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An Econometric Model of Housing Price, Permanent Income, Tenure Choice, and Housing Demand

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This paper addresses the determination of housing price, permanent income, tenure choice, and housing demand. *Full* housing demand elasticities incorporate the interactive effects among the four stages of the model. Price and income have major effects in the tenure choice equation. Sociodemographic variables, such as age, have complex effects that may be lost in simpler forms of estimation.

There are several unanswered questions in housing demand models. Although there are both consumption and investment aspects to the housing purchase (especially for owner-occupied housing), most analysts look at one aspect or the other, but seldom both. Most agree that permanent income is a major factor in the housing decision, but are unclear as to whether it belongs in the tenure choice, the demand regression, or both. Similar problems occur in specifying sociodemographic variables such as age, race, or education.

This paper presents a model of permanent income, housing price, tenure choice, and housing demand. Several useful findings emerge from a national sample of owners and renters from the Annual Housing Survey (AHS). Hedonic price indices for both owners and renters show good explanatory power on a national sample with regional indicators. Consistent with Goodman and Kawai [8], the renter sample appears to be more nearly linear than the owner sample.

Permanent income estimates, using a human capital model, provide similar results for owners and renters. An investigation of functional form (like Heckman and Polachek [14]) suggests that a square root transformation of income leads to better estimates than the typical linear or log–linear transformation.

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The joint tenure choice-housing demand decision is modeled using "Heckit" estimation procedures in a manner popularized by Lee and Trost [16] and Rosen [21]. A major advance is the separation of the consumption and the investment motives in the tenure choice decision, through the formulation of owner–renter price ratios and value-rent ratios. The decision to own is inversely related to the former and directly related to the latter. Permanent income is a significant determinant of tenure choice.

Separate owner and renter demand elasticities are calculated. They are then combined to form "full" income and price demand elasticities, taking into account permanent income, tenure choice, *and* the separate demands for owner and renter housing. Follain [6] conducted a similar analysis to this one, although he concentrated more on inflation and less on permanent income and sociodemographic factors.

Finally, there is a significant simultaneity between the tenure choice and the housing demand decisions. Once permanent income is used to consider tenure choice, *current* income provides more satisfactory demand estimates than does permanent income. The impacts of several sociodemographic variables are also affected.

1. HOUSING DEMAND

In recent years, it has become apparent that housing analysis involving sample censoring (on housing tenure, for example) should use two stage estimation procedures (for example, [13]) to consider the likely simultaneity problems between the censoring process and the subsequent estimates. Consider first the demand for either owner or renter housing,

$$Q = Q(Y, P, Z), \tag{1}$$

where

Q = flow of housing services demanded.

Y = real income (in terms of a numeraire good).

P = price of housing services (relative to the numeraire good).

Z = other variables such as tastes and household characteristics.

To measure demand among cities, it is desirable to deflate the prices and incomes by cost of living indices representing the prices of nonhousing items.

The jointness of tenure choice and quantity of housing demanded can also lead to simultaneity problems. Until recently, large housing units in most areas were more likely to be owner units. Moreover, housing provides a good hedge in times of inflation; once again the decision to own is joint with the decision about how much to buy. Ignoring this simultaneity can lead to biased demand elasticity estimates, as well as to acceptance of the proposition that variables (especially, sociodemographic variables) are significant in the demand regression, when they belong more properly in the tenure choice regression.

This study will estimate four relationships:

(a) Hedonic price methods define price indices for owner and renter housing and define value-rent ratios for the investment components of the housing purchase.

(b) Permanent income is estimated for both owners and renters.

(c) Tenure choice is estimated using the prices, value-rent ratios, permanent and transitory incomes, and sociodemographic variables.

(d) Housing demand is estimated for both renters and owners.

Full elasticities are then calculated using (a) through (d).

2. VALUE-RENT RATIOS

Although recent literature has considered both the consumption and the investment components of housing demand, it has been difficult to devise a house-specific measure that summarizes the dwelling unit's investment possibilities. This section considers the ratio of house value to rental value, referred to as ψ, as such an indicator.

Analysts have become increasingly aware that even though traditional mortgage and interest costs were rising, expected capital gains could offset the increased costs. Although such offsets can be discussed in theory [5], it is quite another matter to measure them in practice [23]. Since asset value is related both to the stream of services that it produces and to the expected capital gain to its owner, an increased cost of the stream of owner services, relative to renter services, should tilt the tenure choice toward renting. On the other hand, a high value-rent ratio, from an investment standpoint, indicates that owning is more attractive.[1]

Consider a national housing market consisting of a set of metropolitan areas. Mobility within metropolitan areas is easy relative to mobility among them, leading to differing housing prices in differing locales. Buyers can purchase housing in either the rental market or in the owner market. Consumers purchase both housing and a local public good which is financed by a proportional property tax.

[1] Phillips [19] presents a detailed analysis of capitalization rates (the inverse of value-rent ratios). Rapid inflation appears to raise residential values relative to current rental flows independent of the indirect impact of real after-tax financing costs. Expectations relative to future rents and values are also capitalized into asset prices with residential values expected to be high (low) relative to current rents if future rents are expected to increase (decrease).

In equilibrium, the value of an owner-occupied unit in locality i, yielding y_n units per year of housing services is

$$V_{ni} = Dy_n + D'\tau_{ni}V_{ni} + D(X_i - t_iV_{ni}), \tag{2}$$

where D is a discount factor for the stream of services, and τ_{ni} is the expected capital gain, along with its discount factor, D'. X_i is the dollar value of local public goods in locality i, and t_i is the property tax rate in the locality.[2] Within a metropolitan area, V_{ni} adjusts to capitalize the discounted value of the expected capital gains and the fiscal surplus, or deficit, $(X_i - t_iV_{ni})$. Rearranging (2):

$$V_{ni} = D(y_n + X_i)/(1 + Dt_i - D'\tau_{ni}). \tag{3}$$

All else equal, increases in y_n or X_i lead to increases in value. Increases in the property tax rate, not reflected in increased provision of public goods, decrease the value, and increased expectations of capital gains increase it.[3]

Consider a rental unit in the same municipality, also providing y_n units of housing. Since renters are paying for the stream of housing and public services, rather than for their capitalized values, the market rent is the sum of y_n and X_i, or $R_{ni} = y_n + X_i$. A new variable, ψ_{ni} can now be formed to relate V_{ni} to R_{ni}:

$$\psi_{ni} = V_{ni}/R_{ni} = D/(1 + Dt_i - D'\tau_{ni}). \tag{4}$$

ψ_{ni} is also negatively related to the tax rate and positively related to the expected capital gain. It is well-recognized as a measure of asset viability (in the real estate market), or growth potential in the stock market.

