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A SYSTEM-WIDE APPROACH TO DEMAND ANALYSIS FOR RENTAL HOUSING CHARACTERISTICS IN HONOLULU SMSA AND EFFECTS OF DEMOGRAPHIC VARIABLES ON HOUSING CHARACTERISTICS

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A SYSTEM-WIDE APPROACH TO DEMAND ANALYSIS

FOR RENTAL HOUSING CHARACTERISTICS IN HONOLULU SMSA

AND EFFECTS OF DEMOGRAPHIC VARIABLES ON HOUSING CHARACTERISTICS

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ABSTRACT

The central focus of this study is to investigate household demand for Lancastrian housing characteristics in a system-wide approach in the Honolulu SMSA, and to investigate the effect of demographic difference across households on the demand for rental housing characteristics. Interview data from seventeen hundred and forty households are used in an effort to examine the importance of demographic variables in influencing housing consumption patterns.

Total rental expenditure is allocated among seventeen housing attributes by applying the hedonic technique. These housing attributes are aggregated into three basic housing characteristics: interior space, structure quality, and neighborhood condition. Three different demand models are utilized. One model, the linear expenditure system, first applied by Stone(1954), assumes additive preferences and is considered in light of the limitations associated with an additive framework. Another model, the translog demand system, introduced by Christensen, Jorgenson, and Lau(1975), assumes non-additive preferences and is considered in light of its flexibility in capturing cross price effects. The other model, the almost ideal demand system, introduced by Deaton and Muellbauer(1980), also assumes non-additive preferences and is applied in light of its ease of estimation in addition to non-additive structure. Homotheticity and additivity of households preference underlying housing consumption are rejected in the translog model. Homogeneity and symmetry in

consumption of housing characteristics are also rejected. The almost ideal demand system is preferable to the translog model in terms of economic interpretation and computing cost. In general, the non-additive system yields a better explanation of household consuming behavior of housing services in the Honolulu rental housing market.

Five demographic variables reflecting household composition and size are incorporated into the three demand systems. The inclusion of household size, age, race, and sex of household head, and the level of education of head reveals that such demographic variables play a crucial role in shaping household preferences for housing services and affect the recognized prices of housing characteristics.

TABLES OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

1.1 Background

Housing has been distinguished from most goods traded in the economy in its principal features: its relatively high cost of supply, its durability, its heterogeneity, and its local fixity. Durability and supply cost indicate that the supply curve for housing services is inelastic even over relatively extended periods. Durability, heterogeneity and local fixity together suggest that the housing market is a collection of closely related, but segmented, markets for particular packages of underlying commodities differentiated by size, physical arrangement, quality, and location. Given the peculiar nature of the housing market, research on the demand for residential housing has proceeded in the direction of a more detailed analysis of the substitution of components within the bundle of housing services in response to variations in household income and demographic composition.

Since housing is collectively consumed by household members and households differ in size, age composition, educational level,and other characteristics, the inclusion of demographic variables in the analysis of consumption patterns of housing is desirable. Systematic differences in the consumption behavior of households with different demographic characteristics are expected. In most housing demand analyses, the effect of demographic variables has been typically handled in an ad hoc way, such as simply adding them to demand equations. It would be more reasonable and useful to model the effects of household characteristics in a system of demand equations in which the information of systematic differences in the consumption behavior of households can be provided.

1.2 Objectives of the Study

The purpose of this study is twofold: One is to investigate the household's demand for Lancastrian housing characteristics in a system-wide approach. The other is to examine the impact of demographic difference among households on the demand for housing characteristics in the Honolulu Standard Metropolitan Statistical Area(SMSA) using data from the Annual Housing Survey(AHS). In the study, 'housing' is viewed as a bundle of heterogeneous characteristics rather than a single valued commodity and, instead of assuming households in the sample have identical tastes, only those with the same demographic profiles are assumed to have the same demand functions. Demographic variables affecting the demand for housing are household composition, and the number, types, and ages of household members. In principle any other characteristic can be included in the model to explain the difference in consumption behavior across households.

The hypothesis of this study is that the demographic characteristics of households are as important as prices and income in the determination of the demand for housing characteristics. The major questions to be pursued are :

(1) What is the nature of consumers' preferences for housing commodities in Honolulu SMSA? Additivity of preferences across housing characteristics and homotheticity of preferences are investigated.

(2) What are the features of demand equations for housing characteristics in Honolulu SMSA? Validity of hypotheses derived from the theory of consumer behavior are empirically verified by imposing restrictions and testing hypotheses. These include adding-up, homogeneity, symmetry, and negativity of the Slutsky matrix. Expenditure, price and substitution elasticities are appraised for some aggregated housing characteristics within the specified systems of demand equations. Prices for housing attributes are imputed by employing the hedonic technique.

(3) What are the impacts of alternative demographic structure (size and composition) on the composition of housing consumption? More specifically, what are the effects of demographic variables on the demand for the characteristics of housing services? Household size, age compositon, race and sex of household head, and the level of education are employed to explain the different actual quantity of housing characteristics purchased in the market.

1.3 Outline of the Study

Chapter II will review the literature of demand analysis for housing services. In Chapter III, a theoretical structure of demand analysis for housing characteristics, with special emphasis on the effect of demographic variables, and its empirical specification will be described. The first two sections of Chapter IV will present the description of the data and the estimating technique. Evaluation of the empirical results will follow in the next three sections. The final chapter includes the summary of findings and concluding implications of the study.

CHAPTER II

REVIEW OF THE LITERATURE

The literature on housing demand can be classified into two main categories. One category treats housing as an aggregate bundle of services that enters as a single argument in the household preference function. The other treats housing as a disaggregated bundle of housing attributes or components that can be individually included in households' preference functions with specific market prices. Along with these two categories, the empirical studies of the effects of demographic variables on the housing demand will be reviewed in the first two sections. Several procedures incorporating demographic characteristics will be reviewed in the last section.

2.1 Demographic variables in the Study of Aggregate Housing Expenditure

Demographic variables are handled in a simple way in most aggregate housing demand analysis. They are used as stratifying variables (Morgan(1965),de Leeuw(1968), Straszheim(1975)), or added to demand equations in a simple functional form(Lee(1971), Maisel, Burnham, and Austin(1971), Carliner(1973), King and Mieszkowski(1973), David and Legg(1975), King and Quigley (1976), Hanushek and Quigley(1979)). Although there is little uniformity in the selection of variables used in different analyses, the frequently included

TABLE 2-1

Demographic Varaibles in Aggregate Housing Demand Analysis

Author(s)	Demographic Variables Employed	Data Description
Morgan, J. M. (1965)	Age, Sex, Education, Race	1959 Surveys of Consumer Finances
Lee, Tong Hun (1968)	Size of Family, Race, Age, Education, Years Married	1960-1961-1962 Survey of Consumer Finances, 523 Owner-Occupied & 164 Rental Houses.
de Leeuw, Frank (1971)	Household Size, Race	1960 Census, 19 Metropolitan Area
Maisel, Burnham, Austin (1971)	Household Size	2,900 New Home Purchases in 29 SMSA's by FHA in 1966.
Carliner, G. (1973)	Race, Age, Sex	"A Panel Study of Income Dynamics"
King, T and P. Mieszkowski (1973)	Race, Sex	220 Rental Units in New Haven, Conn., (1968-1969)
Straszheim, M. R. (1975)	Race, Age, Marital Status, Household Size	Household Interview in San Francisco
Kain, J. F., & J. M. Quigley (1975)	Family Size, Age, Sex, Race, Marital Status, Number of Children, Education Level	St. Louis Survey (1967), 1,200 Households
David, J. M., & W. E. Legg (1975)	Household Size, Age, Education	Orlando Metropolitan Area, Florida
Hanushek, E. A. & J. M. Quigley (1980)	Household Size, Race, Age, Education	Housing Allowance Demand Experiment, 586 Households in Pheonix and 799 in Pittsburgh

*Age, race, sex, and education refer to the head of household. Race and sex are used as dummy variables in most cases.

variables are household size, age structure of household, and sex, race, and education of the head (Table 2-1).

A summary review of demographic effects on the demand for housing as an aggregate bundle of services is as follows: (1) The inclusion of household size affects the estimates of price elasticity and income elasticity, but the direction of the size effect is not consistent in the literature.[1] (2) Female-headed households spend relatively more for housing and black-headed households spend less.[2] (3) Housing expenditure of nonwhite households appear to be less income elastic and more price elastic than that of white households. The effect of race on housing expenditure across equivalent households is a bit ambiguous because, in most of the studies reviewed, there is no separation of the effects of demand and supply factors on racial price difference.[3] (4) The level of education, usually measured by

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[1]The income elasticity and the price elasticites estimated by F. de Leeuw are 0.47 and -0.94 for one person family household, respectively, and 0.72 and -0.68 for six or more persons household. Maisel and others(1974) also found that the inclusion of household size lowered the income elasticity and raised the absolute value of price elasticity of demand for housing.

[2]G. Carliner, "Income Elasticity of Housing Demand," Review of Economics and Statistics, Vol. 55, No. 4(November 1973), p. 530. His estimates of income elasticity from regressions including dummy varaibles for heads who are black, female, under 35 and between 35 and 64, are higher than other estimates without those demographic variables. The result is a bit different from that of Lee(1968) in which lower income elasticities were estimated with the inclusion of socio-demographic variables such as age of head, size of family, years married, occupation, education, race, sex of head, and community type and region of the household residence.

[3]For detail, see John F. McDonald(1979), 51-62.

the number of schooling years of the head, is positively associated the level of housing expenditure. In general, the inclusion of demographic variables in the demand analysis for housing services has a significant impact on the level of housing expense and demand elasticities. However, the effects have been rarely accounted for by specifying the household preferences and by incorporating demographic differences into the demand analysis for housing services. Mayo(1981) suggested parameterization of plausible utility functions using demographic variables in order to allow their effect to be derived in demand functions.

Some ambiguous results of demographic effect may be related to the weakness of using housing expenditure to measure the demand for housing services. The differences in housing expenditure can reflect either differences in quantity consumed or differences in prices. When households buy or rent a residence, they simultaneously choose a large number of specific and identifiable attributes. In principle, there is a market price associated with each of these attributes. Since any combination of attributes and quantities may be obtained for the same total outlay, it is virtually impossible to interpret changes in housing outlay without identifying the each attributes, i.e., their quantities and their prices. It is necessary to obtain and analyze the information on the prices and quantities of the attributes included in each bundle of housing services.

2.2 Demographic Variables in Demand Analysis for Housing Characteristics

A major theoretical and empirical difficulty in the demand analysis for each characteristic of housing service is that housing consumers never directly observe the prices of individual characteristics, and thus, cannot purchase characteristics individually. Instead, characteristics must be purchased as part of an entire bundle of residential services. The prices must be imputed from the differences in the cost of "other things being equal" bundles. Kelvin J. Lancaster (1966) provided a theoretical basis for the demand analysis of each characteristic. Sherwin Rosen(1974) suggested empirical procedures to impute prices to each characteristic from a hedonic price equation. Using these implicit prices, the structural demand and supply equations for each housing characteristic can be estimated.

The demand functions for the housing characteristics have been estimated either separately for each component (David(1962), Straszheim (1975), Kain and Quigley(1975), Linneman(1981), Witte, Sumka, and Erekson(1979)) or jointly for all characteristics (Kain and Quigley, King (1977), McMillan(1979)).

The first attempt to analyze the demand for housing characteristics was made by M. H. David. In his analysis of 847 renters and 697 owner-occupant households from the 1955 Survey of Consumer Finances, David obtained OLS estimates for two measures of housing services: housing quantity measured by the number of rooms, and housing quality measured by rent per room or house-value per room. The number of rooms occupied appeared to increase significantly with income and family size for renter households and owner households. The rent per room increased with income but decreased with family size for both groups. As family size increased, the demand for quantity increased and the demand for quality decreased. The net effect of an increase in family size turned out to be a decline in expenditure on housing, which resulted from substituting housing quantity with housing quality.[4]

The demand functions for two attributes of housing--age and lot size of housing--were estimated by Straszheim separately for sixteen life-cycle groups. Straszheim classified the sample of 28,000 households from the San Francisco Bay Area taken in 1965 by marital status, age of head, and the number of children. Among married homeowners, structural age rises with age of head and older households of a given family size occupy smaller and older units. Dwelling-unit size increases significantly with the number of children, but the effect of family size on lot-size appears only for households with head over forty. Income elasticity for room is positively related to the age of the head and to the number of children. There is no difference in the

[4]His analysis showed that the decline came from the consumption of more rooms and less quality in housing. As family size increases, economies of scale also appeared to reduce the expenditures of the large renting family below what might be expected on the single basis of quality adjustment. See M. H. David(1962), pp. 53-81.

price coefficients of rooms across life-cycle groups. The income and price elasticities for structure age are higher for the households comprised of single and separated individuals without children than for married households.

