Tenure Choice, Housing Demand and Residential Location

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Abstract. **This paper incorporates location and tenure choice into a simultaneous equation model of housing demand. The estimation results reveal that an important asymmetry may exist between renters and homeowners in terms of their respective housing decisions. The most important finding in this paper is that for homeowners housing quantity and locations are jointly determined. Equally important, the decision process for homeowners appears to be sequential in nature, with tenure choice independent of the housing demand and location decisions. However, this does not appear to be the case for renters. It may be that for tenants location and housing quantity choices are more limited than for homeowners.**

Introduction

An individual's observed consumption of what we call "housing" is, in reality, the consumption of a complex bundle of characteristics. Theoretical work on housing has long acknowledged the nature of housing consumption and several other components have been incorporated into the decision process. Despite the recognition of the complexity of the housing decision, translation of the various aspects of the choice process into empirically testable models has been slow to develop.

Initially, the important components of these choices have been analyzed as separate, and, by implication, independent decisions. For example, there is an extensive literature on the determinants of housing demand [2], [19], [22].[1] Similarly, there are a number of studies on the factors governing the choice between ownership and rental of one's housing, or more compactly, tenure choice [18], [27]. More recent research has begun to recognise the potentially joint nature of these two decisions, and models have developed that incorporate these choices into a simultaneous system of equations [12], [16], [17], [24].[2]

A third aspect of the housing decision is location.[3] Much of the work on locational decisions can be associated with one of two basic approaches. One approach argues that locational housing choice is largely the result of the effects of various neighborhood and governmental externalities on households [7[, [26], [30]. A different, though not mutually exclusive, approach is based upon spatial equilibrium theories, derived from the seminal contributions of Muth [21] and Alonso [1], which posit that locational choices result from the trade-off between the cost of commuting and the price of land and housing.

While existing empirical research on residential real estate has made significant contributions to our understanding of the factors affecting housing decisions, the

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Date Revised—December 2, 1991; Accepted—December 12, 1991.

multidimensional nature of the process has not been adequately integrated into models of housing choice. The purpose of this paper is to explore an alternative approach to incorporating locational characteristics into an empirical framework that also includes housing quantity and tenure choice. In so doing we shed some light on whether these attributes of the housing decision are jointly or separately determined.

In the next section of this paper previous research on the nature of the housing decision is reviewed. In section three an empirical model of the housing decision is presented and the data and methodology are described. The empirical results are presented in the fourth section, followed by a summary and conclusion.

Residential Real Estate Demand, Tenure Decisions and Household Location

Incorporation of locational characteristics into economic models of housing is but one segment of a body of research that has been developing in recent years, in which scholars have sought to imbue their models with the unique characteristics of real estate, making models that are theoretically sound as well as realistic. Other factors and characteristics that have been explored include durability, spatial fixity, nonhomogeneity and government policies toward housing markets.[4] To gain some perspective regarding these current developments, we focus first on some earlier work on housing demand.

A review of the earliest efforts to model housing largely ignore these characteristics by assuming that the demand for housing is a demand for an unobservable homogeneous commodity called "housing services." Intertemporal and spatial attributes of housing are not considered and households are assumed to possess homogeneous tastes and income. Housing services are, thus, one of the commodities in the utility function that households attempt to maximize subject to a budget constraint within a competitive market.

While these simple, single equation models can provide insights into the effects of income or price on the demand for housing services, they cannot address such issues as tenure[5] or location choice. Moreover, much of the early research that uses these models (de Leeuw [8], Mayo [19]) generates divergent estimates of price and demand elasticities for housing demand. Researchers, recognizing the deficiencies of earlier work, have developed increasingly sophisticated models to capture more of the unique aspects of housing.