If units could either be owned or rented then hedonic price regressions could be estimated for both markets. The availability of detailed data on both owner and rental housing allows estimation of the relevant parameters. Consider bundle $(y_1, \dots, y_k, X_1, \dots, X_m)$, where y refers to structural characteristics of the bundle, and X refers to location-specific characteristics (including distance from a central location, property tax rate, and other neighborhood characteristics). The market value as an owner-occupied (renter) bundle is:

$$V = V(y, X) \tag{5a}$$

$$R = R(y, X). \tag{5b}$$

The price of an owner (renter) unit with characteristics (y^*, X^*) at a given

[2] The property tax treatment follows Hamilton [12]. Equation (2) provides an equilibrium condition rather than identification of willingness to pay for services. Differential services are handled through the hedonic price function.

[3] In the context of this model, this refers to *partial* rather than *total* differentiation of the equilibrium condition with respect to the tax rate.

location is P_o (P_r), or

$$P_o = V(y^*, X^*) \tag{5c}$$

$$P_r = R(y^*, X^*). \tag{5d}$$

Owner (renter) quantity is then determined by dividing $V(R)$ by P_o (P_r).[4]

The hedonic price function can be used to estimate the value-rent ratio as well. Hedonic coefficients can be interpreted as the sums of replacement costs (through the offer curve, as described by Rosen [22]) and quasi-rents [15]. Through a well-specified function, one can *reconstruct* any rental (owner) unit as if it were owned (rented). A set of high quasi-rents for a specific bundle suggests a market-indicated expectation for capital gain. Low quasi-rents (i.e., negative) may suggest that units of a given type are no longer being built because of their lack of investment potential. Since the ratio of relative prices, $\gamma = P_o/P_r$, is also formed from the same hedonic price functions, it, too, indicates a measure of housing value relative to nonhousing capital. Holding γ constant, the value-rent ratio, ψ, compares one unit to another for investment potential.[5]

3. SOCIOECONOMIC VARIABLES AND PERMANENT INCOME

Mayo [18] provides a good review of the use of sociodemographic variables in housing demand analysis and concludes that there is little to conclude. There has recently been innovative work in demand systems (see [1, 10, 20]), but even these are incomplete. At the limit, a model that makes permanent income, tenure choice, moving choice, and quantity demanded endogenous is necessary. However, by considering each of these choices separately, it is possible to examine the individual effects.

Analysts have agreed that long-term, or permanent, income is necessary, at least in any equation used to estimate housing demand (as opposed, for example, to tenure choice). Lagged income, samples permitting, is a traditional method. Another method is a *human capital* model in which income is related to investment in human and nonhuman capital. In such models,

$$Y = Y^{P} + Y^{T}, \tag{6}$$

where Y equals current income and the P and T refer to permanent and transitory components. If Y^{P} is a function of human capital assets (such as

[4] Here, X^* may refer to neighborhood and public services, which should be allowed to vary. Distances, which may reflect differential costs, are not standardized.

[5] Others (Follain [6] and Schwab [23]) have estimated analogs to the value-rent ratio, using lagged changes in house values. This measure also has appeal, but it imposes restrictions on the lag structure of expectations and requires expectations to apply equally to *all* houses in a market. Lagged changes in both value and value-rent ratios were also used (as suggested by the referee). The results, available on request, were inferior to those presented.

education, age, or training) and nonhuman assets, then the regression of Y on these variables provides permanent income, Y^{P}, as the fitted value of the regression, and transitory income, Y^{T}, as the residual.

An understanding of permanent income provides insight into many of the sociodemographic effects. Goodman and Kawai [7] show how the impacts of education, age, and training on permanent income are likely to be nonmonotonic. Under those circumstances, if the life-cycle effects are ignored in the permanent income formulation, then the nonmonotonic effects persist in the demand regression, through the coefficient on permanent income.

Age might plausibly be included in estimates of permanent income, tenure choice, *and* housing demand. Permanent income considers job experience. The tenure choice function may concern expectations over the immediate future with respect to moving costs and the possible investment characteristics of the housing bundle. The demand function may involve the household's wish to "spread out" (at least up to some age) irrespective of household size.

Many have included age and education variables, for example, along with Y, to account for permanent income effects. Suppose, however, that the true model relates permanent income to age and education, and that housing quantity is related to permanent and transitory incomes only (ignoring price and other variables for the moment). Thus, the appropriate regressions are:

$$Y = Y^{\mathrm{P}} + Y^{\mathrm{T}} = \nu E + \phi A + u \tag{7}$$

$$Q = \alpha Y^{\mathrm{P}} + \beta Y^{\mathrm{T}} + e. \tag{8}$$

Substituting $(\nu E + \phi A)$ for Y^{P}, and $(Y - \nu E - \phi A)$ for Y^{T}, results in the rearrangement:

$$Q = (\alpha - \beta)\nu E + (\alpha - \beta)\phi A + \beta Y + e, \tag{9}$$

or:

$$Q = \Theta_1 E + \Theta_2 A + \Theta_3 Y + e, \tag{9a}$$

which is precisely (with Θ indicating the reduced form parameters) the equation that many have estimated. Small or insignificant coefficients (and elasticities) for Θ_3 should not be surprising, since they provide estimates for β rather than α, or *transitory* rather than permanent income elasticities.

4. CALCULATING DEMAND ELASTICITIES

Given the system of household equations, it is important to consider the *total effects*, system-wide, as opposed to the partial effects within any single equation. There are both theoretical and econometric aspects to this discussion.