Among renter households, household size affects dwelling-unit size; households with children rent large units. With respect to the age of the structure, married households with head under forty occupy significantly newer units than single and separated households. The income elasticity for rooms does not vary across household groups and the price elasticity for married households is insignificant for most age and family size group. In the lot-size equation, only single and separate household exhibit a significant negative price elasticity.[5]

Separate estimation of the demand for housing attributes across groups classified by demographic variables are essentially simple, and results among subgroups can be easily compared. The method implicitly assumes that households have different preferences among different subgroups. However, it is feasible only when a sufficient amount of data exists for each of the separate groups. If an appropriate procedure of normalizing the differences among subgroups could be applied to the whole sample, it would be more enlightening to observe the effect of demographic variables on the demand for housing services.

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[5]For detail, see Straszheim, An Econometric Analysis of Urban Housing Market, pp. 103-115.

Kain and Quigley estimated the demand functions for 21 housing attributes; five dwelling-unit quality, four dwelling-unit size, seven neighborhood, and five structure type attributes.[6] The effect of family-size on the consumption of dwelling-unit quality, dwelling size and neighborhood quality appeared quite consistent. In particular, the family-size variable indicates a clear pattern of substitution of dwelling-unit size for dwelling-unit quality.[7] The increase of the number of children accords to that of rooms with decreasing rate. Additional education increases household demand for the attributes of dwelling-unit quality. For households with similar characteristics, blacks consume a considerably smaller amount of dwelling-unit quality and desirable neighborhood attributes. However, separate analyses by race show qualitatively similar effects of family composition upon the demand for housing attributes.

A weakness of single equation estimates for separate housing attributes is that OLS estimates assume independence of the demand for each attribute. In the consumption of housing services, it is improbable that the demand for housing attributes are independent, because households consume various housing attributes jointly. Kain and

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[6]Their analysis are based on the sample of roughly twelve hundred St. Louis households interviewed in 1967 as part of the St. Louis Community Renewal Program.

[7]"...larger households consume substantially more of the attributes of physical size, particularly dwelling-unit size, and less of the attributes of dwelling-unit and residential quality." J. F. Kain and J. M. Quigley, Housing Markets and Racial Discrimination: A Microeconomic Analysis, pp. 254-255.

Quigley grouped eighteen housing attributes into four bundle components, and estimated jointly the demand functions for four housing characteristics: dwelling quality, interior space, neighborhood quality and exterior space. Increase in family size is associated with greater consumption of interior space. The household with younger children is associated with greater increase in interior space than either the household with infants or only adults. Black households consume substantially less dwelling quality, less neighborhood quality, and less exterior space than white households with identical size and composition.[8]

T. King assumes a housing bundle composed of four characteristics: special structural features, interior and exterior quality, interior space, and land, public services and neighborhood quality. Based upon the study about housing demand in the New Haven area, he found that the number of persons in the family at the time a house is purchased appears to be positively related with interior space and negatively with housing quality and neighbor quality.[9]

A simultaneous equations model of bid and offer functions for

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[8]For detail, see J. F. Kain and J. M. Quigley, op. cit., pp. 256-282.

[9]"...larger families have a significant tendency to purchase more SPACE, less QUAL and SITE..... The result is particularly interesting since elsewhere in studying the demand for "housing" I found no evidence whatever that family size influences the outlay. The present study refines this by showing that family size does influence the composition of the bundle if not the total cost." A. Thomas King, "The Demand for Housing: A Lancasterian Approach," Southern Economic Journal, Vol. 43, 1976, p. 1084.p.1084.

housing characteristics, dwelling quality, dwelling size, and lot size, was estimated by Witte, Sumka, and Erekson using the data from a survey of over 500 rental dwellings from four nonmetropolitan cities throughout North Carolina in 1972.[10] Household size appears to increase the bid price for dwelling size and to decrease the bid price for lot-size and dwelling quality. The level of education is proportionate to the bid price for dwelling quality.

Linneman(1981) specified child-related characteristics in the household's utility and estimated the demand functions separately for three housing characteristics, rooms, work access, and neighborhood homogeneity. He included the presence of children, the expected child in the next year, and age difference between the oldest and youngest children in the demand equations as independent variables. His findings indicate that the inclusion of child-related family characteristics importantly increases the explanatory power of the demand functions for location-specific traits of residential housing.[11].

To sum up, several common findings appear in the literature. (1) Household size has been most frequently found to be positively

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[10]The functional form of their hedonic price equation was basically quadratic in housing attributes and thus their structural equations were linear. These functional forms turned out later having some pitfalls as commented by J. N. Brown and H. S. Rosen(1982).

[11]His empirical analysis notes that children are important in determining residential preferences, with special attention to the endogeneity of children with respect to the process of residential choice.

related with the consumption of interior space, and negatively with housing quality, which is structure quality or neighborhood quality. (2) Older people occupy older housing units, which probably reflects reluctance to move to a new house. (3) The number of children is closely related with the interior space of housing quantity.
(4) Black headed households consume less exterior space and housing quality. (5) Finally, the level of education is positively associated with the consumption of exterior space and structure quality. The effect of education may be considered together with that of income because the effects of income and education are related (Kain and Quigley(1975)).

The unit of housing consumption is, in general, a household or a family. Accordingly, the effects of the household characteristics have to be modeled in the demand analysis of housing services. However, in the literature, the effects are frequently modeled by simply adding a list of household characteristics without much systematic consideration of household's behavior with respect to household composition.

Introduction of the notion of an equivalent unit of consumption into the demand analysis for housing enables welfare comparisons across households. Several procedures of incorporating household characteristics into the systems of household expenditure equations could be applied also in the demand analysis for housing characteristics if housing can be considered as a weakly separable branch of household consumption.

2.3 Incorporation of Demographic Variables in the Systems of Household Expenditure Equations

The basic philosophy of incorporating demographic factors into demand analysis is that demographic variables play a crucial role in shaping a household's preferences and affect the recognized prices of various good and services on which a household spends. There are two different ways to examine demographic effects in systems of demand equations. One is to introduce additional parameters, which depend only on the demographic variables, into the system. This technique has the advantage of allowing explicit measurement of demographic effects across different groups of consumers. The other is to estimate separate systems of demand equations for each of several groups, where the demographic factors define membership in one of the groups of different consuming units. Since this technique is only feasible when sufficient degrees of freedom exist for each group and since there can be many possible subgroups, the review primarily focuses on the first category of incorporating demographic effects.[12]

The specific functional form of a complete system of demand equations is determined by the form of the given utility function and budget constraint. When preferences change, the demand system also

[12]Derrick and Wolken(1982) compared the two methods in an attempt to determine which method more appropriately explains the effects that demographic factors have on household consumption. They showed that separate demand systems are more appropriately estimated for each of the individual family types considered but the approach is expensive in terms of the use of data.

changes. An implicit assumption of estimating a demand system is that the utility function and the budget constraint remain unchanged over the sample space. Since the consumption of housing characteristics are collectively shared by a household's members and the preferences for collectively consumed commodities could be reasonably assumed specific to the composition of the household, demographic variables should be modified in the demand analysis for housing characteristics. Four procedures of incorporating demographic variables into the demand system are reviewed: demographic scaling, demographic translating, Gorman specification, and reverse Gorman specification. All four procedures yield a theoretically plausible demand system that can be derived from specific "well-behaved" utility functions. Modification of the utility function, and the subsquent systems of demand equations are summarized in Table 2-2.[13]

Demographic scaling, first proposed by Barten(1964), introduces scaling factors, m_1, $m_2, \ldots, m_n$, which depend on the demographic variables in any convenient functional form, into the original systems of demand equations so that both preference and demand behavior can be viewed in terms of demographically scaled prices or quantities. Scaling factors can be interpreted as reflecting the number of

[13]It is shown by Robert Pollack and Terence Wales(1981) that all the procedures can be applied to any theoretically plausible demand system. They introduced one more procedure, which they named "modified Prais-Houthakker procedure", but it is ignored here because they proved that it yields a theoretically plausible demand system if and only if the original demand system coresponds to an additive direct utility function.

TABLE 2-2

Modification of Demand Systems
by Incorporating Demographic Variables

Incorporating Procedure	Modified Demand System	Modified Utility Function
Original System	$x_i=f_i(P,y),\ i=1,\ldots,n$	$U(x)$
Demographic Scaling	$x_i=m_i f^i(p_1m_1,\ldots,p_nm_n,y)$ $i=1,\ldots,n$	$U(X/M)$
Demographic Translating	$x_i=d_i+f^i(P,y-\sum_{k=1}^{n} p_kd_k),$ $i=1,\ldots,n$	$U(X-D)$
Gorman Specification	$x_i=d_i+f^i(p_1m_1,\ldots,p_nm_n,y-\sum_{k=1}^{f} p_kd_k)$ $i=1,\ldots,n$	$U((X-D)/M)$
Reverse Gorman Specification	$x_i=m_i(d_i+f^i(p_1m_1,\ldots,p_nm_n,$ $y-\sum_{k=1}^{f} p_km_kd_k)),\ \ i=1,\ldots,n$	$U(X/y-D)$

*The original demand systems, $x_i = f_i(p, y)$, where x's denote quantities, p's prices, y total expenditureare theoretically plausible, for they can be derived from "well-behaved" preferences. In the modified demand systems, d's are transition parameters and m's scaling parameters.

"equivalent adults" across the households.[14]

Demographic translation was first employed by Pollak and Wales (1978) as a general procedure for incorporating demographic variables into classes of demand systems. It introduces "translation parameters", $d_1, d_2, \ldots, d_n$, into the demand systems and postulates that these parameters depend on demographic variables. Translating can often be interpreted as allowing "necessary" or "subsistence" parameters of a demand system(Pollak and Wales (1980,1981)).[15]

First scaling and then translating represents Gorman specification for equivalent scales , whereas first translating and then scaling represents the reverse Gorman specification procedure (Gorman (1976), Pollak and Wales(1981)). If scaling factors and translating factors are postulated by linear functions of demographic variables, it is possible to test linear translating or linear scaling against Gorman specifications.

While the above procedures of incorporating demographic

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[14]The most common demographic variables used as scaling deflators are family size(Ray(1980, 1982)), the number of children in the family, and their ages(Pollack and Wales(1978, 1980)). Note that any other demographic characteristics can be placed upon scaling specification.

[15]Derrick and Wolken(1982) employed the number of children and the number of adults in the translating procedure, while Pollak and Wales(1978) used the number of children and their ages to specify the translating parameters of the demand system. Howe(1977) also estimated significantly different subsistence expenditure among different age groups in a Bogota household expenditure analysis, which gives another empirical justification of introducing translating parameters into the demand system.

variables are desirable in the analysis of household behovior, their empirical implementation is often impractical in systems of demand equations. These procedures introduce the demographic parameters into each equation of the system in a complicated nonlinear format. If we have a system of n demand equations and we want to incorporate m demographic variables, then we have to specify at least (n x m) new parameters in each share equation, which could result in failure of the system to converge. A compromise might be necessary between theoretical incorporation of demographic variables and its emprical application to the real problem.

CHAPTER III

THEORETICAL STRUCTURE AND EMPIRICAL SPECIFICATION

3.1 A Theoretical Framework of Demand Analysis for Housing Characteristics and Effects of Demographic Variables

Housing consumption is assumed to be a weakly separable branch of household preference ordering[1]. This is both necessary and sufficient for the second stage of two-stage maximization procedure. Households are assumed to proceed in two steps under the assumption of weak separability: First, they decide how much of their total budget they will allocate to the housing consumption. Then, given this amount of housing budget, they decide the combination of various housing characteristics to acquire with it. Under this proposition, we are assuming that the marginal rate of substitution between housing characteristics is independent of the quantities of goods in other branches so that the housing quantities purchased can be written as a

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[1]Consumer's preferences are defined weakly separable if the whole commodity vector can be partitioned into several subgroups. Separable preferences are represented by a utility function of the form $U = f(v_1(q_1),\ldots,v_n(q_n))$ for commodities subvectors $q_1,\ldots, q_n$, one of which can be housing services and f is some increasing function of branch utility function, v's. The utility function was first defined as being weakly separable by Robert H. Strotz in his article, "The Empirical Implication of a Utility Tree," Econometrica, (April 1957), 269-280. For more details of the implication of weak separability, see L. Phlips Applied Consumption Analysis, 1983, Chapter III and Deaton and Muellbauer, Economics and Consumer Behavior, 1980, pp.120-147.

function of housing expenditure and prices of housing characteristics alone. Detailed expenditure for specific housing characteristics can be related to housing outlay and housing prices within the housing branch. Since the decision procedure for the housing purchase or rent seems reasonable, weak separability of the housing branch would be acceptable in the practical demand analysis of housing services.

We assume also that consumption of housing commodities is an activity in which housing attributes such as number of rooms, age of the building structure, freedom from airplane noise, etc., are inputs and in which the output is a collection of housing characteristics such as appropriate interior space, proper structure quality, and good neighborhood condition. Preference ordering of housing consumption is assumed to arrange collections of housing characteristics directly and is only assumed to arrange collections of housing attributes indirectly through characteristics. Following the Lancastrian rationale of consumer theory, the basic properties of the characteristics approach to the housing demand analysis can be summarized as follows[2]:

1. The housing attribute does not give utility directly to the consumer; it posseses several housing characteristics and utility arises from these characteristics.

