haven, East Haven, Woodbridge, Orange, Cheshire, and Wallingford. Essentially, this is the New Haven SMSA, except that four small outlying areas are excluded (Branford, North Branford, Guilford, Bethany) and Cheshire and Wallingford are added. All these towns lie within a semicircle of about ten miles radius centered on New Haven.

[12] The cooperation of the Board of Realtors in making these data available for this and other studies is gratefully acknowledged.

[13] It is important to emphasize that careful examination of these data found no significant evidence of inaccuracies in reporting either the sales price or the components. Furthermore, there was little evidence that homes sold through the MLS were distributed differently geographically from the total housing stock or were unrepresentative of its values in each census tract. This evidence is presented in King (1973a, Chapter III).

rected to each purchasing household. The questions covered such things as income, family size, education, place of work, and the like.[14] Somewhat more than 45 percent of the questionnaires were returned with usable information; however, some of these were rejected following internal consistency checks or because of failure to provide complete information. In addition, no responses from Cheshire are used. Responses for the remaining 683 households are examined in the demand analysis of this study.[15]

## V. MEASURING NEIGHBORHOOD QUALITY

The set of physical descriptions for houses and the responses of purchasers to the survey questionnaire provide two exceptionally rich data sources for housing market analysis. They provide information explicitly for the hedonic price equations, and for demand analysis, and with some manipulation, for the model of location choice. The household's work site, of course, is obtained directly from the questionnaire, while the hedonic price equations provide the means for calculating price variations across the metropolitan area. Though some information on the third goal of residential location – neighborhood quality – was readily available as information on public services, to gain a more complete index of quality by neighborhood a novel procedure was developed and is described in this section.

Measuring neighborhood quality so that comparisons between places are possible is an extraordinarily difficult task for which two alternative approaches have been suggested. Some studies have attempted measurement by assembling so-called objective data: school achievement test scores, crime rates, fire damage, particulate matter in the air;[16] other studies have argued that the quality of a neighborhood is largely a matter of perception: the fear of crime will make a neighborhood undesirable regardless of whether crime actually occurs. Per-

[14] The exact household characteristics used in the demand study are defined in Table 7 below.

[15] It should be noted that the responses to the survey have been carefully examined for biases and accuracy. Rather good tests were possible; and although these suggested the presence of biases normally associated with mail surveys (toward overrepresentation of high-income, educated households), the biases were slight and not statistically significant. For a complete description see King (1973a, Chapter III).

[16] The outstanding example of this approach is Kain and Quigley's study of St. Louis which assembled data for some 32 neighborhood characteristics (1970). Other less ambitious studies have used such measures as average family income or education in the neighborhood, reasoning that high-income and highly educated families would choose high-quality neighborhoods.

ceptions may be based upon objective differences, but it is not certain that the relationship will be very exact.[17]

To my knowledge, despite the general recognition that use of perceptions is potentially a very desirable way to describe quality variations, the New Haven MLS data set is the only one for which this is actually attempted. For this collection of housing data, perceived neighborhood quality was obtained in the responses to a special set of questions in the mail survey of purchasers. Each respondent was asked to evaluate various neighborhood aspects on a scale of 1 (excellent) to 5 (bad); these included such things as the quality of the neighborhood elementary school, amount of air pollution, and danger of crime.[18]

To make use of these, I have defined neighborhoods by the attendance boundaries of each public elementary school in the metropolitan region. These had the advantage of being physically compact; and because they were twice as numerous as census tracts, were on the average smaller. The evaluations from respondents in each neighborhood, so defined, were averaged to yield an overall rating for each neighborhood characteristic.[19]

As might be expected, the evaluations of specific characteristics within each neighborhood proved to be correlated. Principal component analysis of the subjective evaluations revealed that more than three-fourths of the total variance could be accounted for by just two components.[20] None of the remaining six components individually accounted for more than eight per cent of the total variance, nor, as will be explained, was it possible to interpret any of them. Accordingly, this study will use just the first two components to describe the variation in perceived neighborhood amenity levels.[21]

As shown in Table 2, the first component is highly correlated with six of the original variables: *ELEMSC, HIGHSC, TRAFIC, FIRE,*

[17] For a discussion of this see Oates (1969) or King (1973a).

[18] The questions and responses used in the analysis are indicated in Table 1.

[19] Whatever the merits of perceptions, on abstract grounds, it is important to understand that the uses to which these are put in the present study involve the assumption that data obtained from an ordinal scale can be treated as cardinal. Clearly this is not always acceptable; however. certain theoretical arguments, experience with these data and their transformations, and comparison with various objective alternatives persuade me that for this study at least the assumption is reasonable. For a more complete discussion of this issue, see King (1973a, Chapter IV).

[20] For a complete discussion of this technique see M. G. Kendall, *A Course in Multivariate Analysis* (New York: Hafner Publishing Co., 1968).

[21] The decision to use only the first two components accords with the rule sometimes suggested of using only the components which have eigenvalues greater than 1.0, as the eigenvalue for the third component is 0.64.

TABLE 1

Correlations of Subjective Measures of Neighborhood Quality

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *ELEMSC* | 1.00 | | | | | | | |
| *GARBGE* | −.12 | 1.00 | | | | | | |
| *LIGHTG* | .13 | .57 | 1.00 | | | | | |
| *HIGHSC* | .82 | −.17 | .12 | 1.00 | | | | |
| *TRAFIC* | .44 | −.17 | −.07 | .53 | 1.00 | | | |
| *FIRE* | .74 | −.11 | .27 | .63 | .51 | 1.00 | | |
| *AIRPOL* | .67 | −.37 | −.02 | .77 | .63 | .65 | 1.00 | |
| *CRIME* | .79 | −.36 | .01 | .74 | .56 | .76 | .80 | 1.00 |

NOTE: Definition of Variables
*ELEMSC:* quality of local public elementary school.
*GARBGE:* quality of garbage collection.
*LIGHTG:* quality of street lighting, sweeping, and maintenance.
*HIGHSC:* quality of local public high school.
*TRAFIC:* amount of traffic on neighborhood streets.
*FIRE:* danger of fire.
*AIRPOL:* amount of air pollution.
*CRIME:* danger of crime.

TABLE 2

Correlations of the First Two Components and the Original Variables

| | *GEN Q* | *SERVCE* |
|---|---|---|
| *ELEMSC* | .87 | .17 |
| *GARBGE* | −.32 | .84 |
| *LIGHTG* | .06 | .91 |
| *HIGHSC* | .88 | .10 |
| *TRAFIC* | .69 | −.10 |
| *FIRE* | .84 | .25 |
| *AIRPOL* | .89 | −.12 |
| *CRIME* | .92 | −.06 |

Eigenvalues for first two components: 4.45, 1.66.
Percentage of total variance accounted for: 76.4.

NOTE: Responses were aggregated by elementary public school district. The means calculated for each variable were used in this analysis.

*AIRPOL*, and *CRIME*, and the second component with the remaining two; thus, the components distinguish what appear to be two separate aspects of neighborhood quality. Because of the high correlation with variables which seem to measure "goodness of life" or "pleasantness of surroundings," I consider the first component to be a measure of the general quality of the neighborhood and refer to it as *GEN Q*. The second component, on the other hand, seems to reflect the provision of specific urban services and is named *SERVCE*.