Rental and Owner-Occupied Housing

The coexistence of rental and owner-occupied housing markets requires a change in the basic housing models regarding the assumption of a homogeneous population. Now such factors as the size of households, their age, income and education levels and the availability of mortgage financing had to be incorporated into models that considered both the type and quantity of shelter. Early work in the area treats the tenure choice as independent and focuses only on the factors affecting this decision (e.g., Li [18]). More recently, however, the interdependence of the rent-own decision and the consumption of housing services has been modeled as a joint decision. This translates into an empirical

approach in which the tenure choice is estimated by probit analysis [12], [17], [24]. An implicit assumption of these models is that consumer demand for housing is based on service flows provided by durable goods rather than the level or stock of housing. The effects of the existing housing stock are ignored.

Location

The other major attribute of housing that has been accorded increasing attention in the literature is location. Specifically, researchers have attempted to explain the observation that in many metropolitan areas upper income households tend to live outside the center city in suburban locations, while lower income families continue to reside in the cities, close to employment centers. In the spatial equilibrium models developed to explain this location pattern, households have the same tastes and income. A family's optimal location is based on weighing the costs of travel and land, where commuting costs increase and housing costs decline as the distance from the center city increases. Households choose particular residential locations by comparing the income elasticity of their demand for land with the income elasticity of travel costs. If higher incomes are associated with higher income elasticities for land than for travel costs, higher income households will locate outside the city. The actual results of the comparative statics depends upon the assumptions of the model regarding whether and to what degree commuting costs change with income [5].[6] Both Muth [21] and Alonso [1] assume that commuting costs (which includes time) are constant with respect to income. If commuting costs increase with income, and if this increase is sufficiently large, more affluent households would choose central city locations (if the value of commuting time is more income elastic than the demand for land).

The above hypothesis, although theoretically rigorous, suffers from some restrictive assumptions and has generated mixed results when tested empirically.[7] For example, while To, Lapointe, and Kryzanowski [31] found the preference-based Muth-Alonso model was consistent with the pattern of spatial location for Montreal, Wheaton's [33] empirical test using the San Francisco Bay area did not support the predictions of this preference model. For the sample population, which was stratified by income, the income elasticity of the demand for land was approximately the same as the income elasticity of travel costs.

Other attempts to assess the impact of location on housing demand have focused on the influence of neighborhood externalities [6], [14], [15] and local government. Henderson [14] suggests that more distant locations may have more attractive features and amenities, despite their longer commute. Some researchers have indirectly attempted to account for these factors by incorporating indices of housing costs, which include local taxes into tenure choice models [12]. Unfortunately, the mix of public goods and services can be very different in different locations, even if total public expenditures are the same. As Tiebout [30] first hypothesized, households with similar tastes, reveal their preferences by 'voting with their feet,' gravitating to municipalities that offer their desired mix of public goods and taxes.[8] A number of papers have used hedonic pricing models to investigate the effects of neighborhood characteristics on property values (e.g., Segal [26]). A third approach, as developed by Haugen and Heins [13] and Yinger [35], Becker [4], and Bailey [3], among others,[9] suggests that the spatial distribution of

households in metropolitan areas is race related. Haugen and Heins, for example, have shown that the rapid growth of the non-white population causes price differentials between inner city and suburban locations that can be explained by a market separation model. The size of the price differentials depends on the nature and effectiveness of white containment and black population growth and expansion from core city locations. More recent research (Jud and Bennett [15]; Burnell [6]) has found that racial composition and neighborhood externalities are interrelated and that both factors affect household location.

What all this analysis seems to indicate is that housing choice is not simply a unidimensional parameter. Besides distance to work, housing consumption also encompasses the characteristics and quality of the neighborhood, which, in turn, reflects, at least to some degree, the local government within which a property is located. Effectively, then, it may well be that the quantity of housing, accessibility to work, and neighborhood are all purchased jointly.

An Empirical Model of Housing Demand, Tenure Choice and Location

Following the approach of Rosen [24], in which homeownership and renting are mutually exclusive activities, we assume that the tenure choice is based upon a comparison of the utility derived from each of these two states. In the homeownership state, the individual households's utility[10] is

$$V_o = V_o\,(y, p_o, p_z), \tag{1}$$

where $V(\cdot)$ is the indirect utility function, y is household income, p_o is the price of a unit of housing and p_z is the price of composite consumption commodity. The subscript 'o' denotes the choice of homeownership.