We consider a system in which tenure choice is a function of relative prices, γ, value-rent ratio, ψ, income, and age (representing other characteristics), and quantity demanded is a function of own-price, ψ, income, age, and other sociodemographic characteristics (suppressed in the notation):

$$Q_o = Q_o(P_o, \psi, Y, A) \tag{10a}$$

$$Q_r = Q_r(P_r, \psi, Y, A). \tag{10b}$$

Let the probability of owning rather than renting, f, be:

$$f = f(\gamma, \psi, Y, A). \tag{11}$$

Income, either current or permanent, is a function of age and other variables, such that $Y = Y(A)$, where Y' is positive (up to a preretirement level of A), then negative, and Y'' is negative.

Housing demand, $H(Q)$, is the sum of the probability of owning (or, percentage owners), multiplied by the amount of housing demanded by owners, plus the comparable probabilities (percentages) for renters, or:

$$H(Q) = fQ_o + (1 - f)Q_r. \tag{12}$$

Differentiating (12) totally provides (13)–(17):

$$\begin{aligned}\eta_Y^* &= (\partial H(Q)/\partial Y)(Y/H(Q)) \\ &= \left[(1-f)\eta_{Q_rY}Q_r + f\eta_{Q_oY}Q_o\right]\Big/H(Q) + \left[1 - (Q_r/H(Q))\right]\eta_{fY}\end{aligned} \tag{13}$$

$$\begin{aligned}\eta_\psi^* &= (\partial H(Q)/\partial \psi)(\psi/H(Q)) \\ &= \left[(1-f)\eta_{Q_r\psi}Q_r + f\eta_{Q_o\psi}Q_o\right]\Big/H(Q) + \left[1 - (Q_r/H(Q))\right]\eta_{f\psi}\end{aligned} \tag{14}$$

$$\begin{aligned}\eta_{P_r}^* &= (\partial H(Q)/\partial P_r)(P_r/H(Q)) \\ &= \left[Q_r(1-f)\eta_{Q_rP}\right]\Big/H(Q) - \left[1 - (Q_r/H(Q))\right]\eta_{fp}\end{aligned} \tag{15}$$

$$\begin{aligned}\eta_{P_o}^* &= (\partial H(Q)/\partial P_o)(P_o/H(Q)) \\ &= \left[Q_o f\eta_{Q_oP}\right]\Big/H(Q) + \left[1 - (Q_r/H(Q))\right]\eta_{fp}\end{aligned} \tag{16}$$

$$\begin{aligned}\eta_A^* &= (\partial H(Q)/\partial A)(A/H(Q)) \\ &= \left[(1-f)(\eta_{Q_rY}\eta_{YA} + \eta_{Q_rA})Q_r + f(\eta_{Q_oY}\eta_{YA} + \eta_{Q_oA})Q_o\right]\Big/H(Q) \\ &\quad + \left[1 - (Q_r/H(Q))\right](\eta_{fY}\eta_{YA} + \eta_{fA}).\end{aligned} \tag{17}$$

Equation (13) examines income elasticity, (14) examines value-rent elasticity, (15) examines renter price elasticity, (16) examines owner price elasticity, and (17) examines age elasticity. Consider income elasticity, (13). An individual either owns or rents. If he or she owns (rents), f equals 1 (0), $H(Q)$ equals Q_o (Q_r), and $\eta^*_{Y_o}$ ($\eta^*_{Y_r}$) equals η_{Q_oY} (η_{Q_rY}).

We wish to estimate demand *across* individuals, however, and the resulting inferences involve the tenure choice decisions through income (price, or age) changes. Thus, the *total* income elasticity of demand is the weighted sum of the owner and renter elasticities, *plus* the probability that increased income (price, or age) moves the household from renter to owner housing, $f(\cdot)$, weighted by the different housing quantity purchased as an owner rather than as a renter. If Q_o is greater (less) than Q_r, omission of this term leads to a downward (upward) bias in the imputed income elasticity. Reasons why Q_o and Q_r may be different are discussed below.

The value-rent elasticity is similar. Expected appreciation, as implied by (2), reduces the user cost of housing. As a result, high values of ψ suggest a lower user cost (relative to elsewhere, and relative to renting). These, too, are likely to influence overall demand, depending on the relative weights accorded by Q_o and Q_r.

Estimation biases also arise for price elasticities. Both (15) and (16) contain equal and opposite terms with respect to the tenure choice elasticity. An increase in P_r, relative to P_o, decreases the amount of renter housing, but also increases the probability of changing to owner housing, increasing the demand for owner housing. Thus, the usual measure of rental housing price elasticity is too high by this factor. This raises the possibility of a positive total renter price elasticity, if $[1 - (Q_r/H(Q))]$ is positive and η_{fp} is negative. Similarly an increase in P_o leads to a decrease in Q_o, as well as the probability of moving to renter housing, which further decreases demand. As a result, the usual price elasticity measure for owner housing is too low.

A *total* price elasticity measure can be derived by adding $\eta^*_{P_r}$ and $\eta^*_{P_o}$. The equal and opposite terms in (15) and (16) cancel, and the result is the weighted sum of the owner and renter price elasticities.[6] Many have found that renter demand is more price elastic than owner demand. There are many reasons for this [8, 9] but failure to model tenure choice properly can lead to biases away from (toward) zero for renter (owner) elasticities.

Age (or other sociodemographic) effects provide similar results. There are two types of terms in (18). The first is weighted sum of the age elasticities, with the weights referring to the relative frequencies of the housing tenures. If all three relevant elasticities are positive, then the age effect is positive.

[6] Equal percentage increases in both prices offset each other, although demand for housing, relative to all other goods, decreases.

On the other hand, both η_{YA} and $\eta_{Q_r A}$ might be negative for either owners *or* renters, especially at more advanced ages.

The second term refers to tenure adjustment. According to our estimates, only η_{YA} is likely to be negative. Therefore the tenure adjustment term provides an increase in housing quantity with respect to age. Along with the other evidence of bias due to the naive inclusion of age as a for permanent income proxy, such as (9), it is not surprising that the relationship between age and demand has been uncertain [18].