To confirm the identification of the components, I have examined the scores attained by specific neighborhoods of the region. As one would expect, those areas favorably rated on the first component are high-income neighborhoods, not densely settled, with local reputations as pleasant places to live.[22] The badly rated neighborhoods are in poor, slum regions of New Haven. Similarly, the areas rated worst by the second component are parts of East Haven, which is notorious as a poor provider of public services.

## VI. THE PRICES OF HOUSING BUNDLE COMPONENTS

The empirical task in this section is the estimation of hedonic price equations like (3.1) for each housing submarket in the New Haven region. These will both describe price surfaces and permit the construction of gross housing characteristics.

### *A. Defining Submarket Areas*

Before the hedonic prices can be estimated, there is one difficulty to be resolved: How should the limits of each submarket be determined? If the component prices were known at each point, it would be a simple matter to group places with identical or very similar prices into homogeneous market areas. But, of course, it is precisely because prices are not directly observable that the hedonic estimates are required.

I suggested previously that the extent of submarkets with uniform internal prices would depend on the nature of supply and demand functions. Following the model of residential location choice set out above, it seems likely that a major cause of geographically fragmented demand should be the variations between towns in public services, taxes, and location amenities. Location of work should also play a role, but in this small, compact region, accessibility should be relatively good everywhere, and its influence correspondingly reduced. Accord-

[22] Recall that a high score (5) on the subjective evaluation indicated that the neighborhood was undesirable. Thus, a favorable rating corresponds to a low score. This is important in evaluating the hedonic prices estimated in Section VI.

ingly, for this study, submarket boundaries will be defined by political boundaries; specifically, each town will be treated as a separate submarket.[23]

It might be suggested that whole towns are still too large to possess uniform housing prices—perhaps something smaller, like census tracts, would be more appropriate. This was considered but rejected for several reasons. First, the varieties of combinations of housing bundle components are not markedly different among the census tracts of each town. The average or most common bundle differs from place to place, but to a surprising extent the range of choices in each tract is quite wide. Thus, from the supply side of the market there is little reason to expect much within-town price variation. Second, and more pragmatically, the data requirements for satisfactory estimation of the hedonic price equations simply precluded work on markets much smaller than towns. As will be seen, even at the town level, limited variation in some characteristics have made it difficult to obtain reliable hedonic prices.[24]

### *B. Empirical Estimates*

Given that housing submarkets will be defined by town boundaries, I can proceed to study the price variations among them in a straightforward manner. For each town, a hedonic price equation like (3.1) is defined, in which the observed sales price for the bundle is a function

[23] The only exceptions are the towns of Orange and Woodbridge, which are adjacent and very similar, sharing, for example, a common high school. They are combined and treated as a single unit.

[24] For this same reason, I have not adopted the method of using the data to determine submarket areas. In principle, it is correct to argue that submarkets could be distinguished by estimating separate equations for small areas and then making an F test for significantly different price patterns. However, because the housing bundle is so complex, the data requirements and the costs of meaningful tests are enormous. As a first prerequisite, it is essential that the hedonic equation be very fully specified. If not, it is virtually certain that correlations with improperly omitted variables will bias the estimates of those included. An F test between submarkets might then indicate a change in hedonic prices for bedrooms when what actually was occurring was a change in the correlation of bedrooms with swimming pools. It would be improper to conclude from such a test that the bundles are in separate markets, as the true prices of bedrooms and swimming pools taken separately might be identical. If the data base is sufficiently detailed to avoid this problem—as in the present case—it may still be that limited sample size results in inadequate variation of some component within some submarkets. This will result in price estimates that are spurious though strongly significant. In sum, the sample must be quite detailed, very large and exceedingly varied. The data set used in this study is one of the best now available for housing market analysis, but even it cannot meet these conditions fully. The solution adopted in this paper is to define submarkets following plausible a priori boundaries and thereby make the demand estimates contingent on the market definitions chosen.

of the various Structural Components – rooms, floor space, insulation, and construction materials; Location Components – measures of perceived neighborhood quality and certain public services; and Land purchased. The estimated coefficients for this equation will be the dollar value for units of each component, given the supply and demand relationships in the market.

The variables used in the hedonic equations are defined in Table 3, and the prices, estimated by ordinary least squares (OLS), appear in Table 4. In general, the equations are quite satisfactory; a large part of the variance in sales price is accounted for, and though individual coefficients vary among markets, the range of values often seem plausible. Note in particular the values for *HARDWD*, *GARG*1, *GARG*2, *FIREPL*, 2 + *BATH*, and *LAVTRY*, for which there may be a sense of construction costs to aid in evaluation. The reader will also observe that each equation includes several constrained values; this is one aspect which requires more extended comment.

As explained in note 24 above, the data requirements for satisfactory estimation of a hedonic price equation for housing are uncommonly severe because of the extraordinarily complex nature of the bundles. Improper specification of any regression equation will create biases in the estimates for included variables if correlations exist between the included and the improperly excluded variables. For housing, the penalty for using an inadequately detailed base will be erroneous implications for the component price surfaces across the metropolitan area.

While the data base available to this study is large by most standards and is uniquely rich in detail, it lacks sufficient variation of some characteristics in some markets. In New Haven, for example, though the total number of observations is quite adequate, only three houses had no basements. The coefficient for this variable reflected the overall departure of these observations from the regression and was significantly positive, rather than negative as expected. As another example, 2 + *BATH* had a strongly significant negative coefficient in East Haven; examination of the sample found that only one house in this generally low-income market had a second bath.

When hedonic prices for the individual town regressions took sizes and magnitudes contrary to reasonable a priori expectations, and when examination showed this to result from too few observations, it seemed best to reject these results. If accepted uncritically, they would lead to false conclusions about the budget constraint which households face in the market.

TABLE 3

Definitions of Variables for Hedonic Price Equations

| | |
|---|---|
| *FULLIN* | 0–1 dummy, 1 if house has full insulation. (S) |
| *GARG*1<br>*GARG*2 | 0–1 dummies, 1 if house has a one-car garage or a two-car garage. |
| 2+*BATH* | 0–1 dummy, 1 if house has two or more baths. |
| *LAVTRY* | 0–1 dummy, 1 if house has a partial bath. |
| *BLAUND* | 0–1 dummy, 1 if house has a basement laundry area with drains and spigots. |
| *HARDWD* | 0–1 dummy, 1 if house has hardwood flooring. (S) |
| *FIREPL* | Number of fireplaces in house. |
| 75+*AMP* | 0–1 dummy, 1 if house has wiring to supply more than 75 amperes. |
| *STEAM* | 0–1 dummy, 1 if house has a steam heating system. (S) |
| *EXCLNT*<br>*VGOOD*<br>*FAIR* | 0–1, 1 if realtor's evaluation of house quality was excellent, very good, or fair; relative to good. (S) |
| *FACBSS*<br>*FACASB* | 0–1 dummies, 1 if house had facing respectively of brick, stone, or stucco; or of asbestos shingles. (R) |
| *AGE*<br>*AGESQ* | Age and age squared of home in decades. (S) |
| *SQFT*<br>*SQFTSQ* | Floor space and floor space squared in house in thousands of square feet. |
| *SQFT/R* | Average room size in thousands of square feet. |
| *SMROOM* | Number of small, special purpose rooms. |
| *FINBMT*<br>*NOBMT* | 0–1 dummies, 1 if house had a finished basement or no basement. |
| 2*STORY* | 0–1 dummy, 1 if house had more than one story. (S) |
| *SIZLOT*<br>*SIZLT*2 | Lot size and lot size squared in thousands of square feet. |
| *DISCBD* | Natural logarithm of distance from house to New Haven Green multiplied by lot size. |
| *GEN Q* | A measure of the quality of the local elementary school and high school, danger of crime and fire, amount of heavy traffic on neighborhood streets, and severity of air pollution. This measure is constructed from the perceptions of |