Similarly, if the household chooses to rent, utility is given by

$$V_r = V_r\,(y, p_r, p_z), \tag{2}$$

where p_r is the rental price and the subscript 'r' denotes the rental choice.

The selection made depends, for a given individual, on whether (1) or (2) yields a higher utility. Thus, the individual chooses to own when

$$V_o - V_r > 0. \tag{3}$$

If the inequality is reversed, then the individual chooses to rent. This may be used to formulate the joint determination housing demand and tenure choice. The former is given by

$$q_o = h_o\,(y, p_o, p_z), \tag{4a}$$

when the inequality (3) holds; and when it is reversed, housing demand is given by

$$q_r = h_r\,(y, p_r, p_z). \tag{4b}$$

q_o and q_r denote, respectively, the quantity of housing when choosing to own and when choosing to rent.

The choice of tenure given by (3) can be thought of as being measured by an index value I^* which determines whether the choice is to own or to rent. This index cannot be measured directly, but it is a function of the determinants of the decision process which is recoverable from the utility function and we can observe the tenure choice that is made. We thus have

$$I\,(=1,\,0)=g\,(y,\,p_o,\,p_r,\,x)+\varepsilon_i \tag{5}$$

where I is defined to equal 1 if the determination is to own a home, and is 0 for those who rent; x is a vector of observable demographic and other characteristics and ε_i is a random error term. If ε_i is normally distributed, then (5) can be estimated by probit regression methods. This is the standard model, as developed by Lee and Trost [17].

Residential Location

We do not have a complete model, however, if either the Externalities argument or the Muth-Alonso framework (or both) have validity. The implication of both of these approaches is that the utility maximizing location is simultaneously determined with housing demand, and by implication, tenure choice. Thus, the model should contain an additional equation:

$$k=k\,(y,\,p_o,\,p_r,\,x,\,m). \tag{6}$$

k is a locational metric, and m represents a vector of location-specific characteristics associated with the housing choice. In the formulation we use below, k is measured by the distance to work for the household head.

The model consists of three equations: tenure choice (equation 5), housing demand (4), and residential location (6). This structure allows a test of the hypothesis that housing demand and location are simultaneously determined with tenure choice. The alternative hypothesis is that the decision is sequential; first, the decision to rent or own is made, and then the housing demand and residential location choices are made. To address this, we utilize the two-stage estimation procedure developed by Lee and Trost [17]. This approach will allow us to test for the presence of selection bias, and will control for its effects if it exists. The procedure augments the regressions with the variable *LAMBDA*, which is an estimate of the covariance between the error terms in the tenure choice equation and the housing demand and distance equations.[11] If there is no apparent simultaneity, then housing demand and residential location estimates can be conducted using conventional simultaneous equations techniques. This is implemented by estimating a three-stage least squares model for the housing demand and residential distance equations.

Data and the Variables Selected

The primary source of data for the estimates is from the University of Michigan's Panel Study of Income Dynamics (PSID) and our sample is taken from Wave 14 of this

study. This wave provides data for housing choices made by families in the survey for the year 1981. The selection of this year is based upon the availability of the locational measure for households; in subsequent waves, the data becomes unavailable. To facilitate matters, the sample consists of single-worker households (so as to have only one family member commuting to work) with heads of households between the ages of 18 and 65. We also choose to select only those households residing in or near specific Standard Metropolitan Statistical Areas (SMSAs), because we merge to this data housing price indices from the Bureau of Labor Statistics (from the Detailed CPI) which is available only for specific SMSAs. Observations were excluded based upon these criteria and when there was missing data. This selection process yields a sample of 968 households.