Why might Q_o and Q_r differ? In the United States, housing tenure is generally stratified on house size. Until recently, it was easier to purchase small (large) amounts of housing by renting (owning). As a result, households with tastes for small (large) units would rent (buy). Condominium housing in many markets has eased this restriction to some extent, although in 1978 (the sample year) they constituted only 1.45% of the housing units.[7]

It is also important to acknowledge investment demand. A dwelling unit involves both housing services *and* a housing asset (for many households, it represents the largest asset). If housing capital is perceived as a good (bad) investment, one might purchase a house that is bigger (smaller) than if one were interested only in the consumption aspects.[8]

A third reason concerns the lumpiness of housing capital. Suppose housing had only one dimension, floor space, and dwelling units were built only in multiples of 100 square feet. A household wishing to buy 950 square feet of housing is forced to buy 1000. In theory, the owner could rent out the remaining 50 square feet, although transactions costs generally make it impractical. Our discussion treats this as housing investment, although it is clearly a dead-weight loss.[9]

These biases, independently of econometric estimation biases, have policy implications. There has been a heated debate concerning rental housing, with reported increases in the rent/income ratio from 1970 to 1980 [24]. As incomes rise, renters become owners. Therefore the more affluent renters of 1970 became owners by 1980, biasing the 1980 ratio upward relative to the 1970 ratio. This model implies that *any* tenure-specific income elasticities are likely to be biased downward, and that household data can be used to address the tenure change question.

[7]Of 82.8 million occupied year-round housing units, in 1978, only 1.2 million were cooperatives or condominiums.

[8]In this context the rental housing purchase may serve as a measure of the demand for housing services, as opposed to housing capital, with the remainder interpreted as the positive or negative investment demand for housing.

[9]The sum of such discrepancies across households is likely to be positive (for example, with a Cobb–Douglas utility function of the form, $U = Ah^{\alpha}$, where h represents housing and $0 < \alpha < 1$). That is, 50 square feet too many would give less disutility than 50 square feet too few.

TABLE 1
Descriptive Statistics for Renters and Owners

	Renters	Owners
AGE	40.2	44.2
	(17.9)	(12.5)
HHSIZE	2.40	3.36
	(1.59)	(1.57)
BLACK	0.128	0.068
	(0.334)	(0.079)
MALE	0.635	0.899
	(0.482)	(0.095)
INCOME	12096	24424
	(9292)	(13460)
SWORK	0.236	0.498
	(0.425)	(0.500)
TIME	3.51	9.81
	(7.35)	(11.31)
RENT (VALUE)	216.4	53486
	(98.3)	(34081)
ROOMS	4.11	6.00
	(1.45)	(1.66)
BUILT	29.19	25.19
	(18.81)	(17.90)

Note. Standard deviations in parentheses.

5. EMPIRICAL RESULTS

The analyses presented above are tested with the 1978 AHS National Sample. The observations were collected between September 26, 1978 and February 6, 1979. A 1-in-10 sample was drawn, since the nonlinear tenure choice estimation, in particular, can be quite expensive for large samples. After adjustments for vacancies and missing values, 2857 observations (2007 owners, 850 renters) were available.[10]

Table 1 displays summary statistics. The owner units are larger (number of rooms) and have more facilities. The average owner unit has 6.00 rooms compared to 4.11 rooms for the average renter unit. Owners are generally more affluent ($24,400 vs. $12,100 for renters). The sample of owner households is about 6.8% black; the renter percentage is 12.8%. Approximately 90% of the owner households are male-headed, in contrast to 63.5% of the renter households.

[10] The hedonic price and permanent income estimates used weighted least-squares analysis. Tenure choice estimates were unweighted due to difficulties in nonlinear estimation. The demand estimates also used unweighted data.

a. Price Indices

Hedonic price indices are estimated for a national housing market, with regional dummy variables, following the formula

$$V \text{ or } R^{(\lambda)} = \nu_o + \sum \nu_k X_k + e, \qquad (18)$$

where V (R) equals the value (rent) of the dwelling unit, deflated for the cost of living in the SMSA in which the unit is located, and λ is the Box–Cox nonlinear transformation parameter.[11] Although R is in dollars of gross rent, V is coded in intervals, with an open-ended interval at $250,000 and over.[12] The fitted value for the owner units is $352,500. The imputed income for the open-ended income category (income over $50,000) is $71,100.

Table 2 presents the hedonic price regressions for both owner and renter units. The Box–Cox parameter λ equals 0.3 for owner housing and 0.6 for renter housing. Rosen [22] implies that the more feasible it is to repackage a good, the more linear is the relationship.[13] Goodman and Kawai [8] find rental housing functions regularly more linear than owner functions, suggesting that landlords are more inclined to combine, divide, or otherwise alter housing units than are owners. This analysis, with a different data set, supports the same inference.

Although the house values are interval mid-points (albeit adjusted for price level differentials among metropolitan areas), rather than the exact amounts used for the gross rents, the adjusted R^2 is 0.6025 for the value regressions, as opposed to 0.4585 for the rent regressions. A bathroom adds 26% to the house value and 28.5% to the apartment rent. An additional room adds 7.3% to the value and 6.0% to the rent. An owner (renter) unit loses about 0.53% (0.28%) of value (rent) per year.

Neighborhood effects are considerably weaker for renter units. A unit improvement in the quality of neighborhood structures leads to a 3.8% rent increase; for owner housing the percentage increase is 7.5%.[14] Property

[11] A Box–Cox transformation of V, for example, is $(V^{\lambda} - 1)/\lambda$, where λ equal to 1 gives the linear transformation (plus a constant), and λ equal to zero (at the limit) gives the logarithmic transformation. See Box and Cox [2].

[12] Cain [4] has shown that truncating samples on the dependent variable (here either income or house value) is likely to bias the estimated coefficients downward. Goodman and Kawai [9] show how this can occur in the estimation of permanent income regressions, and they estimate values for the open-ended variables using the Pareto distribution.

[13] Ability to repackage implies the ability to form linear combinations of the components of interest, thus the tendency toward a linear functional form.

[14] Several analysts, including Goodman and Kawai [8] have noted that AHS neighborhood characteristics are weak due to suppression rules prohibiting use of small area neighborhood (such as census tract) data. Recent vintages of the AHS have addressed this problem, but results for hedonic regressions are not yet clear.