(continued)

TABLE 3 (concluded)

| | |
|---|---|
| | the purchasers of houses in each neighborhood. A high-quality neighborhood will receive a *negative* score on this measure; consequently, a negative hedonic price is expected. The measure is scaled by the lot size of the house. |
| *SERVCE* | A measure of the quality of local street lighting, sweeping, and maintenance, and the quality of garbage collection service. Like *GEN Q*, this measure is constructed from the perceptions of purchasers, and again, a high-quality neighborhood will receive a *negative* score. The measure is scaled by the lot size of the house. |
| *GARBGE* | 0–1 dummy, 1 if house receives municipal garbage collection. |
| *CSEWER* | 0–1 dummy, 1 if house has connection to city sewer. |
| *PRICE* | Sales price of house in thousands of 1967 dollars. |

NOTE: An (S) or (R) following the variable definition indicates that values are scaled by the square feet, or the square root of the square feet, of living space.

The problem arose then of what values should be used to replace the rejected estimates. The choice has been to estimate the same hedonic equation, pooling the observations for the entire metropolitan sample. Rejected values were replaced by the estimates from the pooled equation, and the individual town equation was reestimated incorporating these constraints. It might be objected that this procedure also implies something incorrect about the price set confronting households in each market, since goods apparently virtually unobtainable are assigned a price relevant only to the entire region. Would some very high price not be more appropriate? The proper response to this, I believe, is to note that the sample of homes for which the price equations are estimated includes only a small fraction of all homes in the submarket. The problem, then, is more likely one of sample size than of actual inability to purchase some component.

Estimates from the pooled sample were used also to constrain values for neighborhood qualities – *GEN Q* and *SERVCE* – and the municipal services – *CSEWER* and *GARBGE* – in most submarkets. This was done for two reasons: first, the model of residential location choice implied that differences in neighborhood quality would be an important factor in the household's choice of location. It seems likely that

TABLE 4

Hedonic Prices for Housing Bundle
(thousands of dollars)

| | All Towns | New Haven | Hamden | North Haven |
|---|---|---|---|---|
| *INTERCEPT* | 11.0299 [a] | .8079 | 12.9907 [a] | 15.2437 [a] |
| *FULLIN* | .6517 [a] | .6465 [b] | .9557 [a] | *.6517 |
| *GARG*1 | .9693 [a] | .3736 | 1.0724 [b] | .9710 |
| *GARG*2 | 2.9139 [a] | 1.2129 [c] | 3.0659 [a] | 3.4264 [a] |
| 2+*BATH* | 2.4398 [a] | 1.0889 [c] | *2.4398 | 2.4735 [a] |
| *LAVTRY* | 1.0045 [a] | 1.0026 [b] | .9081 [b] | 1.5998 [a] |
| *BLAUND* | .5467 [b] | 1.7545 [a] | −.1908 | .5323 |
| *HARDWD* | .8791 [a] | 1.2939 [a] | *.8791 | .7210 |
| *FIREPL* | .8488 [a] | .9662 [b] | 1.1845 [a] | 1.1183 [b] |
| 75+*AMP* | .3868 [b] | .8676 | 1.1500 [a] | .8021 [c] |
| *STEAM* | .6080 [a] | .7886 [b] | .3396 | *.6080 |
| *VGOOD* | .5411 [b] | 1.2916 [a] | .1337 | .6380 |
| *EXCLNT* | 1.3412 [a] | 1.1213 [a] | 1.1233 [a] | 1.7103 [b] |
| *FAIR* | −1.0926 [b] | .3951 | .2036 | −3.5326 [b] |
| *FACBSS* | 1.5686 [a] | 2.5228 [a] | .7144 [c] | 1.4319 [b] |
| *FACASB* | −1.8922 [a] | −.8831 | −1.5611 | *−1.8992 |
| *AGE* | −1.1324 [a] | −1.2323 [a] | −.1958 | −.3541 |
| *AGESQ* | .0545 [a] | .1033 [a] | −.0917 | −.0250 |
| *SQFT* | 6.6966 [a] | 7.7909 [a] | 3.6654 [b] | 1.0753 |
| *SQFTSQ* | .8491 [a] | .1476 | 1.5856 [a] | 2.0239 [a] |
| *SQFT/R* | −28.6988 [a] | 12.2736 [c] | −32.6113 [b] | −25.1213 [b] |
| *SMROOM* | .6047 [a] | −.0448 | .6858 [a] | .7522 [a] |
| *FINBMT* | .6834 [a] | −.7349 | 1.2947 [b] | .9674 |
| *NOBMT* | .2351 | *−1.5000 | 1.1513 | −1.1198 |
| 2*STORY* | .1100 | −1.3043 [a] | −.1830 | .5729 [c] |
| *SIZLOT* | .2305 [a] | .7128 [a] | .3707 [a] | .0513 |
| *SIZLT*2 | −.0005 [b] | −.0028 | −.0014 [b] | .0002 |
| *DISCBD* | −.0662 [a] | −.1870 [b] | −.1523 [a] | −.0424 |
| *GEN Q* | −.0678 [a] | −.2164 | *−.0678 | *−.0678 |
| *SRVCE* | −.0192 [a] | *−.0192 | −.1041 | −.0456 |
| *GARBGE* | .3068 | *.3068 | *.3068 | *.3068 |
| *CSEWER* | .4684 [b] | *.4684 | *.4684 | *.4684 |
| $\bar{R}^2$ | .82 | .86 | .71 | .75 |
| Standard Error | 4.10 | 4.06 | 3.88 | 3.98 |
| Number of observations | 1,802 | 300 | 407 | 217 |

(continued)

TABLE 4 (concluded)