2. As a whole, an attribute will have more than one housing characteristic, and many characteristics will be shared by more than

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[2]Kelvin J. Lancaster, "A New Approach to the Consumer Theory," Journal of Political Economy, Vol. 74, No. 2(April 1966), 132-157.

one housing attribute.

3. Any combined bundle of housing attributes can produce housing characteristics different from those pertaining to the housing attributes separately.

Defining b_{ij} as the quantity of the i-th characteristic contained in a unit amount of j-th housing attribute, we can define a household production function B which transforms the housing attributes into the characteristics they yield. Consumer theory asserts that households seek to maximize utility (3.1), defined on characteristics-space subject to the budget constraint, (3.2), in attributes space with transformation equation or consumption technology, (3.3).[3]

(3.1) Maximize $U(z)$

(3.2) Subject to $p_x{}'x = y$

(3.3) with $z = Bx$, where z is vector of characteristics,
p is vector of attribute prices, and
x is attribute vector.

Since the unit of housing consumption is primarily a household rather than an individual, we have to take account of the effect of household composition. The same amount of housing attributes does not give the same output of housing characteristics among households with

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[3]Kelvin J. Lancaster, "Changes and Innovation in the Technology of Consumption," American Economic Review, Vol. 56 (May 1966), 14-23. See also the same author, "The Theory of Household Behavior: Some Foundations," Anals of Economic and Social Measurement, Vol. 4, No. 1(Winter 1975), 5--22.

different demographic composition. Let us introduce demographic normalization, (3.4), where M is a diagonal matrix whose diagonal elements are scaling parameters which depend only on demographic variables, and d is a vector of translating parameters.

$$(3.4) \quad x = Mq - d,$$

where x is the amount of housing attributes with which households with different composition can produce equivalent amount of housing characteristics and q is the amount of attributes actually purchased. When d is a zero vector, we are incorporating demographic variables only through scaling parameters. If M is an identity matrix, then we are applying translation alone.

Demand functions for the various housing characteristics--derived in the usual way from utility maximization subject to budget constraint with transformation equation and demographic normalization --can be written (3.5):[4]

(3.5) $z = f(p_z, y, c)$ where p_z is price vector and c is a vector of demographic variables.

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[4]By substituting (3.4) into (3.3), we have $z = BMq - Bd$ where BM is the consumption technology in which demographic scaling is incorporated and Bd is the consumption technology in which demographic translating parameters are included. Assuming BM has an inverse matrix and substituting $q = (BM)^{-1}(z + Bd)$ into (3.2), we have the maximizing problem in characteristics-space, from the first-order condition of which we can derive a system of demand equations.

Economic theory has nothing to say about the sign of demographic effect in the absence of particular specification of the utility function incorporating demographic variables. Since there are many possible conbinations of demographic variables in the utility function, it is an empirical question to determine which demographic change will affect which housing characteristics and in which direction.

3.2 Empirical Specification of the Systems of Demand Equations for Housing Characteristics

A theoretically plausible system of demand equations can be formulated in three different ways. Consumer maximization of a direct utility function, which has positive first-order derivatives and continuous second-order derivatives, subject to budget constraint will result in a demand system. We can also obtain it from a well-behaved indirect utility function, which specifies the maximum utility level that can be attained when income and prices are given, by applying Roy's identity. The third way, which has become increasingly useful in deriving systems of demand equations, is the consumer cost function approach. Minimizing the cost function, defined as the smallest amount of expenditure that enables the consumer to enjoy a given utility level at the given price level, is equivalent to maximizing the direct utility function subject to the budget constraint. Following the above lines, we will specify three systems of demand equations for the purpose of investigating household behavior of housing consumption and the effect of a household's demographic composition. These are the linear expenditure system(LES), the transcendental logarithmic demand system(TRANSLOG), and the almost ideal demand system (AIDS). The validity of general restrictions and particular restrictions in housing consumption are to be empirically examined by imposing appropriate restrictions on the specified systems.

4.2.1 The Linear Expenditure System

Let z_i be the quantity of the ith characteristic and y be the total expenditure on a group of housing characteristics. Maximizing the well known Stone-Geary utility function,

$u = \sum_{i=1}^{n} (z_i - r_i)^{b_i}$, we can derive the famous 'linear expenditure system' of demand equations:

(3.9)

$$s_i = p_i^* r_i + b_i(1 - \sum_{j=1}^{n} p_j^* r_j), \quad i = 1,\ldots,n$$

where p_j^* the normalized price of the j-th characteristic(p/y). In the system the b's represent marginal budget shares, the r's are usually

interpreted as 'subsistentence quantities', and $(y - \sum_{j=1}^{n} p_j r_j)$ as supernumerary income.[5]

Homogeneity and symmetry restrictions are built into the system The adding-up implications of consumer theory can be imposed on the system as $\sum_{i=1}^{n} b_i = 1$. The negativity of Slutsky matrix of price effect can be verified by examining whether $0 < b_i < 1$ and $z_i > r_i$ for all i.

While one of the most striking features of the demand system is

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[5]The linear expenditure system has its roots in the seminal study of Richard Stone, "Linear Expenditure Systems and Demand Analysis: An Application to the Pattern of British Demand," The Economic Journal, Vol. 64, No.255(September 1954), 511-527.

the fact that it has only 2n-1 parameters, the linear expenditure system often tends to oversimplify reality by its additive nature. Moreover, it permits little flexibility for cross-price effects, whose quantification is very often one of the main goals of estimating complete systems of demand equations.[6] In most empirical studies, models that are derived from a general functional form of the utility function, show a closer fit to data than those from the additive utility function.[7]

3.2.2 Transcendental Logarithmic Demand System

Following Christensen, Jorgensen and Lau(1972), we can assume the logarithm of the indirect utility function to be a quadratic function in logarithms of normalized prices of housing characteristics with respect to housing expenditure :

(3.10)

$$\ln V = \sum_{i=1}^{n} a_i \ln p_j^* + .5 \sum_{i=1}^{n} \sum_{j=1}^{n} b_{ij} \ln p_i^* \ln p_j^*$$

where, $b_{ij} = b_{ji}$, for symmetry. The translog utility function can be interpreted as a utility function in its own right. However, it is primarily interpreted as a second order approximation of an arbitrary utility function. Unlike the additive demand systems,

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[6]Even under the additive utility function, the cross substitution effect does not vanish completely because there remains an overall effect. See L Phlips(1983), pp. 60-63.

[7]For a comparative study of complete systems of demand equations, See N. A. Klevmarken(1979).

the translog form can be estimated without imposing homotheticity and additivity, which is the feature that makes the translog function appealing.[8]

$$s_i = \frac{a_i + \sum_{j=1}^{n} b_{ij} \ln p_j^*}{\sum_{j=1}^{n} a_j + \sum_{i=1}^{n} \sum_{j=1}^{n} b_{ij} \ln p_j^*}, \quad i = 1, \ldots, n \tag{3.11}$$

Making use of Roy's identity, we obtain a set of budget share equations (3.11), in which expenditure shares of housing characteristics are allowed to vary with the ratio of price to expenditure, and a variety of substitution patterns is permited. Homotheticity can be imposed on the indirect translog function by restricting sums of second-order parameters to be equal to zero, $\sum_{i=1}^{n} b_{ij} = 0$, for all j, and additivity can be imposed by eliminating all interactions between normalized prices: $b_{ij} = 0$, for all i and j.

A disadvantage of the translog model compared to the linear expenditure system is that its coefficients have no simple economic interpretation, and the number of parameters increase about proportionally to the square of the number of goods. Another problem is that testing of homogeneity of degree zero of the budget shares,

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[8]The translog model has been proposed and applied in systemwide demand analysis by Christensen, Jorgenson and Lau(1975), and Christensen and Manser(1975).

which are often more questionable hypothesis to determine the validity of the theory of demand, is not allowed.[9] In a practical sense, the translog system is also quite expensive, for, in general it requires complicated non-linear estimation.

3.2.3 An Almost Ideal Demand System

Maximization of the direct utility function subject to a budget constraint leads to a system of demand equations. Substitution of these equations into the direct utility function gives the indirect utility function. Then the dual problem of maximizing utility is to minimize total expenditure subject to a given utility level. This minimum is the expenditure function or cost function. Shephard's lemma says that partial differentiation of the cost function with respect to price gives a constant-utility demand function or compensated demand function. To find the ordinary demand function, is sufficient to solve the cost function for utility as a function of price and income and to substitute this into the constant-utility demand function.

Deaton and Muellbauer have explored this approach and recently suggested 'an almost ideal demand system'.[10] They write the cost function as (3.12). Using Shephard's lemma and substituting for U,

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[9] P. Simmons and D. Wieserbs(1979) suggest an alternative translog functional forms and associate demand systems in which a distinct test of homogeneity is allowed.

they derive the share equations (3.13).

(3.12)

$$\ln C(p,U)=a_0 + \sum_{j=1}^{n} a_j \ln p_j + 0.5 \sum_{i=1}^{n}\sum_{j=1}^{n} r^*_{ij} \ln p_i \ln p_j + U \prod_{j=1}^{n} P_j^{b_j}$$

(3.13) $$s_i = a_i + \sum_{j=1}^{n} r_{ij} \ln P_j + b_i \ln (Y/P),\ i=1,\ldots,n,$$

where P is a price index defined by

(3.14) $$\ln P = a_0 + \sum_{j=1}^{n} a_j \ln P_j + .5 \sum_{i=1}^{n}\sum_{j=1}^{n} r_{ij} \ln P_i \ln P_j, \text{ and}$$

$$r_{ij} = .5(r^*_{ij} + r^*_{ji}) = r_{ji}.$$

The advantage of this system is its ease of estimation relative to the linear expenditure system or the translog system. It also can be used to test homogeneity(and symmetry) through linear restrictions on parameters, which is not feasible in the translog or linear expenditure system. Yet it has the advantage of being derived explicitly from utility maximization, unlike the differential approach in the Rotterdam demand system. Following Deaton and Muellbauer, we approximate the price index by the Stone index;

(3.15) $$\ln P = \sum_{i=1}^{n} s_i \ln P_i,$$

and the system converts into an easily estimable linear system:

(3.16) $$s_i = a_i + \sum_{j=1}^{n} r_{ij} \ln P_j + b_i \ln(Y/P),\ i=1,\ldots,n.$$

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[10]Angus Deaton and John Muellbauer, "An Almost Ideal Demand System," American Economic Review, Vol. 70, No. 3(June 1980), 312-326.

The adding-up restriction implies (3.17)

$$(3.17) \quad \sum_{i=1}^{n} a_i = 1, \qquad \sum_{i=1}^{n} b_i = 0, \qquad \sum_{i=1}^{n} r_{ij} = 0,$$

and the symmetry restriction can be expressed as $r_{ij} = r_{ji}$. In the system, the b_i coefficients reflect the effect of changes in real expenditure and the coefficients r_{ij} reflect the impact of changes in relative prices.

Given the adding-up restriction of the demand theory, imposing the symmetry restriction in (3.16) implies immediately that the system satisfies the homogeneity restriction, but not the inverse. Imposing the homogeneity restriction with the adding-up restriction does not indicate that the system is also symmetric. This result gives an empirical implication for testing the homogeneity and symmetry hypotheses of the theory .
Testing symmetry in (3.13) or (3.16) with the adding-up restriction implies that we are jointly testing symmetry and homogeneity. Imposing symmetry with the adding-up restriction is equivalent to imposing all three restriction: adding-up, homogeneity, and symmetry. Thus, testing symmetry alone has no meaning in the system. However, we can test symmetry with respect to homogeneity with the given adding-up restriction.

3.3 Incorporation of Demographic Variables into the Systems of Demand Equations for Housing Characteristics

To determine the importance of the demographic characteristics and what the effects of alternative demographic structures are on the composition of housing demand, a compromise technique between an ad hoc and purely theoretical way of incorporating demographic profiles will be used.[11] It includes demograhic variables in the share equations in a convenient functional form and imposes restrictions such that the share equations satisfy the adding-up condition. This is an attempt to determine the effects that demographic factors have on the estimated parameters of the demand system. Identifying the demograhic variables that most meaningfully capture household structure must precede the incorporating procedure. Applying this procedure on (3.9), (3.11), and (3.16), we can specify the following three sets of demand systems, (3.19), (3.20), and (3.21), respectively, in which the effects of demopraphic variables are combined. The adding-up property can be maintained by imposing

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[11]The above compromise has only empirical justification. In our systems of demand equations for three housing characteristics, any theoretically plausible method of incorporating five demographic variables requires introducing at least fifteen new parameters into each equation of the system in a complicated nonlinear functional format. Parameter estimation of the system have difficulty converging.