TABLE 2
Hedonic Regressions

Variable	Renter (RENT) coefficient	Hedonic price (PCT)	Owner (VALUE) coefficient	Hedonic price (PCT)
CONSTANT	22.848		40.239	
	(10.24)		(14.61)	
AIRSYS	5.073	0.2094	2.023	0.134
	(4.90)		(2.53)	
BADHEAT	−4.017	−0.1544	−3.242	−0.119
	(2.72)		(1.66)	
BATHR	7.185	0.2853	6.747	0.260
	(7.82)		(11.70)	
BEDRMS	0.303	0.0120	0.698	0.027
	(0.46)		(1.37)	
BRKDOWNS	0.072	0.0029	−0.0395	−0.001
	(0.009)		(0.004)	
BUILT	−0.071	−0.0028	−0.137	−0.005
	(3.13)		(6.04)	
CELLAR	2.429	0.0983	3.049	0.122
	(2.96)		(4.21)	
CFUELE	1.196	0.0479	0.761	0.002
	(1.62)		(1.17)	
CRACKS	1.188	0.0476	2.077	0.082
	(1.15)		(2.30)	
HADDL	2.300	0.0930	−1.381	−0.052
	(2.01)		(1.21)	
HEQP	1.765	0.0711	−0.563	−0.021
	(2.30)		(0.76)	
HFUEL	0.283	0.0113	−0.777	−0.029
	(0.29)		(0.80)	
HOWHR	−0.243	−0.0096	−2.155	−0.083
	(0.55)		(3.85)	
HOWNR	−0.950	−0.0377	−1.937	−0.074
	(2.17)		(4.23)	
IFBLOW	0.854	0.0341	1.329	0.052
	(0.82)		(1.58)	
LAV	0.854	0.0341	1.425	0.056
	(0.61)		(1.95)	
MOVED	−0.279	−0.0111	−0.065	−0.002
	(6.40)		(2.82)	
NUMU	0.333	0.0133	*	
	(0.76)			
NUNMD	−0.530	−0.0210	−3.115	−0.115
	(0.52)		(3.34)	
PLASTER	0.553	0.0221	−5.946	−0.211
	(0.041)		(2.73)	
PRIVNR	−1.262	−0.0496	−4.253	−0.155
	(1.46)		(3.45)	
RATS	−1.474	−0.0578	−0.361	0.014
	(1.60)		(0.40)	

TABLE 2—*Continued*

Variable	Renter (RENT) coefficient	Hedonic price (PCT)	Owner (VALUE) coefficient	Hedonic price (PCT)
ROOMS	1.506	0.0598	1.896	0.073
	(3.30)		(6.61)	
LNTAX	*		−4.629	−0.089
			(11.51)	
GARAGE	2.295	0.0928	3.297	0.133
	(2.51)		(4.46)	
NCENT	−2.511	−0.0977	−1.305	−0.495
	(2.44)		(1.39)	
SOUTH	−0.276	−0.0109	−3.367	−0.124
	(0.24)		(3.02)	
WEST	0.856	0.0342	4.331	0.177
	(0.68)		(3.77)	
CC	0.042	0.0017	−0.605	−0.023
	(0.006)		(0.65)	
CAL	5.253	0.2172	12.534	0.571
	(3.95)		(8.09)	
NYC	0.885	0.0359	4.674	0.192
	(0.64)		(2.61)	
DC	2.021	0.0815	6.188	0.259
	(0.83)		(1.97)	
ELEVI	−0.845	−0.0333	*	
	(0.39)			
EXTRA	2.225	0.883	*	
	(3.75)			
FLOORS	0.344	0.0014	*	
	(1.35)			
PAYHT	−0.419	−0.0166	*	
	(0.39)			
SF	−0.306	−0.0121	*	
	(0.29)			
MSE	8.334139		9.872992	
$\bar{R}^2$	0.4585		0.6025	
R^2	0.4819		0.6127	
λ	0.6		0.3	

Note. *t* statistics in parentheses. * Indicates that parameter was not estimated.

taxes are capitalized with a predictable negative sign for owner housing (renter property taxes are not available).

Regional dummy variables were included for the North Central, South, and West, along with dummies for California, the New York City area (but not solely the New York SMSA), and the Washington, D.C. SMSA. Adjusted for the regional cost of living, owner housing is about 4.9% less expensive in the North Central area (relative to the East), about 12.4% less expensive in the South, and approximately 17.7% more expensive in the West. Owner units in California are an additional 57.2% higher in price and premia for New York City and the District of Columbia SMSAs are 19.2 and 26.0% higher than the East.

While there is significant regional variation in owner housing prices, there is less variation in quality-adjusted rents. Only the North Central discount (approximately 9.8%) and the California premium (17.8%) are significant. This suggests a more national market for rental housing than for owner housing, following Linneman [17] or Butler [3]. Where owner housing was more expensive, so, too, was renter housing, implying that systematic area-specific variation outside of California was unlikely.[15]

b. Permanent Income

Permanent income regressions use separate samples of owners and renters with positive wage incomes. Income is deflated for cost of living, and only those categories related to human capital [salary income, unemployment compensation (based on previous earnings), and workman's compensation, for example] are included. Interest and dividend payments, which are expected and can be measured accurately, are added to the permanent income estimated from the regressions. The mean values of these additions for owners (renters) is $2700 ($1200). The dependent variables use a Box–Cox transformation, with λ equal to 0.0, 0.5, and 1.0, for logarithmic, square root, and linear transformations, respectively.[16]

In both cases, as noted in Table 3, the square root transform is the best of the three alternatives and, remarkably, the adjusted R^2 is identical to four decimal places in each case (0.3756). Education is significant for both owners and renters, although it is nonmonotonic for renters. Age has a weaker impact than has been found elsewhere (see, for example Goodman and Kawai [8]), and it, too, is nonmonotonic. Black permanent income is approximately 30.4% lower for renters and 18.0% lower for owners. Female-headed households have lower permanent incomes (31.6% for renters, 35.7% for owners). Marital status is insignificant, and second workers have strongly positive impacts.

[15] Additional estimates were performed for regionally stratified rental markets, on the premise that the relatively low explanation of variance was due to aggregation of separate submarkets. Adjusted R^2 increased for the South, but the others were worse than before. Results are available on request.