| | East Haven | West Haven | Orange Woodbridge | Wallingford |
|---|---|---|---|---|
| *INTERCEPT* | 8.5135 [a] | 14.2757 [a] | 17.4090 [a] | 15.9887 [a] |
| *FULLIN* | .2762 | .7213 [b] | *.6517 | *.6517 |
| *GARG1* | .4952 [c] | 1.1068 [a] | 1.4759 | .7683 [c] |
| *GARG2* | 2.1016 [a] | 1.0102 [b] | 2.6323 | 2.9629 [a] |
| 2+*BATH* | *2.4398 | 2.5510 [a] | 1.2516 | .2508 |
| *LAVTRY* | .9623 [a] | 1.1976 [a] | .3671 | .7036 [c] |
| *BLAUND* | .6251 [c] | 1.2807 [a] | −1.1041 | .7952 |
| *HARDWD* | *.8791 | .9237 [b] | .6756 | .4902 |
| *FIREPL* | .2953 | 1.3380 [a] | 1.0454 [c] | 1.1416 [a] |
| 75+*AMP* | *.3868 | .3791 | .4057 | .7243 [c] |
| *STEAM* | *.6080 | .3000 | *.6080 | *.6080 |
| *VGOOD* | .4956 | .2385 | 1.2719 | .2181 |
| *EXCLNT* | .8055 [b] | 1.1681 [a] | 1.5848 [b] | 1.1563 [c] |
| *FAIR* | −2.7934 [a] | −3.6185 [a] | *−1.0926 | *−1.0926 |
| *FACBSS* | 2.5600 [a] | *1.5686 | 1.5740 [b] | *1.5686 |
| *FACASB* | *−1.8922 | −.5186 | *−1.8992 | *−1.8992 |
| *AGE* | −1.0615 [a] | −1.5280 [a] | −1.0247 [a] | −.6772 |
| *AGESQ* | .0819 [a] | .1343 [a] | .0513 | .0366 |
| *SQFT* | 10.9198 [b] | 4.4838 [c] | 8.5781 [b] | 6.8369 [b] |
| *SQFTSQ* | −3.0565 [b] | .5098 | .8184 | .4724 |
| *SQFT/R* | −13.2051 [b] | −29.2845 [a] | −40.7100 [a] | −47.2890 [a] |
| *SMROOM* | .3592 [b] | .1295 | .6697 [c] | .0027 |
| *FINBMT* | .7400 [c] | 1.2089 [b] | 1.1308 | 1.3726 [b] |
| *NOBMT* | −1.2208 | −.4199 | 2.0493 [c] | −.7944 |
| *2STORY* | .0969 | .6859 [c] | −.4962 | 1.0454 [b] |
| *SIZLOT* | .3053 [a] | .1853 [b] | −.0815 | .1303 [b] |
| *SIZLT2* | −.0045 [b] | .0015 [c] | .0014 | .0015 [c] |
| *DISCBD* | −.0430 | −.0625 | −.0059 | *−.0662 |
| *GEN Q* | *−.0678 | −.2358 | *−.0678 | *−.0678 |
| *SRVCE* | *−.0192 | −.0667 | *−.0192 | *−.0192 |
| *GARBGE* | *.3068 | *.3068 | *.3068 | *.3068 |
| *CSEWER* | *.4684 | *.4684 | *.4684 | *.4684 |
| $\bar{R}^2$ | .54 | .64 | .62 | .85 |
| Standard Error | 1.95 | 2.60 | 5.42 | 2.13 |
| Number of observations | 166 | 217 | 193 | 112 |

NOTE: Asterisk denotes constrained values (see text). Significance levels: [a] $t > 2.33$; [b] $t > 1.65$; [c] $t > 1.28$.

this would tend to promote a common price, since the demand for neighborhood quality would not be fragmented but metropolitan-area-wide. Consequently, in the absence of strong evidence that it was inappropriate, the market-wide price was imposed.[25] Second, for some services there was no within-town variation and therefore no possibility of calculating separate hedonic prices. All the homes in a town might, for example, receive municipal garbage collection, in which case the hedonic price equation for that town could not identify a value for the service. Yet to omit the variable in such towns would bias coefficients of included variables and lead to incorrect comparisons across towns.

### *C. Constructing the Housing Characteristics*

To convert the observed housing components into gross Lancastrian housing characteristics, I make some important simplifying assumptions. The housing bundle is regarded as divisible into four gross characteristics: basic structure (*BSTRUK*), interior quality (*QUAL*), interior space (*SPACE*), and land, public services, and neighborhood quality (*SITE*).[26] These four characteristics are what the household actually demands. To get them, however, it must purchase specific housing components, a garage, a fireplace, a basement, and land. I assume that each component supplies only one characteristic, making it a simple matter to calculate the total expenditure on each characteristic by adding together the hedonic prices for all appropriate components. The assignment of components to characteristics is indicated in Table 5.

It must be recognized explicitly that the characteristics I define are arbitrary in several respects. First, there is no certainty that households do perceive the housing bundle as consisting of exactly these four components, put together in exactly this way, although the combinations seem quite reasonable. Second, Lancaster's theory implies that households will demand something like Interior Space, but the

[25] The constraints are not imposed for *GEN Q* in New Haven and West Haven or for *SERVCE* in Hamden, North Haven, and West Haven. In these towns preliminary work found the neighborhood quality to be especially high-valued. This appeared to reflect the existence within the town of a limited number of high-quality neighborhoods. If, for whatever reason, a family felt compelled to live in, say, New Haven, it would face keen competition for a dwelling in the superior neighborhood.

[26] Public services and neighborhood quality are incorporated into *SITE* because their capitalized values will be reflected in the cost of land. This does not mean that households can increase their purchase of, for example, good public schools by buying more land. A better quality school is available only by choosing a different location.

TABLE 5

Elements of the Housing Characteristics

| Basic Structure (*BSTRUK*) | Interior Quality (*QUAL*) | Interior Space (*SPACE*)[a] | Site (*SITE*)[a] |
|---|---|---|---|
| *FULLIN* | *HARDWD* | *SQFT* | *SIZLOT* |
| *GARG*1 | *FIREPL* | *SQFTSQ* | *SZLOT*2 |
| *GARG*2 | 75+*AMP* | *SQFT/R* | *DISCBD* |
| 2+*BATH* | *STEAM* | *SMROOM* | *GEN Q* |
| *LAVTRY* | *EXCLNT* | *FINBMT* | *SRVCE* |
| *BLAUND* | *VGOOD* | *NOBMT* | *GARBGE* |
| | *FAIR* | 2*STORY* | *CSEWER* |
| | *FACBSS* | | |
| | *FACASB* | | |
| | *AGE* | | |
| | *AGESQ* | | |

[a] The intercept term is allocated 80 per cent to *SPACE* and 20 per cent to *SITE.*

construction here adds the additional constraint that Interior Space is amalgamated entirely from items purchased as part of the housing bundle. Conceivably, items like room dividers or mirrors are also a part of Interior Space. Third, what to do with the equation intercept is a problem in constructing these gross components. Here it has been allocated 80 per cent to *SPACE* and 20 percent to *SITE*, in accordance with the ratio of structure to site value suggested by Housing and Urban Development (HUD) statistics (1970, p. 198). This can be justified by observing that the intercept is the value of structure and site after all special quality features and location advantages are stripped away. Admittedly, this is not entirely satisfactory, but there is no alternative which seems clearly better.

The price indexes for the four gross characteristics in each town are shown in Table 6. To obtain these, I have specified a standard housing bundle and have then calculated the cost of characteristics by summing the costs of the individual elements as given in Table 4. Finally, each entry has been normalized by dividing by the cost of *SPACE* in New Haven.

TABLE 6

Price Indexes for Housing Components [a]

| | New Haven | Hamden | North Haven | East Haven | West Haven | Orange/ Woodbridge | Walling-ford |
|---|---|---|---|---|---|---|---|
| *BSTRUK* | .37 | .79 | .79 | .57 | .53 | .55 | .48 |
| *QUAL* | .88 | .78 | .77 | .48 | .86 | .81 | .66 |
| *SPACE* | 1.00 | 1.22 | 1.44 | 1.21 | 1.06 | 1.82 | 1.49 |
| *SITE* | 1.63 | .85 | .42 | .66 | .99 | .36 | .47 |

[a] The standard bundle from which these were derived included *FULLIN*, *GARG*2, 2+*BATH*, 2*STORY*, *HARDWD*, *FIREPL*, 75+*AMP*, *EXCLNT* condition, 1 decade *AGE*, 1,420 *SQFT*, 20,000 *SIZLOT*, *GENQ*, and *SRVCE* of −.5 each. Distance from the CBD is an approximate median distance for the town as a whole. In the demand functions of Section V, the price of *SITE* is calculated for each house, according to the distance of that house to the CBD. Thus, the entries for *SITE* here are only illustrative.