$\sum_{i=1}^{n} b_{ik}=0$, for all k in each system. The hypothesis that demographic variables play an important role in determining the combination of housing characteristics can be verified by testing the joint hypotheses H_0: $b_{ik} = 0$, for all i and k.

$$(3.19) \quad s_i = \sum_{k=1}^{n} b_{ik}d_k + p_i^* r_i + b_i(1-\sum_{j=1}^{n} P_j^* r_j),$$

$$(3.20) \quad s_i = {}_k\, b_{ik}d_k + \frac{a_i + \sum_{j=1}^{n} b_{ij}\ln P_j^*}{\sum_{j=1}^{n} a_j + \sum_{j=1}^{n}\sum_{i=1}^{n} b_{ij}\ln P_j^*},$$

$$(3.21) \quad s_i = \sum_{k=1}^{n} b_{ik}d_k + a_i + \sum_{j=1}^{n} r_{ij}\ln P_j + b_i\ln(Y/P),$$

where b_{ik}'s show the effect of k-th demographic variable on the share of rental expenditure for i-th housing characteristics, and s_i is the share of rental expenditure for i-th housing characteristics. p_i is the price and p_i^* is normalized price, while y/P is real income.

CHAPTER IV

ESTIMATION AND EMPIRICAL RESULTS

The data used in this study are from the Annual Housing Survey(AHS) in the Honolulu SMSA, and the estimating technique is primarily 'seemingly unrelated' regression in its linear and nonlinear versions. The first two sections will describe the data and the estimating technique. Estimated rental hedonic price equation will be presented in 4.3, which will be followed by the result of the three estimated systems of demand equations for housing characteristics in 4.4. The final section will discuss the result of incorporating demographic variables in the share equations for housing characteristics.

4.1 Data from Annual Housing Survey

The Annual Housing Survey SMSA is designed to provide a current series of information for selected metropolitan areas concerning such subjects as the size and the composition of the housing inventory, the characteristics of the occupants, indicators of housing and neighborhood quality, and the characteristics of recently arrived

[1]For more details regarding the data from the AHS, see J. M. Goering, Housing in America: The Characteristics and Uses of the Annual Housing Survey, November 1979, Department of Housing and Urban Development.

neighbors. The data set utilized in this study is included in the public-use computer tape file of the AHS.[1] The data were completed in Honolulu SMSA through direct personal interview by the Bureau of the Census from April 1976 to March 1977. The AHS sample in Honolulu SMSA consists of approximately 5,000 housing units for each period of interview. Out of the sample, this study concentratesits empirical concerns only on the rental housing units, for there is no unique way to define home-owners' expenditure for housing services.

In the data, houses are composed of or associated with a large number of attributes occurring in a wide variety of combinations. The demand for each attribute can be defined. It is impractical, however, to work with a large number of individual attributes that are all recognized as influencing the value of housing services. Table 4-1 reports the definition of selected housing attributes for the analysis. Applying the Lancastrian characteristics approach to demand analysis, we can collapse the numerous features of a housing unit into a few basic characteristics. The aggregation of necessary attributes is arbitrary, but three characteristics are chosen: interior space, structural features of the house, and neighborhood quality. The specific attributes are assigned to each of the basic characteristics in the following way:

1. Space includes count of bedrooms, number of rooms, number of bathrooms, and complete kitchen facilities.

2. Structural quality includes age of the housing unit, presence of passenger elevator, existence of paint peeling, connection to the

TABLE 4-1

Definition of Housing Attibutes

Variable Name	Definition
BEDRM	Number of bedrooms
ROOM	Number of whole rooms
BATH	Number of bathrooms
KITCHEN	1 if complete kitchen facilities, 0 otherwise
AGE	Age of the sturcture
ELEV	1 if passenger elevator, 0 otherwise
PAINT	0 if any peeling paint over 1 square feet, 1 otherwise
PUBSEW	1 if the unit connected to public sewer, 0 otherwise
HSRT	1 if house rating is excellent or good, 0 otherwise
ARNOISE	1 if no airplane noise, 0 otherwise
MOVIN	Number of years staying in the unit
RNDNHS	1 if occupied unit not in run down condition, 0 otherwise
STLIGHT	1 if no poor street lighting, 0 otherwise
STIMPASS	1 if roads not impassible, 0 otherwise
TRASH	1 if no trash, litter, or junk in the streets, 0 otherwise
PBTRANS	1 if adequate public transportation, 0 otherwise
NBRT	1 if neighborhoood rating is excellent or good, 0 otherwise

public sewer, and house rating.

3. Neighborhood condition includes neighborhood rating, absence of air plane noise, street lighting, impassible street, occupied housing unit in run down condition, trash and appropriate public transportation.

More specific concepts of the housing attributes outlined in Table 4-1 are arranged as follows. The following definitions and explanations of housing attributes are summarized from the Appendix A in published reports of SMSA sample of the AHS:

BEDRM: The number of bedrooms in the unit is the count of rooms used mainly used for sleeping, even if also used for other purposes. Rooms reserved for sleepiing such as guest room are counted as bedrooms, while rooms used mainly for other purposes, even though used also for sleeping, are not considered bedrooms.

ROOM: Rooms counted include whole rooms used for living purposes, such as living rooms, dining rooms, kitchens, finished attics or basement rooms, recreation rooms, permanently enclosed porches that are suitable for year-round use, and lodger's rooms. Also included are rooms used for offices by a person living in the unit.

BATH: A housing unit is considered having a complete bathroom if it has a room with a flush toilet and bathtub or shower and a washbasin, as well as piped hot water in the structure for the exclusive use of the occupants of the unit.

KITCHEN: A unit has complete kitchen facilities when it has all three of the following for the exclusive use of the occupants of the unit:

(1) An installed sink with piped water, (2) a range or cook stove, and (3) a mechanical refregerator.

AGE: Age of the structure refers to the number of years from initial consturction, not when it was remodeled, added to or converted.

ELEV: Elevator in the sample refers to the housing unit in structure with four floors or more which have a passenger elevator.

PAINT: Peeling paint on the interior ceilings or walls of a housing unit refers to the inside walls or ceilings, and at least one area of the peeling paint must be approxomately one square feet or larger.

PUBSEW: A public sewer is connected to a city, county, sanitory dixtrict, neighborhood, or subdivision sewer system. It may be operated by a governmental body or private organization.

HSRT: The data presented are based on the respondent's overall opinion of his house or building as a place to live.

ARNOISE: This category refers to the respondent's opinion concerning noise made by airplanes in landing or taking off or sonic booms from nearby airports of military basis.

MOVIN: The variable refers to the period when the present occupancy of the household head began. The year the head moves is not necessarily the same year other members of the household move, although, in the great majority of cases, the entire household moves at the same time.

RNDNHS: This category refers to occupied housing units which, in the respondent's opinion, are in run down condition.

STLIGHT: Poor street lighting includes areas that, in the opinion of the respondent, have no street lighting, streets with insufficient lighting, and streets where the lighting does not work adequately.

STIMPASS: Roads inpassible refer to roads that the respondent reports is neglected by state, county, or city crews during snowstorms, heavy rain storms, or other such conditions that makes a road impassible.

TRASH: Included are all types of trash, debris, or junk such as paper, cans, or abondoned cars in the street, on empty lots, or on properties on the street which the respondent considers litter.

PBTRANS: These data reflect the respondent's opinion of the availability of public transportation, such as bus, subway, or taxicab service.

NBRT: The data presented are based on the respondent's overall opinion of the neighborhood, according to the neighborhood conditions and services available.

4.2 Estimation Procedure

An empirical study of housing demand ideally should encompass all the information on the housing market including both supply and demand sides. Such a specification is, however, not appropriate here because the AHS data does not include information on housing supply. It is permissible to examine the demand for housing characteristics themselves when the unit of demand observation is not sufficiently large enough to have an impact on market prices. For demand analysis with microdata, the traditional view of the simultaneity between demand and supply would not pose a serious problem. In practice, identification problems are ignored whenever complete systems of demand equations or several demand equations are to be estimated, because it is entirely impractical to specify supply equations for a number of commodities.

To estimate parameters of the demand systems for housing characteristics, the following procedures are in order:

(1) estimation of rental hedonic price equation,

(2) imputation of implicit prices for individual housing attribute,

(3) generation of the index of quantities and prices for housing characteristics, using the implicit prices for housing attributes,

(4) estimation of systems of demand equations for housing characteristics, and

(5) incorporation of demographic variables into the systems of demand equations for basic housing characteristics.

Data on the prices and quantities of the basichousing characteristics that are necessary for estimation of the expenditure share equation are not at hand in the market. The value of a house, however, can be associated with a bundle of attributes. Different houses have different bundles, and the market process in balancing supply and demand establishes a price equation or hedonic relationship.[2] From the estimated hedonic price equation, the implicit prices can be imputed to each housing attribute. Accordingly we can combine the information on the specific attributes to define prices and quantities for the basic housing characteristics. The application of hedonic theory to the housing market is justified by the fact that housing is not a homogeneous commodity, but a label for a collection of distinct attributes.

The hedonic price equation for housing reflects only the sets of market clearing prices associated with bundles of housing services.[3] It is, in general, neither the demand nor supply function for housing. Rather, the hedonic equation and its

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[2]The hedonic price technique was developed by Z. Grilliche and others initially for the purpose of estimating the value of quality change in consumer goods. See Z. Grilliche(ed), Price Indexes and Quality Change, 1971

[3]Sherwin Rosen, "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition," Journal of Political Economy, Vol. 82(1974).

associated partial derivatives are the locus of demand-equals-supply points for each specific housing attribute. Whenever the hedonic price equation is estimated, it is implicitly assumed that the prices are the balancing locus of demand and supply.

There is no strong a priori notion of the correct functional form, but empirical estimation of the hedonic price equation for housing attributes has been carried out in the following functional forms:[4]

(1) linear model(Butler(1982), King(1976), Kain and Quigley(1975)),

(2) semilog model(Harrison and Rubinfeld(1978), Malpezzi, Stephen, Ozanne and Thibodean(1980), Kain and Quigley(1975), McMillan, Reid and Gillan(1980)),

(3) quadratic form(Witte, Sumka, and Erekson(1979)),

(4) log linear form(McMillan(1979), Kain and Quigley(1975)),

(5) linear Box-Cox model(Linneman(1980), Blomquist(1981), Blomquist and Worley(1982)),

(6) quadratic Box-Cox form(Halvorsen and Pollalowski(1981)).

While various nonlinear versions of the hedonic price equation give better fitting estimates, one of its weaknesses is that the sum of shares for housing attributes, which are obtained using the implicit prices from the estimated hedonic price equation, is not necessarily equal to 1. Since the purpose of this study is to

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[4]A comparative study between several functional forms of hedonic price equations can be found in Robert Halvorsen and Henry O. Pollakowski, "Choice of Functional Form for Hedonic Price Equations," Journal of Urban Economics, Vol. 10(1981), 37-49.

estimate the system of demand equations for housing services using the estimated prices, the adding-up property of housing expenditure, which implies the expenditure shares for each housing attribute sum to 1, is desirable. If we can estimate the hedonic rent equation which is homogenous of degree one in various housing attributes, the adding-up property can be satisfied. In this study, interactive terms defined as the multiplication of square root of housing attributes are a compromis in the linear hedonic rent equation.

From the best fitting rental hedonic price equation, the implicit prices are computed by taking partial derivatives of the equation with respect to each housing attribute. Using these implicit prices, we can construct a quantity index for aggregated housing characteristics. The Divisia index, which provides a relatively unrestricted method of constructing aggregated quantities, is utilized.[5] The discrete cross-sectional Divisia index for the quantity of an aggregated characteristic m composed of n component attributes is

$$(4.1) \quad \ln q_m - \ln q_m^o = \sum_{s=1}^{n} w_s(\ln q_s - \ln q_s^o),$$

where the o superscript denotes the base value. The weight is an average of the observation's expenditure share on that attribute and the base share as (4.2):

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[5]For more rigorous details of Divisia index, see W. E. Diewert, "Exact and Superative Index," Journal of Econometrics, Vol. 4, (1976), 115-145. and "Superative Index Numbers and Consistency in Aggregation," Econometrica Vol. 46(July 1978), 883-900.

$$(4.2) \quad w_s = .5\,[p_s q_s / \sum_{s=1}^{n} p_s q_s + p_s^o q_s^o / \sum_{s=1}^{n} p_s^o q_s^o],$$

where average prices and quantities are used as base values. Prices are defined by dividing the expenditure share for each characteristic by its quantity index.[6] The index of prices and quantities for housing characteristics are used in estimating the systems of demand equations for housing services. Because the error terms of share equations are not independent due to the budget constraint, the parameters are obtained from the estimates of the full set less one of the demand equations. For the estimation of parameters in the LES and the translog system which are nonlinear systems of demand equations, the modified Gauss-Newton iterative method is used to solve for the nonlinear 'seemingly unrelated' regression model. For the estimation of the AIDS, we can apply the usual 'seemingly unrelated' regression technique, which was originally developed by Arnold Zellner(1962).

4.3 Rental Hedonic Price Equation in Honolulu SMSA

The ordinary least-square estimates of rental hedonic price equation for the Honolulu SMSA are reported in Table 4-2.