For homeowners in this sample an adjustment is made to the housing cost measure so as to account for the tax treatment of owner-occupied housing. This adjustment follows the standard approach discussed in Rosen [24] (variants of which are used by Rosenthal [25] and Gillingham and Hagemann [12]).[12]

Exhibit 1
Probit Estimates of Tenure Status

	(1)	(2)
CONSTANT	−11.05	−11.671
	(8.346)	(7.694)
FAMSIZE	0.0490	0.0593
	(1.204)	(1.424)
HDAGE	0.0368	0.0372
	(7.565)	(7.579)
MALE	0.1778	0.1511
	(1.503)	(1.257)
KIDUM	0.4337	0.4584
	(2.970)	(3.071)
MOVEDUM	−0.8208	−0.8221
	(5.673)	(5.593)
PBTRAN	−0.2194	−0.1081
	(1.969)	(0.890)
PERMINC	0.9647	0.8847
	(7.201)	(6.426)
LPRICE	−1.328	−1.478
	(3.657)	(3.875)
URBAN	—	0.0069
		(1.069)
WHITE	—	0.0139
		(2.633)
HSGRAD	—	−0.0032
		(0.416)
EDPUPIL	—	−0.1282
		(1.200)
Log-Likelihood	−401.02	−395.02
CHI-square	465.91	477.89

Note: asymptotic *t*-statistics in parentheses

Added to this basic data set is a vector of location-specific measures that provides information about the characteristics of the county in which the household resides. These data are obtained from the Bureau of the Census' 1983 *City and County Data Book*, and is derived from the 1980 Census of the Population. Detailed definition of these and all of the other variables used in the study are provided in the Appendix.

Empirical Results

Tenure Choice Estimates

The estimates of the parameters of the tenure choice equation are shown in Exhibit 1, which displays two different specifications of the model. Intuition suggests that household characteristics should be important factors in determining tenure choice. The results bear out this expectation. The age of the household head, the presence of children and income level are all positively related to homeownership. The coefficients of these three variables are all statistically significant at the 1% level.

Homeownership is negatively related to the relative price of homeownership, and whether the household had moved during the previous year. If mobility is valued by a household, or if one is new to an area, renting, at least in the short term, may be the preferred choice. This latter result is also consistent with Rosenthal's [25] finding that residence time influences tenure choice by affecting the relative cost of owning to renting (through its impact on discounted legal and agent fees paid by homeowners).

We also would expect that renting is more likely in situations where the head of household used public transportation to work, given that apartment availability may be greater (or conversely, homes are more scarce) near public bus and rail facilities. This result is found for the first version of the model, but when the set of neighborhood characteristics are added to the specification (i.e., *URBAN, WHITE, HSGRAD* and *EDPUPIL*), *PBTRAN* is no longer significant. This finding suggests that the availability and use of public transportation is closely related to other characteristics of the community. Indeed, it may be that *PBTRAN* serves as a proxy for other location-specific factors.

Reduced Form Estimates of Housing Demand and Residential Location

The reduced form estimates of housing services consumed and distance to work are shown in Exhibit 2 for both homeowners and renters. For homeowners, the quantity of housing consumed is, as one would predict, positively related to permanent income and such demographic factors as the presence of children, while inversely related to housing costs. Interestingly, the results also show that demand is negatively associated with the size of family. This may imply that housing quantity is constrained by the increased costs associated with larger families.[13] The use of public transportation facilities is also inversely related to housing quantity.

Demographic factors such as age, sex of the household head, and family size prove to be less important determinants of housing demand for renters, although the presence of children in the household is statistically significant and positive. Permanent income is an