[16] Other estimates included households that lived on nonwage income alone. The weaker results lead to concerns about using a human capital model for households in which members are not working.

TABLE 3
Income Regressions

Variable	Renters	Owners	Variable	Renters	Owners
CONSTANT	179.38	181.02	AGE10	−28.25	0.83
	(6.43)	(6.40)		(0.99)	(0.31)
GRADEA	16.42	25.21	AGE11	18.74	−46.20
	(1.40)	(2.35)		(0.56)	(1.67)
GRADEB	37.76	44.77	AGE12	−148.84	−70.58
	(3.32)	(4.35)		(3.14)	(−2.32)
GRADEC	37.80	53.95	BLACK	−23.19	−19.02
	(3.11)	(4.92)		(3.18)	(2.30)
GRADED	61.20	81.37	SEX	−39.34	−60.43
	(4.67)	(7.00)		(6.28)	(6.17)
GRADEE	48.24	95.79	MAR	−0.28	6.48
	(3.68)	(8.38)		(0.04)	(0.78)
AGE1	−65.80	−64.91	SWORK	51.61	44.11
	(2.35)	(0.92)		(8.86)	(10.48)
AGE2	−42.16	−5.52	NCENT	2.00	4.43
	(1.62)	(0.19)		(0.25)	(0.70)
AGE3	−10.08	−0.29	SOUTH	−3.54	−7.59
	(0.39)	(0.01)		(0.46)	(1.23)
AGE4	0.06	16.58	WEST	5.76	2.57
	(0.00)	(0.64)		(0.64)	(0.35)
AGE5	11.01	27.38	CAL	10.91	16.65
	(0.41)	(1.06)		(1.08)	(1.53)
AGE6	−1.19	31.91	NYC	39.07	40.19
	(0.04)	(1.23)		(3.80)	(3.22)
AGE7	−0.47	43.48	DC	37.46	87.48
	(0.02)	(1.68)		(2.09)	(4.79)
AGE8	5.07	24.16	MSE	6602.830	10834.032
	(0.19)	(0.93)	$\bar{R}^2$	0.3756	0.3756
AGE9	−7.39	16.61			
	(0.26)	(0.64)			

Note. t statistics in parentheses.

Permanent income is then calculated as the predicted value of the permanent income regression, which is then retransformed as:

$$Y^P = \left[1 + (0.5\,\delta_o) + \left(0.5 \sum \delta_i X_i\right)\right]^2. \tag{19}$$

The return to nonhuman capital is then added to get household permanent income. The nonlinear functional form of the equation allows a nonzero mean for the estimated permanent income (linear form constrains the mean to zero).

c. Tenure Choice

Simultaneity between tenure choice and housing demand can lead to the selection bias in separate estimates for owners and renters. A general specification uses the relative prices of owning and renting, income, and a set of socioeconomic characteristics such as race, age, sex, and marital status. The treatment here uses a nested framework (referring to order of variable inclusion), which includes the various sociodemographic characteristics, permanent and transitory incomes, and the relative price *and* value-rent ratios.

Economic theory is not very helpful on the roles of sociodemographic characteristics in tenure choice. A general treatment would consider tastes, family size, or housing availability (a supply consideration, but exogenous to the household).

The permanent/transitory income problem provides the same econometric concern here as it does with demand. Goodman and Kawai [7] show that:

$$\beta_T < p \lim b < \beta_P, \tag{20}$$

where β refer to the incremental probability of owning due to permanent (P) or transitory (T) incomes. Transitory income may *not* be significant in the tenure choice decision since home purchase typically entails substantial transaction costs that might not be covered by transitory income.[17]

Tenure choice price elasticity estimates may be biased through omitted variables. An increased ratio of owner to renter prices should imply renter tenure. Ceteris paribus, the value-rent ratio should have the opposite effect, identifying the investment motive for owning. Omission of value-rent ratio may bias the estimated price elasticity toward zero.[18]

Table 4 presents tenure choice equations for households with wage income, where 1 refers to owners (1324 or 67.9%) and 0 to renters (667 or 32.1%). The appropriate significance test for the inclusion of additional (groups of) variables compares log-likelihood ratios.[19] All of the incremental inclusions are significant by this criterion.

[17]Closing costs alone may entail 5 to 10% of the bundle price. Search and moving costs add to this.

[18]Suppose the properly specified equation for probability of owning, f, equals $\beta_0\gamma + \beta_1\psi$. If κ represents the correlation between the price ratio and the value-rent ratio, then omission of the value-rent ratio leads to the estimated probability, $f = (\beta_0 + \beta_1\kappa)\gamma$. Since both β_1 and κ are positive, the coefficient is biased toward 0. The same bias (toward 0) can occur with the omission of the value-rent ratio from the demand equations.

[19]Comparing two probit formulations where the K_1 regressors of the first comprise a subset of the K_2 elements of the second ($K_2 > K_1$), -2 times the log-likelihood ratio is distributed χ^2, with $(K_2 - K_1)$ degrees of freedom.

TABLE 4
Probit Regressions

Variable	1	2	3	4	5
Y^P		0.07973		0.07898	0.09392
		(16.29)		(11.74)	(20.19)
Y^T		0.00652		−0.00749	
		(1.64)		(1.82)	
Y	0.03458		0.02019		
	(10.26)		(5.39)		
RATIO	−0.01613	−0.01922	−0.02192	−0.02248	−0.00682
	(14.70)	(16.21)	(16.13)	(16.01)	(14.07)
VALRENT	0.01744	0.01593	0.01731	0.01580	
	(13.67)	(11.82)	(12.87)	(11.31)	
HHSIZE			0.01207	−0.04695	
			(0.50)	(1.82)	
BLACK			−0.23294	−0.10273	
			(1.97)	(0.84)	
AGE			0.02684	0.02252	
			(10.32)	(8.45)	
MAR			0.79964	0.60010	
			(7.47)	(5.33)	
MALE			−0.42312	−0.71007	
			(3.81)	(6.02)	
−2*LLR	493.61	705.29	694.50	832.68	554.59
L^*	−978.23	−872.39	−877.79	−808.70	−947.74

Note. t statistics in parentheses.