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[6]Prices for characteristics are not obtained by the Divisia index because the prices of housing attributes are somewhat endogenously determined from hedonic estimates based on the quantities available.

TABLE 4-2

Rental Hedonic Price Equation in Honolulu SMSA

Dependent Variable: Monthly Rental Expenditure

VARIABLE	PARAMETER ESTIMATE	T FOR H0: PARAMETER=0
BEDRM	19.06126	4.127
ROOM	13.91733	4.448
BATH	33.33120	6.758
KITCHEN	20.90566	1.606
AGE	-1.94640	-4.564
ELEV	-20.63557	-1.057
PAINT	6.10803	0.611
PUBSEW	109.171	3.174
HSRT	29.32334	3.299
NBRT	11.17045	2.204
ARNOISE	33.63224	1.877
MOVIN	-2.27727	-3.252
STLIGHT	11.91281	1.905
RNDNHS	10.01476	1.296
STIMPASS	26.70681	1.916
TRASH	5.41419	0.832
PBTRANS	16.07596	2.832
AGEELEV	12.64833	2.157
BATHPBSW	-80.30243	-4.369
AGEPBSW	4.45383	1.089
ARNSSTMP	-16.34371	-0.883
ELEVMOVN	24.81524	2.587
HSRTMOVN	-16.13490	-3.728

R^2 = .9166 and Adjusted R^2 = .9155
F-Value = 820.311

*AGEELEV = Square Root of (AGE x ELEV)
BATHPBSW = Square Root of (BATH x PUBSEW)
AGEPBSW = Square Root of (AGE x PUBSEW)
ARNSNTMP = Square Root of (ARNOISE x STIMPASS)
ELEVMOVN = Square Root of (ELEV x MOVIN)
HSRTMOVN = Square Root of (HSRT x MOVIN)

The dependent variable in the equation is the sum of monthly contract rent and monthly utility costs such as electricity, gas, water, fuel, garbage collection, furniture, and parking. The equation is originally linear in seventeen housing attributes and additionally includes six interactive terms that reflect the property of jointness in consumption of the housing attributes. The interactive terms are selected on the basis of statistical significance(t-values) and reasonability of the coefficients. The intercept is suppressed in the regression because people do not pay rent for zero residential service.[7] Since no intercept term is used, R^2 is redefined as $[1 - e'e/Y'Y]$, where e is the vector of estimated residuals and Y is the vector of dependent variables. The explanatory power of the selected housing components is quite good, particularly in view of the micronature of the observation. In general, the signs of the price function coefficients are as expected.

Taking the partial derivatives of the estimated hedonic price equation with respect to each housing attribute, we can obtain implicit prices for 17 components of the residential services. Since we have interactive terms, the implicit prices of several attributes are varying over the different combinations. In the equation, two bads, AGE and MOVIN, are interactively included and, accordingly, the implied prices for them are negative by definition. The prices of several other attributes interrelated with the bad attributes also can

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[7]The rental hedonic price equation with intercept term is also estimated and most of the parameter estimates are very similar to those of the equation with no intrcept term and the intercept term itself turns out insignificant at 5% significance level. These are reported in the Appendix A.

be negative. We can interpret these negative prices as the household's marginal willingness to pay for improvement of the bad combinations of housing attributes, following the property value approach used frequently in environmental quality valuation.[8] If we assume that the marginal benefit of improving the bads is constant for each individual household, then the aggregate benefit of removing the bads from the current residential unit is obtained by multiplying the absolute value of the price by the amount of the bad attributes that a household is suffering in the unit. Table 4-3 displays the mean marginal attribute valuation associated with the hedonic price function reported in Table 4-2.

TABLE 4-3

Marginal Attribute Prices Evaluated at Means from Monthly Rental Hedonic Price Equation (unit: dollar)

VARIABLE	PRICE	VARIABLE	PRICE
BEDRM	19.061	NBRT	8.326
ROOM	13.917	ARNOISE	20.170
BATH	9.945	MOVIN	5.278
KITCHEN	20.501	STLIGHT	10.462
AGE	1.504	RNDNHS	9.266
ELEV	1.856	STIMPASS	19.388
PAINT	5.876	TRASH	4.797
PUBSEW	48.886	PBTRANS	13.765
HSRT	10.833		

[8]The use of a residential hedonic price equation to measure the benefit from improving environmental quality can be found in survey by A. M. Freeman III, "Hedonic Prices, Property Values and Measuring Environmental Benefits: A Survey of the Issues," Scandinavian Journal of Economics, Vol. 81, No. 2(1979 d), 154-173.

4.4 Estimated Systems of Demand Equations for Housing Characteristics.

Several common findings are shared in the following three sets of estimated demand systems. (1) The demand for interior space is more sensitive to the change of rental outlay than the other housing characteristics. The expenditure elasticity of interior space is greater than one while the others are less than one. (2) The three housing characteristics are substitutes for each other in the Honolulu SMSA. All estimates of the compensated cross-price elasticities are positive and the own price elasticities are all negative. (3) The degree of substitutability between housing characteristics is consistently higher between structure quality and neighborhood condition, and lower between interior space and the other two housing characteristics. (4) The particular restrictions of consumer theory, homotheticity and additivity, are rejected in the translog model. (5) The homogeneity and symmetry hypotheses in the consumption of housing services are also rejected in AIDS.

4.4.1 Linear Expenditure System

The parameter estimates of the linear expenditure system for housing expenditure are reported in Table 4-4. The marginal budget shares (b_i) are all significantly positive, which implies that the marginal utility of characteristic i is decreasing. The parameters

TABLE 4-4

Estimates of Linear Expenditure System
(t-values in parentheses)

Housing Characteristics	b_i	r_i	Income Elasticity
Interior Space	0.47976 (118.54)	0.113021 (17.12)	1.169 (0.00986)*
Structure Quality	0.31875 (74.23)	.0464322 .(12.47)	1.096 (0.01476)*
Neighborhood Condition	0.26149 (123.03)	0.001846 (1.37)	0.875 (0.00711)*

*Standard errors of elasticity estimates

of minimal subsistence level are also all positive but not significant for neighborhood condition. The greater estimates of b_i and r_i for interior space as well as the smaller estimates for neighborhood condition are reasonable . The estimated income elasticities are all

TABLE 4-5

Compensated Own and Cross Price Elasticities
in Linear Expenditure System
(at mean shares)

Housing Characteristics	Interior Space	Structure Quality	Neighborhood Condition
Interior Space	-0.58273	0.33226	0.34415
Strruc. Qual.	0.37578	-0.66007	0.32083
Neigbor. Con.	0.34431	0.25248	-0.73474

TABLE 4-6

Uncompensated Own and Cross Price Elasticities
(at mean shares)

Housing Characteristics	Interior Space	Structure Quality	Neighborhood Condition
Interior Space	-0.93751	-0.00772	-0.00521
Struc. Qual.	-0.07397	-0.9788	-0.00668
Neighbor. Con.	-0.01476	-0.00198	-0.9962

positive as implied by the model with positive b's. The expenditure elasticities(e_{iy}) in the LES are: $e_{iy} = b_i/s_i$.

Table 4-5 reports the estimates of the compensated own and cross price elasticities. Uncompensated own(e_{ii}) and cross(e_{ij}) price elasticity formulas in the LES are $(r_i(1-b_i)/z_i)-1$, and $-b_i r_j p_j/p_i z_i$, respectively. All compensated own price elasticities are negative, reflecting the general restriction on the sign of the own substitution effect, and are less than 1 in absolute value, implying that housing characteristics are compensated price inelastic. All compensated cross price elasticities are positive so that all housing characteristics are substitutes according to the Hicksian definition. Since the symmetry condition relates only to the cross-derivatives, the cross-price elasticities are not necessarily symmetric. The corresponding uncompensated elasticities are displayed in Table 4-6. They show that housing characteristics are close to unit elastic in own-price change and are inelastic in cross price change as implied in the additive nature of the LES.

4.4.2 Translog System

Parameter estimates of the direct and the indirect translog demand systems are presented in Tables 4-7 and 4-8, respectively. Homothetic, additive, and unrestricted versions of both specifications of the models were attempted. Most of the coefficients are significant at the five percent level of significance. The parameter estimates are themselves of limited interest because they do not show in any apparent way the characteristics of household's preference. The absolute values of the coefficients, in addition, depend upon the index of prices or quantities, which can vary with the indexing procedure adopted.

The goodness of fit in the share equations for each housing characteristic is indicated by the R^2 values in Table 4-9. In general, the indirect versions of the model perform better. The direct and the indirect translog models are not self-dual unless the utility is additive and homothetic. Otherwise, the two specifications represent different preference orderings. The unrestricted form has greater explanatory power in both specifications.[9]

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[9] It has been argued that it is the indirect utility function that is more useful as a functional form for the representation of preferences if the aim of the specification is the derivation of systems of demand equations. See Keith R. McLaren, "Estimation of Translog Demand Systems," Australian Economic Papers, Vol. 21, No. 39 (December 1982), 392-406.

TABLE 4-7

Parameter Estimates for Direct Translog Function
1=Interior Space, 2=Structure Quality,
3=Neighborhood Condition
(t-values in Parentheses)

Parameter	Symmetric Translog	Homothetic Translog	Additive Translog
a_1	0.49367 (78.54)	0.43076 (124.63)	0.41593 (116.45)
a_2	0.23323 (52.12)	0.26128 (87.32)	0.28359 (118.95)
a_3	0.27309 (96.65)	0.30796 (146.89)	0.30048 (117.42)
b_{11}	0.16034 (27.00)	-0.01539 (5.94)	0.00714 (1.08)
b_{12}	0.05693 (9.15)	0.00121 (0.60)	0
b_{13}	0.06115 (11.33)	0.01418 (11.97)	0
b_{22}	0.01392 (1.89)	0.01315 (6.57)	0.04057 (9.49)
b_{23}	-0.00702 (0.96)	-0.01436 (14.77)	0
b_{33}	0.00662 (1.01)	0.00018 (0.20)	-0.000399 (0.29)

TABLE 4-8

Parameter Estimates for Indirect Translog Function
1=Interior Space, 2=Structure Quality,
3=Neighborhood Condition
(t-values in Parentheses)

Parameter	Indirect Translog	Homothetic Translog	Additive Translog
a_1	0.34486 (60.34)	0.39621 (129.57)	0.41248 (118.71)
a_2	0.35157 (66.17)	0.30225 (97.37)	0.32839 (84.91)
a_3	0.30373 (62.16)	0.30154 (138.35)	0.25912 (131.04)
b_{11}	-0.07128 (3.56)	0.05889 (32.76)	0.08216 (21.72)
b_{12}	-0.08441 (4.93)	-0.03911 (26.56)	0
b_{13}	-0.08060 (5.04)	-0.01978 (20.98)	0
b_{22}	0.04406 (6.09)	0.02691 (15.54)	0.04778 (17.01)
b_{23}	0.00114 (0.13)	0.01220 (12.97)	0
b_{33}	-0.01269 (1.31)	0.00758 (9.30)	0.00330 (2.71)

TABLE 4-9

R-Square for Translog Share Equations

Share Equation	Unrestricted	Homothetic	Additive
(Direct Translog Model)			
Interior Space	0.2118	0.0728	0.0048
Structure Quality	0.1904	0.1270	0.0053
Neighborhood Condition	0.1321	0.0183	0.0293
(Indirect Translog Model)			
Interior Space	0.4200	0.3559	0.2512
Structure Quality	0.3704	0.2948	0.2564
Neighborhood Condition	0.1760	0.1723	0.0326

TABLE 4-10

Tests of Homotheticity and Additivity Restrictions
on the Translog Utility Function for Housing Characteristics

	Direct Translog Function			Indirect Translog Function		
Restriction	System Stat*		Assympt.	System Stat.*		Assympt.
	Rest.	Unrest.	X-Square	Rest.	Unrest.	X-Square
Homotheticity	3837	3480	357	3682	3479	203
Symmetry	3978	3480	498	4054	3479	575

*Gallant and Jorgenson(1979) showed that the change in the least square criterion function can be used as an asymptotically valid chi-Square test.

**The critical value of $X^2(3)$ is 11.345 at 0.01 level.

The assumption of homotheticity and additivity of the underlying preferences are tested and rejected as reported in Table 4-10. Homotheticity implying constant expenditure proportions requires that $\sum_{j=1}^{3} b_{ij}=0$. There are three such restrictions.

Additivity constraining the values of the elasticities of substitution requires $b_{ij} = 0$. There are three such restrictions. X^2- tests are conducted to establish whether the overall decline in fit resulting from the imposition of the above restrictions is statistically significant.[10] The Test statistics appearing in the Table 4-10 imply that we can reject both hypotheses.

Expenditure elasticities for housing characteristics are computed from the unrestricted indirect model. They are 1.18260, 0.79605, and 0.94145 for inferior space, structure quality, and neighborhood condition, respectively. The numbers indicate that interior space is more expenditure elastic than the other two characteristics.