Exhibit 2
Reduced Form Estimates

	Owners		Renters	
	Housing Quantity	Residential Distance	Housing Quantity	Residential Distance
CONSTANT	6.609	−1.373	5.169	3.434
	(4.207)	(0.503)	(7.345)	(2.244)
FAMSIZE	−0.0421	−0.0276	0.0223	0.0203
	(2.023)	(0.761)	(1.067)	(0.431)
HDAGE	−0.0027	−0.0020	0.0056	−0.0054
	(0.609)	(0.266)	(1.661)	(0.731)
MALE	0.0758	0.2750	−0.0333	0.4128
	(0.998)	(2.088)	(0.668)	(0.112)
KIDUM	0.2377	0.2445	0.1428	−0.0169
	(2.753)	(1.624)	(2.061)	(0.112)
MOVEDUM	−0.0262	−0.1764	−0.0908	0.1070
	(0.167)	(0.649)	(1.469)	(0.796)
PBTRAN	−0.1516	−0.3513	−0.0154	−0.3021
	(2.532)	(3.367)	(0.0296)	(2.646)
PERMINC	0.4272	0.3311	0.4985	−0.1692
	(3.246)	(1.447)	(7.035)	(1.099)
LPRICE	−0.4483	0.8764	−0.3267	0.0680
	(2.092)	(2.347)	(2.110)	(0.202)
LAMBDA	−0.0856	0.3475	0.3772	0.6352
	(0.413)	(0.965)	(2.534)	(1.927)
No. of Obs	399		569	
Adj. *R*-square	0.3127	0.0641	0.1498	0.0399
F-statistic	20.56	3.95	11.67	3.52

Note: *t*-statistics in parentheses

important determinant of demand, regardless of tenure status and price, as expected, is inversely related to rental housing consumption.

Location

Since this is the first time, to our knowledge, that residential location has been modeled separately for owners and renters, the specification of this equation is more challenging. If housing quantity and location are closely linked, as the housing literature suggests, then factors such as family size, age, income, dependence upon public transportation, neighborhood amenities and fiscal considerations may also have a bearing on locational decisions.[14] Thus, the initial specification for the distance equations uses the same variable set as the demand equations.

The results for homeowners, while not as robust as those for the demand equations, are similar to the housing quantity estimates. The residential location equation shows that, for homeowners, distance from work is positively related to the gender of the household head—male-headed households tend to locate further from work, and that higher prices imply greater distance from the workplace. In contrast, those households

Exhibit 3
Second-Stage Estimates for Renters

	Housing Demand	Residential Distance
CONSTANT	4.993	4.048
	(5.295)	(0.656)
FAMSIZE	0.0218	0.0230
	(0.991)	(0.359)
HDAGE	0.0058	−0.0047
	(1.576)	(0.648)
MALE	−0.0391	0.1088
	(0.727)	(0.886)
KIDUM	0.1437	—
	(2.027)	
MOVEDUM	−0.0963	0.0963
	(1.404)	(0.619)
PBTRAN	—	−0.3039
		(2.672)
PERMINC	0.5071	−0.1100
	(6.358)	(0.222)
LPRICE	−0.3302	0.0292
	(2.078)	(0.063)
LAMBDA	0.4097	−0.5904
	(1.998)	(1.350)
LDIST	0.0511	—
	(0.291)	
LHQ	—	−0.1187
		(0.112)
Adj *R*-square	0.1286	0.0425
F-statistic	9.936	3.690
N	569	

using public transportation choose to locate much closer to work than those families who do not utilize public transport. The results are even less clear cut for renters, which suggests that other factors are important in explaining their location decisions.

Housing Choice: A Simultaneous or Sequential Decision

Of primary interest is what the reduced form equations tell us about the nature of the housing decision process. For homeowners, *LAMBDA*, the variable controlling for selection bias, is statistically insignificant in both the demand and location equations.[15] This finding indicates that the tenure choice for homeowners can be viewed as distinct from the housing quantity and location decision. That is, housing decisions by homeowners should be analyzed as a sequential process, where the tenure choice is made first, and then, separately and independently, housing quantity and location are decided.

In contrast, the reduced form estimates for renters indicate that selection bias is present in both the residential demand and location equations. This implies that the choice of housing quantity and location for renters is intimately linked to their tenure

decision. To test the simultaneity hypothesis and model this process, we utilize the Lee and Trost two-stage estimation technique which has been augmented with a third equation incorporating the residential location choice.