## VII. THE DEMAND FOR HOUSING CHARACTERISTICS

Using the hedonic prices obtained in the previous section to describe housing price surfaces in the metropolitan area and to construct the gross housing characteristics, I can now inquire whether household behavior corresponds to that predicted. The first question is whether households appear to view housing as a bundle of characteristics and modify their purchases in response to price and outlay variations. If they do, I can continue to the second aspect and investigate location choice as an interaction of prices, work site, and neighborhood quality.

To study the household's purchases of housing characteristics, I use the Rotterdam differential demand model of Barten (1964, 1967) and Theil (1965) with slight modifications as required for application to cross-sectional data and a single demand branch.[27] The resulting equations are of the form

$$w_j^* Dq_{ij} = \mu_i D\bar{m}_j + \sum_h S_{ih} Dp_{hj} + u_{ij}$$

$$h, i = 1, 4$$
$$j = 1, n \text{ households}$$

[27] The material in this section draws heavily on my paper "The Demand for Housing: A Lancastrian Approach" (1973b) and the reader is referred to it for additional details.

Here the $q$'s and $p$'s are the four characteristics identified in the previous section and their prices. The term $\bar{m}$ is the real outlay on the housing bundle and replaces an income term because of the assumed separability. The operator $D$ indicates the logarithmic difference $\ln x - \ln \bar{x}$ where $\bar{x}$ is the mean value of the particular data series. Finally, $w_j^* = [(w_{ij} + \bar{w}_i)/2]$, where $w_{ij}$ is the $i$th budget share $p_i q_{ij}/m_j$ for the $j$th household and $\bar{w}_i$ is the mean value of the $i$th budget share.

The "outlay" and price elasticities indicating household behavior are readily obtained from the parameters $\mu_i$ and $S_{ih}$. The former is defined as $\frac{\partial q_i}{\partial m}\frac{m}{q_i}\frac{q_i p_i}{m}$; the latter, as $\frac{\partial q_i}{\partial p_h}\frac{p_h}{q_i}\frac{q_i p_h}{m}$. Thus, deflating both by the budget share will yield the derived elasticities.[28]

The $u_{ij}$'s are random disturbance terms for which we assume $E(u_{ij}) = 0$ for all $i$ and $j$; $E(u_{ij}, u_{hk}) = 0$ for $j \neq k$; but $E(u_{ij}, u_{hk}) \neq 0$ for $j = k$; $i, h = 1, 4$. That is, the errors are uncorrelated across observations but correlated for the purchases of each household as a consequence of the overall restriction on the housing outlay. It follows from this restriction that the covariance matrix of the error terms is singular, and all four demand equations are not independent.

The assumption of separability permits the demands for the four housing characteristics to be studied as a small, independent demand system. As is well known, classical demand theory implies certain restrictions on the parameters of such complete systems: symmetry of cross-price terms in real-income-compensated functions, homogeneity, and negative own-price elasticities. One of the great advantages of the Rotterdam model is the ease with which these restrictions may be imposed (Brown and Deaton, 1972, p. 1190), and because this increases efficiency, I impose symmetry and homogeneity.[29]

To impose restrictions across equations, parameters of the demand system are estimated simultaneously in a "stacked" equation, using the iterative Zellner estimation procedure (1962) to allow for the nonzero covariances of the error terms. Because the error covariance matrix is singular, only three of the four individual demand functions need actually be estimated; parameters of the other are recovered from these, using the budget constraint, symmetry, and homogeneity.[30] The estimated parameters are given in Table 7 and the elasticities at the mean budget shares in Table 8.

[28] The elasticity is, of course, not constant but depends inversely on the budget share.

[29] Negativity, as an inequality constraint, is not readily imposed, but the condition may be used to evaluate the estimates.

[30] The estimates obtained are invariant with respect to the equation omitted.

TABLE 7

The Demand Parameters for Housing Characteristics

| Independent Variables | Dependent Variables *BSTRUK* | *QUAL* | *SPACE* | *SITE* |
|---|---|---|---|---|
| *OUTLAY* | .2400 | .3415 | .3163 | .1022 |
| | (31.94)[a] | (36.11) | (35.73) | (19.06) |
| *PSTRUK* | −.0172 | .0076 | −.0343 | .0439 |
| | (1.77) | (.86) | (4.15) | (10.32) |
| *PQUAL* | [b] | −.0370 | .0096 | .0198 |
| | | (1.85) | (.71) | (2.52) |
| *PSPACE* | | | −.0712 | .0959 |
| | | | (1.49) | (16.37) |
| *PSITE* | | | | −.1596 |
| | | | | (13.29) |
| $R^2$ | .56 | .67 | .68 | .85 |

NOTE: Definition of variables:

*BSTRUK*, *QUAL*, *SPACE*, *SITE*: These are the four Lancastrian characteristics defined in Table 5.

*PSTRUK*, *PQUAL*, *PSPACE*, *PSITE*: These are the prices for the four characteristics. The method of calculation is explained in Section VI and sample values are shown in Table 6.

*OUTLAY* This is the real value of the outlay on the housing bundle.

All variables are measured in natural logarithms and used as deviations from mean values as required for the Rotterdam model.

[a] *t* values in parentheses.

[b] Values below the diagonal are obtained from the symmetry condition.

TABLE 8

Elasticities at Mean Budget Shares

| | *BSTRUK* | *QUAL* | *SPACE* | *SITE* |
|---|---|---|---|---|
| Outlay | 2.06 | 1.71 | .65 | .52 |
| Own-price | −.15 | −.19 | −.15 | −.82 |

As evidence that households perceive housing as a bundle of components and modify purchases in response to prices and outlay, these results seem quite satisfactory. The $R^2$ for each demand function is quite high, especially considering that units of observation are individual households in cross section. All own-price elasticities are negative; cross-price coefficients indicate *BSTRUK* and *SPACE* to be complements, *QUAL* and *SPACE,* and *SPACE* and *SITE* to be substitutes, all of which seem reasonable. Purchases of quality and special structural features are highly responsive to increased outlay and thus, by implication, to income. Interestingly, the marked increase in *SITE* purchases in the outlying markets of the area appears to result more from decreased prices than from increased income.[31]

## VIII. TRADING OFF COMMUTING COSTS, PRICE STRUCTURES AND NEIGHBORHOOD QUALITY

I come now to consider evidence relevant to the first part of the housing demand model set out in Section II. There it was suggested that because location is an integral aspect of a dwelling unit the decision to purchase would involve considerations of the implied journey-to-work costs, the neighborhood quality obtained, and the set of relative prices for housing characteristics. While the evidence for this portion of the model is still incomplete, there are certain regularities discernible even in simple examination, which are quite encouraging.