In Table 4-11, estimated price elasticities are demonstrated. All compensated own prices appear negative and all compensated elasticities are positive, reflecting that the three housing characteristics are substitutes for one another. The compensated response of household's consumption of housing characteristics with respect to their own prices increase in the order of interior space,

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[10] For the test statistics as an analog of the likelihood ratio test in the systems of nonlinear equations, see A. R. Gallant and D. W. Jorgenson, "Statistical Inference for a System of Simultaneous, Nonlinear, Implicit Equations in the Context of Instrumental Variable Estimation," _Journal of Econometrics_, vol. 11 (1979), 275-302.

structure quality, and neighborhood condition. The uncompensated own price elasticities are all negative. The cross price elasticities are also negative except the one between structure quality and neighborhood condition.

The estimated Allen elasticity of substitution, which is a measure of the strength of the substitution between characteristics, is 0.6804 between interior space and structure quality, 0.87655 between interior space and neighborhood condition, and 1.0759 between structure quality and neighborhood condition. These estimates say that interior space is less substitutable with other characteristics, while structure quality and neighborhood condition are more easily substitutable with each other.

TABLE 4-11

Estimated Price Elasticities
from Unrestricted Indirect Translog Model

Housing Characteristics	Interior Space	Structure Quality	Neighborhood Condition
(Compensated own and cross-price elasticities)			
Interior Space	-0.45982	0.19787	0.26194
Structure Quality	0.27933	-0.60123	0.32154
Neighborhood Condition	0.35701	0.31152	-0.67573
(Uncompensated own and cross-price elasticities)			
Interior Space	-0.94512	-0.14604	-0.09145
Structure Quality	-0.04733	-0.83273	0.08366
Neighborhood Condition	-0.02932	0.03774	-0.95707

*Elasticity formulas for the indirect translog model are outlined in Christensen and Manser(1975), pp. 426-427.

4.4.3 Almost Ideal Demand System for Housing Characteristics

Table 4-12 presents the parameter estimates of unrestricted household AIDS, estimated on 1740 cross-sectional housing units. The estimates of b_i classify the interior space characteristic as a luxury and the neighborhood condition is a necessity.[11] A number of r coefficients are significantly different from zero; seven estimates out of nine have t-values greater than 2. The results indicate a moderate degree of price sensitivity of expenditure shares of housing characteristics.

Test statistics of homogeneity of housing consumption, joint restriction of homogeneity and symmetry, and symmetry with respect to homogeneity are shown in Table 4-13. Homogeneity is rejected, which is not a new result of demand analysis. A plausible explanation for the failure of homogeneity in the consumption of housing services may be the relative inflexibility of adjusting housing expenditure. The joint hypotheisis of homogeneity and symmetry is also rejected.

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[11] We acknowledge that the classification is valid only when the income elasticity of total housing expenditure is unitary, for our estimates of b_i are not the indicator of direct income responsiveness but the indicator of the responsiveness in consumption of housing characteristics to the change of housing outlay. The classification of commodities as luxury or necessity need to be more carefully applied in the subsystem of household expenditure.

$$\frac{\partial \ln z}{\partial \ln Y} = \frac{\partial \ln z}{\partial \ln R} \frac{\partial \ln R}{\partial \ln Y},$$ where R is rent and Y is household income.

TABLE 4-12

Parameter Estimates of the Unconstrained
Almost Ideal Demand System for Housing Characteristics
(t-values in parentheses)

Commodity i Parameter	Interior Space	Structure Quality	Neighborhood Condition
a_i	0.34069 (5.62)	0.02385 (0.50)	0.63544 (19.88)
b_i	0.10674 (10.74)	0.000092 (0.0119)	-0.10684 (20.38)
r_{i1}	0.05598 (11.89)	-0.01761 (4.81)	-0.03837 (15.45)
r_{i2}	-0.05879 (10.19)	0.05604 (12.51)	0.00194 (0.63)
r_{i3}	-0.00218 (0.70)	0.01843 (7.68)	-0.01625 (9.96)
Expenditure Elasticity	1.26011 (52.15)	1.00031 (37.28)	0.64247 (36.63)

TABLE 4-13

Tests of Homogeneity and Symmetry

Restriction	F-value (degree of freedom)	Critical Value
Homogeneity	66.6011 (2, 3470)	3.00
Homogeneity and Symmetry	62.6607 (3,3470)	2.60
Symmetry with respect to Homogeneity	54.9476 (1, 3470)	3.84

We can also reject the symmetry restriction with respect to homogeneity.

The price elasticities in Table 4-14 are generally plausible All the compensated own price elasticities are negative, and neighborhood condition is more own price-elastic than the other characteristics are. Positive compensated cross price elasticities confirm that the three characteristics are Hicks-Allen substitutes. Imposing homogeneity or both homogeneity and symmetry yields changes in elasticity estimates as shown in Table 4-15. Own price elasticities for interior space and neighborhood condition decrease across the model, while own price elasticity of structure quality and expenditure elasticity for neighborhood condition increase.

Allen elasticities of substitution are computed from homogeneous and symmetric AIDS as 0.68028 between interior space and structure quality, 0.87236 between interior space and neighborhood condition,

TABLE 4-14

Own and Cross Price Elasticities from Almost Ideal Demand System

Housing Characteristics	Interior Space	Structure Quality	Neighborhood Condition
(Compensated Price Elasticities)			
Interior Space	-0.45322	0.14754	0.29351
Structure Quality	0.35006	-0.51639	0.36220
Neighborhood Condition	0.28195	0.29729	-0.96921
(Uncompensated Price Elasticities)			
Interior Space	-0.97032	-0.21891	-0.08304
Structure Quality	-0.06042	-0.8073	0.06328
Neighborhood Condition	0.01831	0.11046	-1.1612

*The uncompensated(e_{ij}) and compensated(e^*_{ij}) price elasticities are:

$e_{ii} = r_{ii}/s_i - b_i - 1$

$e^*_{ii} = e_{ii} + s_i e_{iy} = r_{ii}/s_i + s_i - 1$

$e_{ij} = r_{ij}/s_i - b_i s_j/s_i$

$e^*_{ij} = e_{ij} + s_j e_{iy} = r_{ij}/s_i + s_j,$

where e_{iy} is the housing expenditure elasticity of ith housing characteristics.

TABLE 4-15

Expenditure and Own Price Elasticities
in Various Almost Ideal Demand Systems

Housing Characteristics	Unrestricted AIDS	Homogenous AIDS	Homogenous & Symmetric AIDS
(Own Price Elasticities)			
Interior Space	-0.97032 (0.0242)	-0.96875 (0.0169)	-0.94336 (0.0204)
Sructure Quality	-0.8073 (0.0265)	-0.86584 (0.0195)	-0.9244 (0.0223)
Neighborhood Condition	-1.1672 (0.0175)	-0.93803 (0.0139)	-0.9332 (0.0147)
(Expenditure Elasticities)			
Interior Space	1.26011 (0.0181)	1.26405 (0.0094)	1.18152 (0.0147)
Structure Quality	1.00031 (0.0190)	0.90925 (0.0077)	0.9895 (0.0054)
Neighborhood Condition	0.64247 (0.0222)	0.7233 (0.0071)	0.7609 (0.0063)

and 1.1961 between structure quality and neighborhood condition.[12] The substitutability is greater between structure quality and neighborhood condition than between others. These results parallel those from the translog model.

[12]When the symmetry hypothesis of consumer behavior is rejected, the elasticity of substituion has no more reason to be symmetric. The Allen elasticities of substitution are also computed from unrestricted and homogenous AIDS and they show different degrees of substitutability between the same pair of housing characteristics reported in Appendix F.

4.5 Effect of Demograhic Variables on the Expenditure Shares for Housing Characteristics

The demographic variables selected are household size, highest grade that head completed, age of head, race of head, and sex of head.[13] Incorporation of the five demographic variables into the demand systems results in a significant improvement of explanatory power. This can be observed by comparing system statistics in LES, translog, and AIDS with demographic variables and without them. The test statistics given in Table 4-16 correspond to the X^2 or F-test on all parameters of demographic variables in the system. As a whole, the hypothesis that all the coefficients of demographic variables are zero can be rejected at 0.01 significance level.[14]

In Table 4-17, Table 4-18, and Table 4-19, specific parameter estimates of the demographic variables are displayed. A large number of d_{ij} coefficient are significantly different from zero; only two or three out of fifteen have t-values absolutely smaller than 2. The estimates of household size confirm a positive effect of family size on the household's consumption of interior space and a negative

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[13]Race and sex are dummy variables defined as 1 for white or male headed household, respectively, and 0 otherwise. Other variables are regarded as continuous.

[14]Ranjan Ray(1980, 1982) included family size explicitly in the AIDS for household expenditure in India, and found significant family size effect on the budget share. See R. Ray, "The Testing and Estimation of Complete Demand System on Household Budget Surveys--An Application of AIDS," European Economic Review, Vol. 17(1982), 349-369.

TABLE 4-16

Tests of Demographic Effect

Model Specification	Test Statistics(d.f.)
LES	748.81(10)*
Indirect Translog	704.03(10)*
Unrestricted AIDS	62.74(10, 3460)**
Homogenous AIDS	58.70(10, 3460)**
Homogenous and Summtric AIDS	62.62(10, 3463)**

*At 1 % significance level, $X^2(10) = 23.21$
**At 1 % significance level, $F(10,\ ) = 2.32$

influence on structure quality and neighborhood quality consistently. The effect of education is similar to that of household size. The parameter estimates of education indicate that, in the Honolulu SMSA rental housing, the more educated is the head of household, the more interior space, and the less structure quality and neighborhood condition are preferred. This result is different from the findings of Kain and Quigley(1975). The age of household does not show any significant effect on the consumption of interior space. However it is related negatively with the expenditure on structure quality and positively with the budget share on neighborhood condition, which may reflect the fact that old people are not willing to move frequently and are thus more concerned with neighborhood quality. Female-headed households spend less for interior space and more for neighborhood

TABLE 4-17

Parameter Estimates of Demographic Variables in LES
(t-values in parentheses)

Parameter	Interior Space	Structure Quality	Neighborhood Condition
Household Size	0.034934 (22.36)	-0.019632 (16.03)	-0.015304 (16.84)
Education	0.003269 (3.75)	-0.002796 (4.20)	-0.000472 (0.95)
Age of Head	-0.0001158 (0.62)	-0.0005761 (4.03)	0.0006919 (6.51)
Race of Head	0.056114 (10.59)	-0.022545 (5.53)	-0.03356 (11.01)
Sex of Head	0.019175 (3.04)	-0.006063 (1.25)	-0.01311 (3.64)
r_i	0.62936 (14.02)	0.034751 (8.10)	-0.002575 (1.95)
b_i	0.238359 (14.94)	0.437636 (35.86)	0.324005 (36.03)

TABLE 4-18

Parameter Estimates of Demographic Variables in Translog Share Equations (t-values in parentheses)

Parameter	Interior Space	Structure Quality	Neighborhood Condition
Household Size	0.026681 (18.79)	-0.015005 (12.96)	-0.116761 (13.27)
Education	0.006095 (7.92)	-0.005181 (8.31)	-0.0009147 (1.97)
Age of Head	0.000061 (0.37)	-0.000858 (6.62)	0.0007979 (8.04)
Race of Head	0.037618 (7.96)	-0.009833 (2.57)	-0.026351 (9.10)
Sex of Head	0.010292 (1.85)	-0.001761 (0.39)	-0.008532 (2.50)
a_i	0.136011 (8.64)	0.501500 (37.39)	0.362489 (37.58)
b_{1i}	-0.035896 (3.57)	-0.106351 (6.70)	-0.066333 (6.56)
b_{2i}	.	-0.003746 (0.22)	-0.023832 (1.81)
b_{3i}	.	.	-0.026313 (2.50)

TABLE 4-19

Parameter Estimates of Demographic Variables in AIDS
(t-values in parentheses)

Parameter	Interior Space	Structure Quality	Neighborhood Condition
Household Size	0.02713 (18.19)	-0.018425 (15.34)	-0.008711 (10.70)
Education	0.00589 (7.34)	-0.00426 (6.6)	-0.001627 (3.71)
Age of Head	0.000203 (1.21)	-0.000863 (6.36)	0.0006593 (7.17)
Race of Head	0.04058 (8.32)	-0.0155 (3.95)	-0.025083 (9.43)
Sex of Head	0.01126 (1.96)	-0.00388 (0.84)	-0.007379 (2.37)
a_i	0.310996 (5.68)	0.056432 (1.28)	0.642572 (21.52)
b_i	0.060991 (6.66)	0.030847 (4.18)	-0.091838 (18.39)
r_{i1}	0.032927 (7.62)	-0.002239 (0.64)	-0.030687 (13.02)
r_{i2}	-0.055223 (10.69)	0.053479 (12.86)	0.001744 (0.62)
r_{i3}	-0.009001 (3.22)	0.024749 (11.01)	-0.015747 (10.33)
Expenditure Elasticity	1.170362	1.106073	0.692675

characteristics, while they do not show any difference in the consumption of structure quality. The effect of race is also quite consistent; white headed households spend more for interior space and less for other housing characteristics. All the above effects of demographic variables on housing consumption are consistently observed in the three estimated systems of demand equations for housing characteristics.