Second-Stage Estimates for Renters

The results of the two-stage estimation of housing demand and location for renters are presented in Exhibit 3.[16] Economic factors predominate the results for the demand equation. The coefficient of the permanent income variable is positive and highly significant. Price is another important determinant of demand, with the coefficient carrying the usual negative sign. Of the other variables, only the variable *KIDUM* has any significant effect on housing demand, with households having young children demanding more housing.

In the distance equation, only the variable *PBTRAN* is statistically significant. *LAMBDA* is still significant (just below the 10% level in the distance equation) in the second-stage estimates. These estimates effectively parallel the results of the reduced form specification.

Taken together, the findings can be interpreted to imply that once the decision to rent is made, either on the basis of preference or of necessity, renters have fewer choices and less flexibility in regard to location and housing quantity, as compared to homeowners. Thus, variables that may influence the choice of location and housing consumed by owners are of less importance or not available choices for tenants. That this is the case is underscored by the lack of significance of the endogenous housing quantity and location variables in the estimated equations.

Three-Stage Least Squares Estimates for Homeowners

Because of the apparent absence of sample selection bias in the homeowner equations, we can test the sequential decisionmaking process by reestimating the demand and distance equations for homeowners using three-stage least squares. By doing so, we can incorporate the cross-equation correlation of the error terms into the estimation procedure, thereby improving the efficiency of the estimates. The results for the homeowners are displayed in Exhibit 4.

It should be noted that the estimation procedure is carried out using all of the variables listed in the reduced form estimates shown in Exhibit 2, but also using the four location-specific variables included in the broader estimate of tenure choice (i.e., *EDPUPIL, HSGRAD, WHITE* and *URBAN*). These variables have been included as instrumental variables to incorporate neighborhood characteristics in the demand and distance equations. As will be noted, their inclusion has an impact on the findings.

In the demand equation, all of the variables save for *LPRICE* are statistically significant and consistent with our previous findings. A male household head and the presence of children are both positively related to demand and statistically significant at the 1% level. Age of the household head is also significant, but is inversely correlated to housing demand. This finding may reflect the tendency of older households to reduce housing

quantity as children grow and leave home. Such a result is likely to assume greater weight as the U.S. population continues to age.

Household heads who rely on public transportation to get to work consume smaller amounts of housing. This may reflect the scarcity of larger homes and the predominance of multifamily dwellings in those locations with greater access to public transportation facilities, which tend to be concentrated in inner-city and contiguous communities. This argument is consistent with the negative and statistically significant *PBTRAN* variable in the distance equation.

The coefficient on household income is positive and highly significant. The price variable carries a positive sign, but is not statistically significant. The sign on the endogenous distance variable (*LDIST*) is contrary to the Muth-Alonso hypothesis, but the result may be due to the manner in which housing quantity has been measured. Since it is based on house value, the result simply reflects the observed fact that value tends to decline as distance to work increases. It should be noted that if the location-specific characteristics are not used as instrumental variables, results very much consistent with the Muth-Alonso hypothesis are obtained; the price coefficient is negative and significant, while the distance variable carries a positive sign and is highly significant.[17]

For the distance equation, the estimates prove quite similar to the reduced form results. As already noted, the use of public transportation facilities and distance are

Exhibit 4
Three-Stage Least Squares
Estimates for Homeowners

	Housing Demand	Residential Distance
CONSTANT	7.084	5.761
	(7.957)	(2.394)
HDAGE	−0.0079	−0.0135
	(2.418)	(2.836)
MALE	0.2051	0.2966
	(2.329)	(2.350)
KIDUM	0.1530	—
	(2.396)	
PBTRAN	−0.3664	−0.4596
	(4.357)	(4.102)
MOVEDUM	—	−0.0317
		(0.194)
PERMINC	0.5129	0.4647
	(5.723)	(2.365)
LPRICE	0.0061	0.6521
	(0.023)	(1.800)
LDIST	−0.5798	—
	(3.416)	
LHQ	—	−0.7189
		(2.285)
N	399	
Weighted Mean Square Error for System		1.283 (760 d.f.)
Weighted *R*-square System		0.2003