Column 1 of Table 4 presents the simplest model with current income (Y), price ratio (RATIO), and value-rent ratio (VALRENT). Column 2 decomposes Y into Y^P and Y^T. β_P (0.07973) is over twice as large as β (0.03458). The impact of RATIO is now slightly larger than VALRENT.

Columns 3 and 4 add sociodemographic variables and the explanatory power is correspondingly enriched. These variables are certainly correlated with income (either Y or Y^P) but income still has a significant impact. They have a larger relative impact on β than on β_P. The coefficient of VALRENT is almost unchanged, but the impact of relative price increases by over 25%. Column 4 presents the best of the probit formulations and is used to estimate demand.

These regressions also provide verification of the conjecture discussed in (7–9), concerning misspecification of the permanent income instrument. Addition of sociodemographic variables to the current income regression yields income elasticities that are similar in size and in significance to the transitory income coefficients of columns 2 and 4. These reaffirm the importance of explicit models of permanent income.

VALRENT merits further discussion. Its effect is significant and substantial in all formulations. Consider a regression that uses RATIO without VALRENT. Reestimating column 2 without VALRENT (presented here as column 5) yields a coefficient of RATIO of −0.00682, or only about 30% of the true coefficient, confirming earlier fears of bias toward 0 when VALRENT is omitted. Increasing both VALRENT and RATIO by one unit (columns 3 or 4) shows a net negative impact on the probability of owning.

The tenure choice regression (column 4) is then used to form Mill's ratio for the demand regression. The fitted value of the probit function for the jth household, I_j, is computed. The estimated probability that the jth family owns rather than rents is $G(I_j)$, where $G(\cdot)$ is the value of the cumulative normal distribution. The second stage variables then become

$$\lambda_o = g(I_j)/G(I_j) \tag{21a}$$

$$\lambda_r = -g(I_j)/G(-I_j) \tag{21b}$$

for owners and renters, respectively, where $g(\cdot)$ is the ordinate of the standard normal distribution, following Lee and Trost [16] and Rosen [21]. Such estimates have customarily been performed in two steps, although simultaneous estimation of the probit and the demand regressions leads to more efficient estimates. Simultaneous estimates are performed here where feasible, although the iterative algorithms do not always converge.[20]

d. Demand Estimates

Having linked the estimated demand elasticities with the tenure choice decision (13)–(17) algebraically, this section examines the empirical results. Tenure choice and housing demand are shown to be jointly determined. Variables have complicated impacts through the different estimation stages.

Tables 5 and 6 present linear owner and renter demand regressions, with tenure choice adjustments, λ_o and λ_r. Columns 1 and 2 show the interaction of tenure choice and demand in a model that uses permanent income. Standard errors are corrected for selection, and ρ^2 is the squared correlation between the demand disturbance and the tenure choice equation. The permanent income elasticity is 0.206 (0.173, in column 2); price elasticity is −0.450 (−0.499, in column 2).[21] Age has a negative impact, household size has little impact, and blacks purchase less housing. These results suggest that a large portion of the demand response to owner price is manifested

[20] The program LIMDEP is used for these estimates. Greene [11] notes that convergence is not always achieved in problems of this type.

[21] Estimates that (incorrectly) omit the adjustments yield income elasticities up to 50% higher.

TABLE 5
Owner Demand Regressions

Variable	QOWN 1	2	3	4
Y^P	0.0138	0.0115		0.02059
	(3.95)	(3.04)		(5.85)
Y^T	0.0202	0.0201		0.02045
	(10.00)	(9.95)		(14.39)
Y			0.0184	
			(9.99)	
PO	−2E − 05	−2E − 05	−2E − 05	−2E − 05
	(5.10)	(6.60)	(7.04)	(5.78)
VALRENT	0.0059	0.0064	0.0065	0.0063
	(8.60)	(9.97)	(9.28)	(8.66)
AGE		−0.007	−0.007	
		(4.03)	(3.97)	
HHSIZE		−0.003	−0.008	
		(0.16)	(0.50)	
BLACK		−0.195	−0.186	
		(2.31)	(2.17)	
MALE		0.1398	0.0859	
		(1.41)	(0.88)	
λ_o	−0.651	−0.740	−0.626	
	(7.87)	(8.51)	(8.25)	
CONSTANT	1.1366	1.5547	1.4323	0.9021
	(8.45)	(9.04)	(8.67)	(5.92)
N	1324	1324	1324	1324
MSE	0.8697	0.8862	0.8585	
ρ^2	0.5610	0.6963	0.5326	0.1972
R^2	0.2643	0.2574	0.2728	
η_Y	0.206	0.173	0.286	0.308
η_P	−0.450	−0.499	−0.531	−0.502

Note. t statistics in parentheses.

through the tenure choice decision. *Current*, rather than permanent income, provides better results in the demand estimates. Column 3 presents the estimated demand elasticities using current income. Owner income elasticity is now 0.286. Permanent income may have its major impact on tenure choice rather than on quantity demanded (or expenditures). Further discussion below, concerning maximum likelihood estimates, strengthens this contention.

Similar results occur in the renter regressions. As noted in Table 6, current income again provides a preferable estimate of income elasticity, given the sample selection. As with the owner estimates, the tenure choice adjustment is highly significant, leading to rejection of the hypothesis that

TABLE 6
Renter Demand Regressions

Variable	QR 1	2	3
Y^P	0.0106	0.0066	
	(3.04)	(1.59)	
Y^T	0.0163	0.0168	
	(7.56)	(7.99)	
Y			0.146
			(7.93)
PR	−4E − 04	−7E − 04	−0.001
	(0.61)	(1.03)	(1.67)
VALRENT	0.008	0.009	0.0011
	(1.78)	(2.08)	(2.46)
AGE		−0.006	−0.006
		(4.66)	(4.59)
MALE		−0.0324	−0.01
		(0.71)	(0.24)
BLACK		−0.073	−0.066
		(1.60)	(1.46)
HHSIZE		0.0164	0.0117
		(1.44)	(1.43)
MAR		−0.032	−0.023
		(0.71)	(0.51)
λ_r	−0.154	−0.244	−0.183
	(3.73)	(4.86)	(4.44)
CONSTANT	0.7581	0.0957	0.002
	(5.36)	(6.17)	(6.56)
N	627	627	627
MSE	0.3841	0.4017	0.3850
ρ^2	0.1610	0.3685	0.2270
R^2	0.1737	0.2035	0.1991
η_Y	0.134	0.0839	0.195
η_P	−0.389	−0.154	−0.239

Note. t statistics in parentheses.

the errors in the single equation tenure and demand estimates are uncorrelated. Income elasticities at the means are lower than for owners, although evaluation at owner incomes (as suggested by Goodman and Kawai [8]) makes them roughly comparable.