Using the parameter estimates, we can interpret how demographically different households consume different conbinations of housing characteristics. Suppose we have two hypothetical households with different family characteristics as in Table 4-20. Let us also assume that they are paying the same amount of rent, three hundred dollars per month. Then, the parameter estimates of the deomgraphic variables in unrestricted AIDS, Table 4-19, imply that household B

TABLE 4-20

Hypothetical Households with Different Family Combination

Household	Size	Education	Age	Race	Sex
A	2	12	30	Nonwhite	Female
B	4	18	40	White	Male

is spending or willing to pay forty three dollars more for interior space, twenty-seven dollars less for structure quality, and sixteen dollars less for neighborhood condition than household A .

The test results on homogeneity and symmetry remain the same in the models including demographic variables. The homogeneity hypothesis is rejected as is symmetry with respect to homogeneity.[15]

[15]F-values(d.f.) for testing homogeneity, homogeneity and symmetry, and symmetry with respect to homogeneity are 79.00(2, 3460), 60.55(3, 3460), and 22.65(1, 3462), respectively.

CHAPTER V

CONCLUSION

This study performs a three-step demand analysis for housing characteristics. The first step constructs the vector of attribute prices via the hedonic price function approach. The estimated attribute prices are employed to build price and quantity indexes for housing characteristics, defined as some aggregation of housing attributes. The indexes are used in the second step to analyze the demand equation for housing characteristics as a function of housing expenditure and prices. The 'seemingly unrelated' regression procedure is used to obtain consistent estimates of the demand parameters. The third step adds several demographic variables into the demand systems while requiring the adding-up restriction. Their effects on the expenditure shares for interior space, structure quality, and neighborhood condition are estimated and evaluated.

5.1 Summary of Findings

A rental hedonic price equation is estimated for the Honolulu SMSA by employing data from the Annual Housing Survey in 1976. Seventeen housing attributes are used to explain the rental housing expenditure. Estimates of the coefficients are generally consistent with a·priori considerations. The functional form of the equation is basically linear, and several square-root interactive terms are indroduced to reflect the interdependence of housing consumption.

Most of the coefficient estimates are significant at commonly used levels of significance. Seventeen housing attributes are combined to form three housing characteristics by the Divisia index procedure.

Three systems of three demand equations for housing characteristics are specified, estimated, and compared to test the theory of household's behavior in housing consumption and the effects of demographic variables on the expenditure shares for each housing characteristic. Homogeneity and symmetry in consumption of housing characteristics are rejected in the 'almost ideal demand system'. Homotheticity and additivity of the household's preference underlying housing consumption are also rejected in the translog share equations. The negativity condition of the Slutsky matrix is satisfied in the linear expenditure system.

The various elasticities of housing consumption derived from the three demand systems are reasonable. The expenditure share for interior space is more sensitive to the total amount of rent, because the rent elasticity of interior space is greater than one while elasticities of other housing characteristics are not. Given positive compensated cross-price elasticities, the three housing characteristics are regarded as substitutes for each other in the Hounolulu rental housing market. Substitutability is more intensive between structural quality and neighborhood condition, and less intensive between interior space and the other two characteristics

Demographic variables such as household size, age composition, and qualitative aspects of family composition, appear to play a significant role in determining the housing bundle. Household size, as expected, is positively related with interior space and negatively with structure quality and neighborhood condition. The level of education shows the same effect as household size. The age of head is unrelated with interior space, negatively related with structure quality, and positively related with neighborhood condition. Nonwhite headed households spend less for interior space, and more for structural quality and neighborhood condition. Male-headed household spend more for interior space and less for other characteristics. All of the above effects of demographic variables are consistently observed in the linear expenditure system, the translog demand system, and the almost ideal demand system.

5.2 Policy Implications of the Results

The estimated rental hedonic price equation, which is linearly homogeneous in housing attributes, provides useful information for the demand study of housing characteristics. The work should be of interest to policymakers because it can provide some advice on rental price differentials across different housing combinations.

The essence of the demand systems approach in housing consumption consists of providing empirical demand analysis within a conceptual framework which deals with the interdependence of demand for various housing characteristics. The approach can supply the empirical basis for forecasting and planning the composition of the housing demand bundle, for the construction of housing price indexes, or for the design of a tax structure. Expenditure elasticities of demand for each housing characteristic can be useful for planning by government and by business. The results of this study indicate that the supply of interior space is more essential in the Honolulu rental housing market. Using own-price elasticities of demand, we can consider the impact on government revenue of a property tax on residential housing units. Similar estimates of uncompensated ownprice elasticities for housing characteristics imply that a different tax structure on different combinations of housing characteristics would not be meaningful in the sample area. Responsiveness of a subsidy program of housing consumption can be ranked in ascending order according to expenditure elasticity estimates. That is, the greater is the value of the expenditure elasticity, the more responsive the subsidy program is. Estimates of expenditure elasticities indicate a the greater responsiveness of a subsidy for interior space than for other housing characteristics. The system approach in the study can also serve as a submodel to be used in other areas of economic research where allocation aspects of housing epxenditure are involved.

Demographic characteristics of the household are brought to bear upon its housing expenditure pattern either via their impact on consumer taste or via their effect on recognized prices and expenditure faced by the household. Better understanding of microeconomic demographic relationship in the consumption of housing will be of interest to analysts or policy makers. Combined with appropriate forecasts of household demographic composition in the future, the results of this study can assist in planning the supply of housing stock and public facilities related with residential services.

5.3 Suggestions for Further Research

Since the estimates of the rental hedonic relationship are to some extent misspecified, and the whole system of demand equations is sensitive to the specified rental hedonic price equation, we should pay attention to the possibility that specification bias affects the results. In this study, it has been observed that the estimated coefficients of several qualitative attributes of housing are easily affected by different specifications of the equation. They especially vary over the inclusion of different interactive terms. Since the number of possible combinations of many housing attributes is great, further search for explicit interactive structures of housing attributes is indicated.

The estimation of demand systems for housing characteristics can be extended to other fields of consumption expenditure such as food and clothing. Since the additivity restriction is often rejected in many studies of broadly defined demand systems, partial maximization in the subsystem of housing expenditure may not be appropriate. Of course, the extensive system of subsystems of household expenditure would be expensive in terms of data collection and computing cost, but increasing accessibility of micro-data and computing facilities suggests a promising future for the system-wide approach in the empirical study of consumer behavior.

Demographic variables could be incorporated in any system approach of demand analysis as applied in this study. Since we compromise some theoretical plausibility in including five demographic variables into the demand systems for housing consumption, further research should exploit a more proper way to introduce many demographic variables into the systems of demand equation .

One promising extension of incorporating demographic characteristics applied in this study is the economic calculus underlying childrearing. By introducing well specified children-characteristics such as specific age structure and number of children in the household expenditure system, the difference in consumption pattern can be utilized to estimate the pecuniary cost of having children.

APPENDIX A

Parameter Estimates of Rental Hedonic
Price Equation with Intercept term

Dependent Variable: Monthly Rental Expenditure

VARIABLE	PARAMETER ESTIMATE	T FOR HO: PATAMETER=0
INTERCEP	-35.98521	-1.138
BEDRM	19.08387	4.132
ROOM	14.09127	4.499
BATH	36.50843	6.441
KITCHEN	28.14566	1.943
AGE	-1.71926	-3.651
ELEV	-22.16722	-1.133
PAINT	10.07998	0.953
PUBSEW	138.387	3.224
HSRT	29.86503	3.355
NBRT	11.18536	2.207
ARNOISE	42.08620	2.170
MOVIN	-2.21283	-3.150
STLIGHT	12.44434	1.985
RNDNHS	10.98982	1.414
STIMPASS	34.15551	2.218
TRASH	5.64184	0.867
PBTRANS	16.80980	2.942
AGEELEV	12.91883	2.202
BATHPBSW	-92.58055	-4.343
AGEPBSW	2.58415	0.586
ARNSSTMP	-24.89606	-1.247
ELEVMOVN	25.12350	2.618
HSRTMOVN	-16.50268	-3.802

R-Square: 0.4048, Adjusted R-Square: 0.3968
F-Value: 50.74

*AGEELEV = Square Root of (AGE x ELEV)
BATHPBSW = Square Root of (BATH x PUBSEW)
AGEPBSW = Square Root of (AGE x PUBSEW)
ARNSNTMP = Square Root of (ARNOISE x STIMPASS)
ELEVMOVN = Square Root of (ELEV x MOVIN)
HSRTMOVN = Square Root of (HSRT x MOVIN)

APPENDIX B

Parameter Estimates of Homogeneous
Almost Ideal Demand System for Housing Characteristics
(t-values in parentheses)

Commodity i Parameter	Interior Space	Structure Quality	Neighborhood Condition
a_i	0.31447 (40.05)	0.32248 (52.89)	0.36304 (87.61)
b_i	0.10907 (13.01)	-0.02639 (4.05)	-0.08268 (18.69)
r_{i1}	0.05784 (29.13)	-0.03882 (25.18)	-0.01902 (18.15)
r_{i2}	-0.05663 (19.31)	0.03134 (13.76)	0.02528 (16.33)
r_{i3}	-0.00121 (0.56)	0.00748 (4.44)	-0.00619 (5.14)

APPENDIX C

Parameter Estimates of Homogeneous and Symmetric Almost Ideal Demand System for Housing Characteristics (t-values in parentheses)

Commodity i Parameter	Interior Space	Structure Quality	Neighborhood Condition
a_i	0.36328 (85.22)	0.29192 (65.07)	0.334479 (103.44)
b_i	0.07449 (10.70)	-0.00304 (0.53)	-0.07145 (17.18)
r_{i1}	0.05381 (28.18)	-0.03815 (24.78)	-0.01565 (16.55)
r_{i2}	-0.03815 (24.78)	0.02110 (11.66)	0.01705 (15.80)
r_{i3}	-0.01565 (16.55)	0.01705 (15.80)	-0.00139 (1.48)

APPENDIX D

Price Elasticity Estimated in Homogenous AIDS

Housing Characteristics	Interior Space	Structure Quality	Neighborhood Condition
(Compensated Price Elasticities)			
Interior Space	-0.45003	0.15280	0.29536
Structure Quality	0.27686	-0.60142	0.32454
Neighborhood	0.34669	0.37539	-0.72188
(Uncompensated Price Elasticities)			
Interior Space	-0.96875	-0.21529	-0.08237
Structure Quality	-0.09625	-0.86584	0.05283
Neighborhood Condition	0.17719	0.16505	-0.93803

APPENDIX E

Price Elasticity Estimates
in Homogenous and Symmetric AIDS

Housing Characteristics	Interior Space	Structure Quality	Neighborhood Condition
(Compensated Price Elasticities)			
Interior Space	-0.45851	0.19784	0.27916
Structure Quality	0.27916	-0.63664	0.35745
Neighborhood	0.35798	0.34785	-0.70582
(Uncompensated Price Elasticities)			
Interior Space	-0.94336	-0.14575	-0.09238
Structure Quality	-0126895	-0.9244	0.06175
Neighborhood Condition	0.04574	0.12658	-0.9332

APPENDIX F

Allen Elasticities of Substitution
in Non-symmetric AIDS

Housing Characteristics	Interior Space	Structure Quality	Neighborhood Condition
(Unrestricted AIDS)			
Interior Space	.	0.50734	0.98219
Structure Quality	0.85305	.	0.99484
Neighborhood	0.68707	1.24548	.
(Homogeneous AIDS)			
Interior Space	.	0.52542	0.9883
Structure Quality	0.67467	.	1.08035
Neighborhood Condition	0.84484	1.2908	.