inversely related. Higher prices, on the other hand, significantly increase the commuting distance. This simply reflects the existence of a trade-off between distance to work and the quantity of housing consumed. Distance is also positively related to income and households with male heads. Together these results imply that the stereotypical image of the nuclear family—the male household head who commutes to work and locates his family in the suburbs in search of a better environment—still characterizes many of our metropolitan areas. These results are consistent with the findings of Straszheim [28] and Wheaton [34] which indicate that higher income families live in more suburban locations because superior environmental and neighborhood amenities outweigh the disutility of longer commutes.

The age variable is negatively related to distance, indicating that older household heads may prefer shorter commuting times (and pay for this by consuming a smaller amount of housing). The endogenous housing quantity variable, *LHQ*, is also negatively related to distance, conforming to the findings in the demand estimates. All told, the results provide strong support for the hypothesis that for homeowners, housing demand and residential location decisions are jointly determined as part of a sequential decision-making process.

Summary and Conclusions

Theoretical models addressing housing demand issues can be traced back to a simple examination of the demand for a homogeneous commodity. As subsequent analysis revealed the complex nature of the commodity being studied, these models have become analytically more rigorous. Empirical analysis has followed a similar path. This paper serves as an attempt to move down this path by incorporating locational factors into empirical models of housing demand and tenure choice.

Perhaps most notable, tenure choice appears to be independent of housing demand and locational decisions for homeowners. This, however, may not be said for renters, and may represent an important asymmetry. The findings also indicate that, for homeowners, there is a simultaneous determination of housing quantity and residential location. This may also be true for renters, although the econometric methods used in this paper do not indicate that this is the case. Based upon these results, future work should be aimed at clarifying these issues by using other data sets and other statistical techniques.

Appendix
Description of Variables Used In Estimation

Dependent Variables:

TENURE	household tenure choice; set to 1 for homeowners, zero for renters
LHQ	for homeowners: the log of value of their house divided by the median house value in the county; for renters: annual rent times 10 divided by median rental cost for county of residence
LDIST	log of distance to work

Independent Variables

FAMSIZE	household family size
HDAGE	age, in years, of household head
MALE	gender of household head (set to 1 for male, 0 for female)
KIDUM	dummy variable indicating presence of child or children under 18 in household (equals 1 when present, 0 otherwise)
PBTRAN	dummy variable set to 1 for households in which head uses public transportation to work (0 otherwise)
MOVEDUM	dummy variable indicating that household had moved during the last calendar year
PERMINC	a proxy for permanent income, calculated as the log of five-year average of total household income (using current year income, previous three years' and following year's income)
HPO	housing price variable for homeowners, calculated as the median monthly housing cost for the county, multiplied by (1-marginal tax rate), divided by the city-specific CPI
HPR	housing price variable for renters, calculated as the median monthly rental cost for county, divided by the city-specific CPI
LPRICE	the log of the ratio of median housing costs (HPO) to the housing price variable for renters (HPR)
URBAN	percentage of household's county that is urbanized
WHITE	percentage of household's county population that is white
HSGRAD	percentage of county population that are high school graduates
EDPUPIL	education spending per pupil in household's county
LAMBDA	inverse Mills ratio, used to test for presence of sample selection bias in the estimates.

Measurement of Housing Quantity and Prices

The quantity of housing services consumed is not directly observable and no single variable can correctly measure this flow, for either homeowners or renters. In the demand equation for homeowners, the dependent variable is the log of house value divided by the median house value for the county. This variable is not a perfect measure of housing services consumed as home prices not only reflect differences in home size, but also reflect the capitalized value of other goods and services consumed along with housing, such as public education, public transportation, police and fire protection. Housing prices similarly reflect the impact of social and neighborhood externalities. The same arguments apply for rent levels. Although not a perfect proxy, these measures represent the best measure available with this data set. Alternative measures were examined, including the number of rooms, but this proved even less satisfactory, as it yields no information on other housing characteristics, such as lot size. Nor would we be able to control for differences in the size of rooms, and consequently, could not accurately measure total square footage of the house.