The method in this section will be the examination of the actual locations chosen by households for evidence that they can be explained as optimal compromise locations given the work sites, neighborhood qualities, and price patterns. From the previous section, it appears that households behave as though they perceive price variations for housing characteristics among the various submarkets. Thus, if place of work and neighborhood quality were no consideration, it would be reasonable to predict that a household would purchase its dwellings in that submarket where the particular combination of characteristics is lowest priced. To test this, I have calculated, for

[31] There are, however, reasons to doubt the precise accuracy of the estimates despite the generally high *t* statistics. First, the determination of prices in hedonic equations will create some problems of measurement error resulting in bias. Second, the households have the alternative of selecting their budget constraint by moving among markets; thus, the estimates of price response cannot be treated as exactly comparable to the parameters in most demand studies. It should be emphasized, however, that households are not likely to choose a location on the basis of prices alone, since location will affect the journey-to-work and neighborhood quality also. These latter two influences will help reduce bias from this second source.

TABLE 9

Distribution of Housing Purchases by Relative Cost of Market
(per cent)

| Town | Low Cost← 1 | 2 | 3 | 4 | 5 | →High Cost 6 | 7 |
|---|---|---|---|---|---|---|---|
| New Haven | 24 | 16 | 18 | 11 | 7 | 13 | 10 |
| Hamden | 20 | 26 | 18 | 11 | 6 | 10 | 9 |
| North Haven | 20 | 26 | 18 | 11 | 6 | 10 | 9 |
| East Haven | 18 | 12 | 14 | 18 | 18 | 19 | 2 |
| West Haven | 33 | 19 | 12 | 9 | 10 | 11 | 6 |
| Woodbridge-Orange | 2 | 18 | 9 | 25 | 22 | 16 | 8 |
| Wallingford | 19 | 20 | 13 | 18 | 18 | 7 | 5 |

NOTE: The entries in this table show for each submarket (town) the percentage of purchases for which this market was the cheapest, second cheapest, etc. For example, of the houses purchased in New Haven, for 24 per cent New Haven was the cheapest market for this type of dwelling; for 10 per cent, it was the most expensive. Percentages may not add to 100 because of rounding.

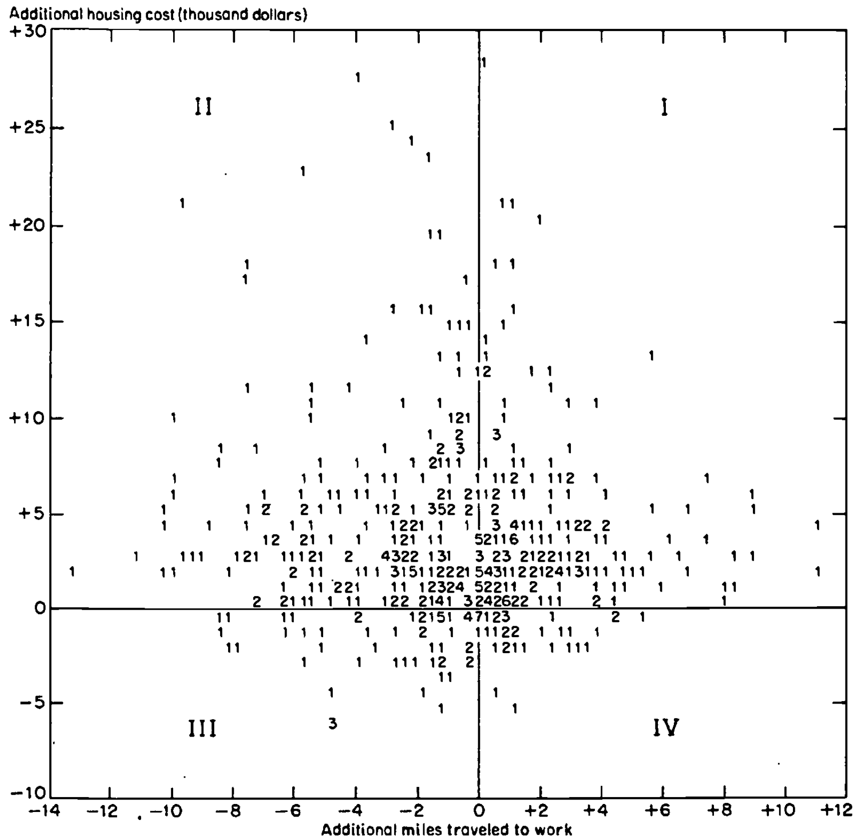
every dwelling actually purchased, its cost in every submarket at the prices prevailing there.

The results are shown in Table 9 as the number of times a dwelling purchased in, e.g., New Haven was purchased in the cheapest, second cheapest, and so on, market in the area. Without making any formal tests, it is apparent that households do not concentrate to any extent in the lowest cost market for their particular dwelling. There is some tendency to buy in the cheaper markets and only rarely do households buy in the highest-cost market. An indication of this is that the mean excess of actual price over lowest possible price is $3,700, while the mean excess of highest price over actual price is $6,100. Overall, however, it is apparent that predicting household location on the basis of where the observed dwelling is cheapest would be quite unsatisfactory.

The question now becomes whether the tendency of households to locate in other than the cheapest market can be explained in terms of the additional goals of low commuting costs and neighborhood quality. The tradeoff of a lengthier work trip for lower housing prices has a venerable standing in the urban economics literature. Although the cost variations for housing examined in this study arose for different

FIGURE 1

Plot of Additional Miles Traveled to Work against Additional Housing Cost




reasons than are usually suggested, the rationale for the tradeoff is the same, and I begin by looking at this.

In Figure 1, the additional dollar cost incurred by purchasing in other than the lowest-cost market is plotted against the difference in the journeys-to-work from the two markets.[32] If households recog-

[32] The number of households examined in Fig. 1 and subsequent Table 10 is only 538 compared to the 683 studied in the demand analysis. For some households, job sites were unknown or outside the area studied; in addition, efforts were made to

nize low-cost markets but accept higher prices to achieve a more desirable commuting trip, the points should lie in quadrants II and IV.[33] It is evident that this clustering does not exist, though more observations lie in II and IV – 292 – than in I – 199. (In addition, there are 60 observations enjoying the double bonus of quadrant III.)[34]

At this point it appears that the hypothesis of an exchange of commuting cost for housing cost must either be abandoned as a rather imprecise description or amended by the introduction of a third goal, the search for neighborhood quality being that suggested. To examine this possibility, I show in Table 10 average excess commuting trips, excess costs, and excess neighborhood quality[35] by income classes for the observations in each quadrant of Figure 1.

The results are quite remarkable. In comparing quadrant I to II, notice that in every income class the neighborhood quality obtained by households in I (henceforth "I's") exceeds that of II's by a wide margin. With one exception where it is equal, the quality available to I's in the low cost market is substantially less than that available to II's. Thus, whereas II's in their choice of location have sacrificed little if any quality (the entries in the "Excess *GEN Q*" are usually small), I's have obtained much greater quality by foregoing the low-cost market. The cost of this to I's appears to be the longer commuting trip both in absolute distance and relative to the commuting trip from the low-cost market.

For the entries in quadrants III and IV, one's expectations from the hypothesis of tradeoffs are not so clear. There would seem to be no reason why the double bargains in III might not be triple

exclude all self-employed persons who might work in their own homes and such persons as traveling salesmen.