APPENDIX G

Parameter Estimates of Homogenous AIDS
with Demographic Variables
(t-values in parentheses)

Housing Characteristics	Interior Space	Structure Quality	Neighborhood Condition
Household Size	0.02667 (17.98)	-0.0173 (14.48)	-0.009372 (11.57)
Education	0.00570 (7.13)	-0.00381 (5.91)	-0.001897 (4.35)
Age of Head	0.000174 (1.03)	-0.00079 (5.84)	0.000617 (6.73)
Race of Head	0.01131 (1.97)	-0.0149 (3.82)	-0.025387 (9.55)
Sex of Head	0.01131 (1.97)	-0.00400 (0.87)	-0.007308 (3.70)
a_i	0.15125 (9.30)	0.44427 (33.95)	0.403147 (45.45)
b_i	0.07602 (9.85)	-0.00566 (0.91)	-0.070364 (16.71)
r_{i1}	0.04478 (23.51)	-0.03103 (20.24)	-0.01375 (13.22)
r_{i2}	-0.04187 (15.16)	0.02107 (9.47)	0.02080 (13.80)
r_{i3}	-0.00291 (1.48)	0.00995 (11.01)	-0.00704 (6.61)

APPENDIX H

Parameter Estimates of Homogenous
and Symmetric AIDS with Demographic Variables
(t-values in parentheses)

Parameter	Interior Space	Structure Quality	Neighborhood Condition
Household Size	0.02798 (19.18)	-0.0177 (14.93)	-0.010208 (12.90)
Education	0.00556 (6.96)	-0.00377 (5.85)	-0.001802 (4.33)
Age of Head	0.000223 (1.32)	-0.000829 (6.14)	0.000607 (6.62)
Race of Head	0.03985 (8.18)	-0.0140 (3.57)	-0.025643 (9.65)
Sex of Head	0.01193 (1.97)	-0.00419 (0.90)	-0.007733 (2.47)
a_i	0.17643 (11.45)	0.42823 (33.95)	0.395336 (45.60)
b_i	0.07602 (9.85)	0.00834 (1.51)	-0.063141 (16.02)
r_{i1}	0.04201 (23.12)	-0.03069 (20.04)	-0.005071 (5.56)
r_{i2}	-0.03069 (20.04)	0.01510 (8.14)	0.015589 (14.66)
r_{i3}	-0.01131 (12.38)	0.01559 (14.62)	-0.004272 (4.73)

BIBLIOGRAPHY

Barten, A. P., "Family Composition, Prices and Expenditure Patterns," Econometric Analysis for National Economic Planning, Proceedings of the 16th Symposium of the Colston Research Society, ed. by Hart, P. E., G. Mills, & J. K. Whitaker, London: Butterworth, 1964.

______,"Estimation Demand Equations," Econometrica, Vol. 36, No. 2 (April, 1968), 213-251.

Berndt, E. R., M. N. Darrough, and W. E. Diewert, "Flexible Functional Forms and Expenditure Distributions: An Application to Canadian Consumer Demand Function," International Economic Review, Vol.18, No. 3(October, 1977), 651-675.

Blomquist, Glenn, "Hedonic Prices, Demand for Urban Housing Amenities, and Benefit Estimates," Journal of Urban Economics, Vol. 9(1981), 212-221.

Brown, James N. and Harvey S. Rosen, "On the Estimation of Structural Hedonic Price Models," Econometrica, Vol. 50, No. 3(May 1980), 765-768.

Butler, Richard V., "The Specification of Hedonic INdexes for Urban Housing," Land Economics, Vol. 58, No. 1(February, 1982), 96-108.

Carliner, Geoffrey, "Income Elasticity of Housing Demand," Review of Economics and Statistics, Vol. 55, No. 4(November, 1973), 528-532.

Christensen, Laurits R., Dale W. Jorgenson, and Lawrence J. Lau, "Transcendental Logarithmic Utility Functions," Amreican Economic Review, Vol. 65, No. 3(June, 1975), 367-383.

______, and Marilyn E. Manser, "Cost-of-Living Indexes and Price Indexes for U.S. Meat and Produce," In N. Terlecky, ed., Household Production and Consumption, NBER, 1975.

David, J. M., W. R. Legg, "An Application of Multivariate Probit Analysis to the Demand for Housing: A Contribution to the Improvement of Predictive Performance of Demand Theory, Preliminary Results," Journal of American Statistical Association, Proceedings, (August, 1975), 295-307.

David, Martin Heidenhain, Family Composition and Consumption, Notrh-Holland Publishing Company, Amstedam, 1962.

De Leeuw, Frank, "The Demand for Housing: A Review of Cross-Section Evidence," The Review of Economics and Statistics, Vol. 53, No. 1 (February 1981), 1-10.

Deaton, Angus and John Muellbauer, "An Almost Ideal Demand System," American Economic Review, Vol. 70, No. 3(June 1980), 312-326

_____, Economics and Consumer Behavior, Cambridge University Press, Cambridge, 1980.

Derrick, Frederick W., and John D. Walken, "Demographic Variables in Complete Demand Systems: Pooled Vs. Unpooled Specifications," Atlantic Economic Journal, Vol. 10, No. 4(December 1982), 53-59.

Diamong, D. D., Jr., and G. S. Tolley, The Economics of Urban Amenities, Academic Press, New York, 1982, 69-102.

Diewert, W.E., "Exact and Superative Index," Journal of Econometrics, Vol. 4(1976), 115-145.

Freeman, A. M. III, "Hedonic Prices, Property Values and Measuring Environmental Benefits: A Survey of the Issues," Scandinavian Journal of Economics, Vol. 81, No. 2(1979 d), 154-173.

Friedman, J. and D. H. Weinberg, The Economics of Housing Vouchers, Academic Press, New York, 1982, 19-62.

Gallant, A. R. and D. W. Jorgenson, "Statistical Inference for a System of Simultaneous, Nonlinear, Implicit Equations in the Context of Instrumental Variable Estimation," Journal of Econometrics, Vol. 11(1979), 275-302.

Goering, J. M., Housing in America: The Characteristics and Uses of the Annual Housing Survey, November 1979, Department of Housing and Urban Development.

Gorman, W. M., "Tricks with Utility Functions," Essays in Economic Analysis , ed. by M. S. Artis and A. R. Nobay, Cambridge University Press, Cambridge, 1976.

Grilliche, Z.(ed), Price Indexes and Quality Change, 1971

Hanushek, Eric A., and John M. Quigley, "The Dynamics of the Housing Market: A Stock Adjustment Model of Housing Consumption," Journal of Urban Economics, Vol. 6(1979), 90-111.

Halvorsen, Rogert and Henry O. Pollakowski, "Choice of Functional Form for Hedonic Price Equations," Journal of Urban Economics, Vol. 10 (1981), 37-49.

Harrison, David, Jr., and Daniel L. Rubinfeld, "The Distribution of Benefits from Improvements in Urban Air Quality, " Journal of Environmental Economics and Management, vol. 5(1978), 313-332.

Hartley, Keith and Clem Tisdell, Micro-Economic Policy, John Wiley & Sons, New York, 1981, 101-130.

Houthakker, H. S.,"An International Comparison of Household Expenditure Patterns, Commemorating the Centenary of Engel's Law," Econometrica, Vol. 25, No. 4(October, 1957), 532-551.

Howe, Howard, "Cross-Section Application of Linear Expenditure Systems: Responses to Sociodemographic Effects," American Journal of Agricultural Economics, Vol. 59, No.1(February 1977), 141-148.

Kain, John R., and John M. Quigley, Housing Markets and Racial Discrimination: A Microeconomic Analysis, NBER, New York, 1975.

King, A. Thomas, "The Demand for Housing: Integrating the Roles of Journey-to-Work, Neighborhood Quality, and Prices," in N. Terlecky, ed. Household Production and Consumption, NBER, New York, 1975.

______,"The Demand for Housing: A Lancasterian Approach," Southern Economic Journal, Vol. 43,(1976), 1077-1087.

______, and Peter Mieszkowski, "Pacial Discrimination, Segregation, and the Price of Housing," Journal of Political Economy. (May/June, 1973), 590-606.

Klevmarken, N. Anders, "A Comparative Study of Complete Systems of Demand Functions," Journal of Econometrics, Vol. 10(1979), 165-191.

Lancaster, Kelvin J., "A New Approach to Consumer Theory," The Journal of Political Economy, Vol. 74, No. 2(April 1966), 132-157.

______,"Changes and Innovation in the Technology of Consumption," American Economic Review, Vol. 56, (May 1966), 14-23.

______,"The Theory of Household Behavior: Some Foundations," Annals of Economic and Social Measurement, Vol. 4, No. 1(Winter 1975), 5-22.

Layard, P. R. G. and A. A. Walters, Microeconomic Theory, McGraw-Hill Book Company, New York, 1978

Lee, Tong Hun, "Housing and Permanent Income: Test Based on a Three-Year Reinterview Survey," Review of Economics and Statistics, Vol. 50, (November 1968), 480-490.

Linneman, Peter, "Some Empirical Results on the Nature of the Hedonic Price Function for the Urban Housing Market," Journal of Urban Economics, Vol. 8(1980), 47-68.

______,"The Demand for Residence Site Characteristics," Journal of Urban Economics, Vol 9(1981), 129-148.

Lluch, Constantino, "Consumer Demand Functions," European Economic Review, (Spring, 1971), 277-302.

______, and Alan Powell, "International Comparisons of Expenditure Patterns," European Economic Review, (1975), 275-303.

Maisel, S. J., J. B. Burnham, and John S. Austin, "The Demand for Housing: A Comment," Review of Economics and Statistics, Vol. 53, No. 3(November, 1971), 410-413.

Mayo, S.K., "Theory and Estimation in the Economics of Housing Demand," Journal of Urban Economics, Vol. 10(1981), 95-116.

McDonald, John R., Economic Analysis of Urban Housing, New York, Academic Pressk, 1979.

McLaren, Keith R., "Estimation of Translog Demand System," Australian Economic Papers, Vol. 21, No. 39(December 1982), 392-406.

McMillan, Melville L., "Estimates of Households' Preferences for Environmental Quality and Other Housing Characteristics from a System of Demand Equations," Scandinavian Journal of Economics, Vol. 81, NO. 2(1979), 142-153.

______, Bradford G. Reid, and David W. Gillen, "An Extension of the Hedonic Approach for Estimating the Value of Quiet," Land Economics Vol. 56, No.3(August,1980), 315-328.

Morgan, James N., "Housing and Ability to Pay," Econometrica, Vol. 33, No. 2(April, 1965), 289-306.

Muelbauer, John, "Household Composition, Engel Curves and Welfare Comparisons Between Households," European Economic Review, Vol. 5 (1974), 103-122.

______,"Testing Barten Model of Household Composition Effects and the Cost of Choldren," Economic Journal, Vol. 87(September, 1977), 460-487.

Parks, Richark W., and Anton p. Barten, "A Cross-Country Comparison of the Effects of Prices, Income and Population Composition on Consumption Patterns," Economic Journal, Vol. 83(Septerber, 1973). 834-852.

Phlips, Louis, Applied Consumption Analysis, North-Holland Publishing Company, 1974, and 1983.

Pollak, Robert A. and Terence J. Wales, "Estimation of the Linear Expenditure System," Econometrica, Vol. 37, No. 4(October, 1969), 611-628.

_____,"Estimation of Complete Demand Systems from Household Budget Data: The Linear and Quadratic Expenditure Systems," American Economic Review, Vol. 68, No. 3(June, 1978), 348-359.

_____,"Welfare Comparison and Equivalence Scales," American Economic Review, Vol. 69, NO. 2(1979), 216-221.

Pollak, Robert A. and Terence J. Wales,"Comparison of the Quadratic Expenditure System and Translog Demand Systems with Alternative Specifications of Demographic Effects," Econometrica, Vol. 48, No. 3(April, 1980), 595-612.

_____,"Demographic Variables in Demand Analysis," Econometrica, Vol. 49, NO. 6(November, 1981), 1533-1551.

Ray, Ranjan, "Analysis of A Time Series of Household Expenditure Surveys for India," The Review of Economics and Statistics, Vol. 62, No. 4(November 1980), 595-602.

_____, "The Testing and Estimation of Complete Demand Systems on Household Budget Surveys," European Economic Review, Vol. 17, (1982), 349-369.

Rosen, Sherwin, "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition," Journal of Political Economy, Vol. 82(January/February, 1974), 34-55.

Segal, David, The Economics of Neighborhood, Academic Press, New York, 1979, 193-216.

Simmons, Peter and Daniel Weiserbs, "Translog Flexible Functional Forms and Associated Demand Systems," American Economic Review, Vol. 69, No. 5(December 1979), 892-901.

Smith, V. K., Advances in Applied Microeconomics, Vol. 1, JAI Press INC. Greenwich, 1981.

Stone, Richard, "Linear Expenditure Systems and Demand Analysis: An Application to the Patterns of British Demand," The Economic Journal, Vol. 64, No. 255(September 1954), 511-527.

Straszheim, Mahlon R., An Econometric Analysis of the Urban Housing Market, NBER, New York, 1975.

Strotz, Robert H., "The Empirical Implications of a Utility Tree," Econometrica, (April 1957), 269-280.

Theil, Henri, The System-Wide Approach to Mocroeconomics, The University of Chicago Press, Chicago, 1980.

Winger, Alan R., "An Approach to Measuring Potential Upgrading Demand in the Housing Market," Review of Economics and Statistics, Vol. 45,(August,1963), 234-244.

Witte, Ann, Howard J. Sumka, and Homer Erecson, "An Estimate of a Structural Hedonic Price Model of the Housing Market: An Applic ation of Rosen's Theory of Implicit Markets," Econometrica, Vol. 47, NO. 5(September, 1979), 1151-1173.

Zellner, Arnold, "An Efficient Method of estimating Seemingly Unrelated Regressions and Test for Aggregation Bias," Journal of American Statistical Association, (June 1962), 348-368.

_____, and David S. Huang, "Further Properties of Efficient Estimators for Seemingly Unrelated Regression Equations," International Economic Journal, Vol. 3, No. 3(September 1962), 300-313.