Finally, it is widely recognized that tenure choice involves both a consumption and investment decision. Given that homeownership is, in part, a portfolio decision, ideally,

housing demand analysis should be intertemporal in framework. In the interests of simplicity, however, we choose to ignore the multiperiod characteristics associated with the rental-ownership decision and estimate a single period model.

Notes

[1]Olsen [23] provides an excellent review of the literature on housing demand.
[2]Rosenthal [25] incorporates homeowner residence time into a semi-Markov model of the housing market in which he shows that the duration of prior ownership affects the tenure choice decision.
[3]There is an extensive body of research on location. See Straszheim [29] for a good review of this literature.
[4]An excellent survey of these issues can be found in Smith, Rosen and Fallis [27].
[5]Similar frameworks have been developed to model the rental market, with the price of owner-occupied housing entered as a substitute for rental housing. Even here, however, these markets are examined separately and independently of the consumption of housing services.
[6]Brown [5] shows that the "price of closeness" varies with both distance and income.
[7]Brown [5] shows that empirical studies which indicate that income varies directly with distance are consistent with the comparative statics finding that an increase in income has an indeterminate effect on location and housing demand.
[8]The Tiebout hypothesis, first formulated in 1956, has since been the subject of substantial empirical testing, much of which has confirmed the basic tenets of the model. See, for example, Zodrow [36], Nelson [22], Frey [10], and Vedder [32].
[9]The effects of racial composition on location continues to be investigated. See Denton and Massey [9], and Gabriel and Rosenthal [11].
[10]The terms household and individual are used interchangeably here despite the obvious differences that may exist between them. Decisionmaking by individuals and by households are treated as though they were simply a single entity.
[11]By following this approach, consistent estimates can be obtained using OLS procedures. While the addition of the third equation (i.e., the location equation) complicates things slightly, it is actually equivalent to adding one more equation to a two-stage least squares model. Nothing else about this approach changes anything about the basic Lee-Trost model. What is necessary is to use the exogenous variables as instruments in the first-stage estimates, and to then use the fitted values, including *LAMBDA* from the probit regression, in the second stage.
[12]Although the PSID has a wealth of information on tax rates facing individuals as well as details on the terms of the individual's mortgage, much of the mortgage data was unusable. Therefore imputation of the interest component of household debt service was not possible and we were forced to use total debt service in computing after-tax housing costs. In contrast to Rosen, the housing cost estimates in this study exclude adjustments for depreciation and maintenance. Incorporating these cost components into the housing cost variable, however, had virtually no effect on the estimate results.
[13]This may also reflect the fact that home size (i.e., the number of bedrooms) does not increase in direct proportion to the size of the family.
[14]Rosen [24] uses demographic variables in his tenure choice equation to control for preference differences among households. A similar rationale can be used for the specification of the distance equation.
[15]Rosen [24], and Lee and Trost [17] also found similar results in their studies. Gillingham and Hagemann [12], however, did find the presence of selection bias for some household types, when stratified by income.
[16]The reduced form estimates use the narrower version of the tenure choice specification (as shown

in column (1) in Exhibit 1). Use of the more inclusive version (as shown in column (2) of Exhibit 1) makes little difference in the results. The second-stage estimates differ from the reduced form estimates displayed in Exhibit 2, with *PBTRAN* omitted from the demand equation and *KIDUM* omitted from the distance equation. Inclusion of *PBTRAN* in the demand equation causes problems in the estimation of the second stage. Addition of *KIDUM* does not improve the quality of the estimates and was omitted.

[17]The price variable becoming statistically significant when the location-specific variables are excluded from the model also suggests that these neighborhood characteristics are capitalized into housing prices.

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