The calculation of the hypothetical work trip from the low-cost market is somewhat crude. Whereas the actual work trip was calculated quite precisely, the hypothetical trip was assumed to begin from a central location in each market. Markets are small (rarely more than two miles in diameter) but in future work this calculation will be refined.

[33] Quadrants III and IV exist because households are sometimes able to buy a dwelling for less than the price predicted for the cheapest market. This might reflect special bargaining skills, seller urgency, or the like. Households in IV can be regarded as trading off their "bargain savings" against a longer commuting trip, while those in III have obtained a double bargain: a shorter commuting trip and a lower price than in the low-cost market.

[34] There is some slight double counting in these figures, as observations lying exactly on an axis are counted as belonging to two quadrants.

[35] Excess commuting trips, costs, and neighborhood quality are all calculated by subtracting these items in the low-cost market from what is actually received. The neighborhood-quality measure is based on *GEN Q* only.

TABLE 10

Housing Costs, Commuting Costs, and Neighborhood Quality

| | Income (Thousands of Dollars) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0–7.5 | 7.5–9.5 | 9.5–13 | 13–17 | 17–21 | 21–25 | 25+ |
| | | | | **Quadrant I** | | | |
| Excess cost | 2.20 | 2.62 | 3.66 | 4.68 | 10.34 | 11.11 | 10.30 |
| Excess miles | 2.19 | 2.85 | 2.35 | 2.01 | 1.66 | .78 | 2.40 |
| Excess *GEN Q* | .26 | .36 | .59 | .56 | .61 | .50 | .67 |
| *Value* | 19.09 | 19.78 | 23.10 | 24.33 | 32.00 | 44.71 | 40.11 |
| *HValue* | 16.90 | 17.16 | 19.44 | 19.65 | 21.67 | 33.61 | 29.81 |
| *Dwork* | 5.41 | 6.32 | 6.13 | 4.99 | 5.47 | 4.11 | 6.51 |
| *HDwork* | 3.22 | 3.46 | 3.78 | 2.98 | 3.81 | 3.33 | 4.12 |
| *GEN Q* [a] | .27 | .44 | .51 | .40 | .71 | .44 | .74 |
| *HGEN Q* [a] | .01 | .08 | –.08 | –.17 | .10 | –.06 | .07 |
| Observations | 25 | 44 | 70 | 31 | 12 | 7 | 10 |
| | | | | **Quadrant II** | | | |
| Excess cost | 2.35 | 3.24 | 3.74 | 5.00 | 8.43 | 10.92 | 12.87 |
| Excess miles | –3.44 | –3.26 | –3.31 | –2.81 | –3.43 | –2.73 | –2.72 |
| Excess *GEN Q* | .06 | –.02 | .00 | –.07 | .10 | –.15 | –.24 |
| *Value* | 17.02 | 20.56 | 22.20 | 26.38 | 33.29 | 37.68 | 46.23 |
| *HValue* | 14.68 | 17.32 | 18.46 | 21.38 | 24.86 | 26.75 | 33.37 |
| *Dwork* | 2.54 | 3.49 | 3.02 | 2.99 | 3.46 | 3.94 | 2.87 |
| *HDwork* | 5.95 | 6.75 | 6.34 | 5.80 | 6.89 | 6.66 | 5.60 |
| *GEN Q* [a] | .06 | .30 | .26 | .21 | .35 | .20 | –.03 |
| *HGEN Q* [a] | .01 | .31 | .26 | .28 | .25 | .35 | .21 |
| Observations | 42 | 57 | 65 | 38 | 24 | 7 | 22 |
| | | | | **Quadrant III** | | | |
| Excess cost | –1.27 | –1.50 | –1.73 | –1.96 | –2.47 | –6.07 | – |
| Excess miles | –2.10 | –2.28 | –3.62 | –2.95 | –2.92 | –4.71 | – |
| Excess *GEN Q* [a] | –.30 | –.54 | –.07 | .35 | .13 | .05 | – |
| *Value* | 13.60 | 16.72 | 19.26 | 24.04 | 27.63 | 26.98 | – |
| *HValue* | 14.87 | 18.21 | 21.00 | 26.00 | 30.10 | 33.05 | – |
| *Dwork* | 1.99 | 3.65 | 3.25 | 4.88 | 4.16 | 2.21 | – |
| *HDwork* | 4.03 | 5.93 | 6.87 | 7.83 | 7.08 | 6.92 | – |
| *GEN Q* [a] | –.42 | –.51 | .17 | .57 | .38 | .70 | – |
| *HGEN Q* [a] | –.12 | .04 | .24 | .21 | .25 | .65 | – |
| Observations | 20 | 13 | 12 | 8 | 6 | 1 | 0 |

TABLE 10 (concluded)

| | Income (Thousands of Dollars) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0–7.5 | 7.5–9.5 | 9.5–13 | 13–17 | 17–21 | 21–25 | 25+ |
| | | | **Quadrant IV** | | | | |
| Excess cost | –.70 | –.98 | –1.30 | –1.16 | –.75 | –4.93 | - |
| Excess miles | 1.44 | 1.95 | 1.57 | 1.19 | .65 | 1.06 | - |
| Excess *GEN Q* [a] | .62 | .42 | .37 | .03 | .63 | .51 | - |
| *Value* | 17.55 | 16.60 | 17.87 | 21.88 | 23.09 | 15.91 | - |
| *HValue* | 18.25 | 17.58 | 19.17 | 23.05 | 23.84 | 20.84 | - |
| *Dwork* | 3.86 | 7.57 | 5.75 | 3.76 | 5.22 | 6.63 | - |
| *HDwork* | 2.41 | 5.61 | 4.18 | 2.57 | 4.57 | 5.58 | - |
| *GEN Q* [a] | –.09 | .44 | .40 | .55 | .68 | .91 | - |
| *HGEN Q* [a] | –.71 | .03 | .03 | .53 | .05 | .40 | - |
| Observations | 5 | 8 | 17 | 4 | 2 | 1 | 0 |

NOTE: Households are classified by quadrant from Figure 1 and by income class (in thousands of dollars) as shown in each column heading.

*Value:* value of housing bundle (thousands of dollars) in market of purchase.
*HValue:* hypothetical value of housing bundle calculated at the set of prices in the lowest-cost town.
*Dwork:* journey-to-work in miles from actual dwelling.
*HDwork:* hypothetical journey-to-work from low-cost town.
*GEN Q:* neighborhood quality.[a]
*HGEN Q:* hypothetical neighborhood quality, an average value for the low-cost town.[a]
Excess cost: *Value* – *HValue*
Excess miles: *Dwork* – *HDwork*
Excess *GEN Q*: *GEN Q* – *HGEN Q* [a]

[a] To provide an easier, more intuitive understanding, I have multiplied the scores for *GEN Q* by –1 *in this table only.* Consequently, a *positive GEN Q* is desirable and a *positive* deviation indicates a better neighborhood. Differences in *GEN Q* of less than about .10 are not meaningful.

bargains as well, offering lower costs, shorter commuting trips and better neighborhood qualities. Still, one might expect that households would sometimes accept lesser quality to obtain the other two bargains, so the net effect is not certain. It appears, in fact, that for the majority of III's, quality is lower than that of I's or II's; moreover, for the same cases, it appears to be lower than that available in the low-cost market. Thus, there is some evidence that for the lower-income families a sacrifice in quality was accepted in order to obtain the dollar savings and the shorter commuting trip.

For quadrant IV, one's expectations are once again uncertain. However, it appears that the main influence on the location choice must have been the possibility of superior neighborhood quality, since the saving of housing cost is rather trivial and the extra commuting trip not great. In contrast, the neighborhood quality is high relative to that obtained in other quadrants for similar income levels, and the excess neighborhood-quality figures are (particularly for low income) among the largest in any quadrant.

## IX. CONCLUSION

Housing markets have long been described as erratic, unpredictable, or even chaotic. Hopefully, the investigations reported here will help dispel some of this. The evaluation is incomplete and certain assumptions used in this analysis are clearly open to question; nevertheless, there can be no doubt that household behavior in purchasing a single-family dwelling and choosing a location conforms quite well to the model set out. Choice of location is surely complex, but it is not a random process; place of work, neighborhood quality, and optimal prices seem to shape the decision. To obtain a superior neighborhood, households will travel further and pay more than they would have to if the house itself were their only concern; conversely, the chance to save on housing costs and work trips will induce households to settle for less neighborhood quality, particularly lower-income families.

If one considers only the choice of dwelling type within a particular market, the evidence of economically rational behavior is unmistakable. Prices and outlay both influence purchases just as would be expected. One particularly interesting implication of these results is that an important heterogeneous good like "housing" can usefully be treated as a collection of fairly specific characteristics. Since the purchases of these different items respond quite differently to price and outlay changes, it is clear that suppressing these, as do the usual studies of "housing demand," will reduce understanding of consumer behavior in a very important market.

Finally, though much of the attention in this paper has been directed toward the model of household behavior, the fundamental role of hedonic price estimation must not be overlooked. Contrary to an established opinion, it appears that housing prices are not chaotic and randomly set; they may vary in relation to components but regularly and over discernible areas. Significantly, choice of dwelling type and location both indicate the price patterns to be sufficiently apparent to households so that decisions bear their marks. When detailed information regarding housing transactions is available, it seems that hedonic price estimation can usefully be employed to indicate to the outside observer the price patterns needed in the investigation of housing market behavior.

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# Comments on "The Demand for Housing: Integrating the Roles of Journey-to-Work, Neighborhood Quality, and Prices"

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STUDYING the demand for housing is conceptually very similar to studying the demand for other goods. There are quantities demanded and prices paid; presumably the quantities can be related to the prices and other household characteristics within the traditional framework of demand analysis. As King points out, however, it is often difficult to obtain information on the prices and quantities of the goods that comprise a dwelling unit. Although the quantities of the physical attributes of housing can be measured, the prices of these individual attributes cannot be observed directly. The only price observed in the housing market is the selling price or rent for the dwelling unit as a whole.

These data problems led many early empirical studies of housing markets to assume that dwelling units produce a homogenous good, "housing services," that sells at a constant price per unit at all locations in a metropolitan area. Since price differences are assumed away by these studies, expenditures are often used as a proxy for the quantity of housing services in demand analyses that relate the expenditure on housing to the income and other characteristics of households.

More recently, hedonic indexes for housing have been estimated so that prices can be imputed to individual housing attributes and the homogeneous housing services assumption can be relaxed. These hedonic indexes also constitute an empirical test for the constant price assumption imbedded in the homogeneous-good approach. Many of the hedonic equations that have been estimated, including those reported by King, suggest that the prices of housing attributes vary significantly within a metropolitan housing market. If attribute prices do differ, variations in housing expenditures include these price differences as well as possible quantity differences, so housing expenditures cannot be used as a pure measure of the quantity of housing consumed.[1]

Whereas a lack of price information inhibited housing market analysis in the past, the estimation of hedonic prices for large numbers of housing attributes has made the abundance of price information a problem for housing demand studies now. For example, King estimates prices for more than twenty attributes of a dwelling unit. These twenty-odd prices could be used in a simultaneous-equations framework to estimate the demand for each attribute, but the estimation problems would be severe. Some simplification is obviously called for to solve this multitude-of-attribute-prices problem.

In addition, different hedonic attribute prices are typically estimated for spatial subareas of a metropolitan housing market; King has estimated hedonic attribute prices for each of seven subareas in the New Haven region. Having different hedonic prices for several subareas may at first appear merely to exacerbate the multitude-of-attribute-prices problem by increasing the number of prices to be considered. However, the spatial stratification actually creates a new problem because a household must buy all of its housing attributes in only one subarea as a spatially tied purchase. This spatially tied purchase requirement differentiates the analysis of housing demand from that of most other consumer goods.

Analyses of housing demand based on hedonic prices differ principally in the way in which they resolve the multitude-of-attribute-prices problem and the spatially tied purchase requirement. King solves the multitude-of-attribute-prices problem by aggregating his

[1] King does not statistically test his individual equations to see if attribute prices differ significantly between towns in the New Haven area. Such tests assume that the specification of the hedonic indexes is correct. It has been argued that specification errors largely explain the spatial differences in attribute prices found by housing market studies; see George Peterson, "The Capitalization of Fiscal Variables," Urban Institute Working Paper 1207-25 (January, 1973).

numerous housing attributes into four "Lancastrian" housing characteristics. This number of characteristics presents few problems of estimation. King then satisfies the spatially tied purchase requirement by assuming that households have no opportunity for substitution among the seven subareas in the New Haven region. For example, if a sampled household has originally chosen a unit in East Haven, only the East Haven prices are allowed to influence that household's chosen quantities of the four housing characteristics. The demand equations are then estimated, using the seven sets of relative prices of the four aggregate housing characteristics as independent variables.

Although these procedures readily permit the estimation of demand equations, they are not without problems. Thus, reducing the number of housing attributes by constructing four aggregate "Lancastrian" characteristics places a strong condition on household utility functions. To be able to use a composite of price-weighted quantities of several housing attributes as an index of the quantity of an aggregate housing characteristic, households must be indifferent to the combination of attributes that comprise a constant expenditure on an aggregate characteristic. That is, a household's indifference curves in attribute space must be coterminous with the price surfaces defined by various expenditures on the attributes that make up each aggregate characteristic. The likelihood of this condition holding for the four aggregate characteristics is doubtless low.

Furthermore, restricting the choice set of households to a particular subarea for purposes of demand estimation severely limits households' substitution possibilities. If households actually do make substitutions among spatial subareas, their opportunity set is defined by the envelope of price surfaces in the seven subareas rather than by the price surface in a single subarea. Of course, using the envelope of price surfaces in demand estimation is not possible with the model put forward by King, because all households would face the same envelope of market prices. These prices would not vary across households; and without price variation, it would not be possible to estimate demand equations. The envelope of prices could only be used in a demand model that allowed the price envelope to vary by household, for example by adding household-specific travel costs to the market prices of housing.

One important housing attribute incorporated in King's demand framework is neighborhood quality, and his analysis in the final section of the paper suggests that neighborhood quality is an important determinant of a household's location choice. This analysis also implies that neighborhood quality cannot be combined with the other attributes in the *SITE* characteristic, because household location is explained or rationalized only when a household's choice of neighborhood quality (*GEN Q*) is included as a separate attribute in the travel cost–housing price tradeoff. King's paper represents an interesting attempt to integrate the choice of housing attributes, neighborhood quality, and travel costs, but he correctly warns the reader that in this area, much work still remains to be done.