The Heckman two-stage procedure provides consistent but inefficient estimates. Maximum likelihood methods can be used where feasible to estimate tenure choice and demand more efficiently. Table 5 (column 4) jointly estimates probit and owner demand (it was impossible to obtain

TABLE 7
Partial and Full Elasticities
Joint Tenure and Demand Estimation

	1	2	3	4
Income	YP	YP	Y	YP (mle)
$\eta_{Q_o Y}$	0.206	0.173	0.285	0.308
$\eta_{Q_r Y}$	0.134	0.084	0.195	0.134
η_Y^*	0.337	0.301	0.413	0.423
Price				
η_{P_o}	−0.450	−0.499	−0.531	−0.502
η_{P_r}	−0.089	−0.154	−0.239	−0.089
$\eta_{P_o}^*$	−0.724	−0.766	−0.792	−0.768
$\eta_{P_r}^*$	0.326	0.311	0.292	0.326
η_P^*	−0.398	−0.454	−0.500	−0.460
Value-rent				
η_ψ^*	0.727	0.775	0.789	0.760
Net: Price and value-rent				
$\eta_{P:\psi}^*$	0.320	0.312	0.276	0.302

convergence for renter demand; regressions containing more variables also did not converge). This more efficient estimate shows Y^P to be essentially equal to Y^T. This provides further support for Y in the demand regression, as opposed to Y^P in the tenure choice regression. Price elasticity is also higher in the maximum likelihood than in the other regressions.

Equations (13)–(17) are now evaluated, using mean permanent income of \$20,521, mean Q_o of 1.525, and mean Q_r of 1.038 (the price indices were defined with the same bundle, thus the amounts of housing are comparable). Function $f(\cdot)$ is evaluated at the mean values of the parameters of the probit function in Table 4 (column 4), as 0.78. Elasticities are estimated for the four owner and renter regressions from Tables 5 and 6.[22] Values are displayed in Table 7. Columns 2 and 3 (for permanent and current incomes, respectively) are discussed further.

The permanent income elasticity of tenure choice from the probit regression, η_{fY}, is 0.589. Equation (13) is evaluated to provide η_Y^* of 0.301 (0.413

[22] The maximum likelihood estimate for owner housing does not have a rental counterpart, so it uses the same renter parameters as does column 2.

APPENDIX: VARIABLE DEFINITIONS

Descriptive

Variable	Definition
AGE	age of household head
HHSIZE	household size
BLACK	1 if black, 0 otherwise
MALE	1 if male-headed household, 0 otherwise
INCOME	current income
SWORK	1 if second worker in household, 0 otherwise
MOVED	time in dwelling unit
RENT	dwelling unit rent
VALUE	dwelling unit value
ROOMS	number of rooms
BUILT	age of unit

Housing

Variable	Definition
AIRSYS	1 if central air, 0 otherwise
BADHEAT	1 if heating breakdowns in past 90 days, 0 otherwise
BATHR	number of full bathrooms
BEDRMS	number of bedrooms
BRKDOWNS	number of utility breakdowns in past 90 days
BUILT	age of house in year
CELLAR	1 if full cellar, 0 otherwise
CFUELE	1 if electricity used for cooking, 0 otherwise
CRACKS	1 if open holes or cracks, 0 otherwise
HADDL	1 if additional heating equipment used, 0 otherwise
HEQP	1 if steam heat, 0 otherwise
HFUEL	1 if gas heat, 0 otherwise
HOWHR	rating of dwelling, 1 (best), . . . , 4 (worst)
HOWNR	rating of neighborhood, 1 (best), . . . , 4 (worst)
IFBLOW	1 if fuses blown in past 90 days, 0 otherwise
LAV	number of lavatories
MOVED	years residing in dwelling unit
NUMU	number of dwelling units in structure
NUNMD	number of rooms without hot air ducts
PLASTER	1 if plaster broken over 1 foot^2, 0 otherwise
PRIVNR	1 if access to other rooms through bedroom, 0 otherwise
RATS	1 if signs of rats in past 90 days, 0 otherwise
ROOMS	number of rooms

LNTAX	logarithm of property tax rate
GARAGE	garage/carport available for use
NCENT	1 if North Central region, 0 otherwise
SOUTH	1 if South region, 0 otherwise
WEST	1 if West region, 0 otherwise
CC	1 if Central City of SMSA, 0 otherwise
CAL	1 if California, 0 otherwise
NYC	1 if New York City region (NY–NJ–CT), 0 otherwise
DC	1 if Washington, D.C. region, 0 otherwise
ELEVI	1 if passenger elevator in building, 0 otherwise
EXTRA	number of extra features included in rent
FLOORS	number of stories in building
PAYHT	1 if heat included in rent, 0 otherwise
SF	1 if single family structure, 0 otherwise

Permanent Income

Variable	Definition
GRADEA	1 if some high school, 0 otherwise
GRADEB	1 if high school graduate, 0 otherwise
GRADEC	1 if some college, 0 otherwise
GRADED	1 if college graduate, 0 otherwise
GRADEE	1 if graduate education, 0 otherwise
AGE1	1 if age 14–19, 0 otherwise
AGE2	1 if age 20–24, 0 otherwise
AGE3	1 if age 25–29, 0 otherwise
AGE4	1 if age 30–34, 0 otherwise
AGE5	1 if age 35–39, 0 otherwise
AGE6	1 if age 40–44, 0 otherwise
AGE7	1 if age 45–49, 0 otherwise
AGE8	1 if age 50–54, 0 otherwise
AGE9	1 if age 55–59, 0 otherwise
AGE10	1 if age 60–64, 0 otherwise
AGE11	1 if age 65–69, 0 otherwise
AGE12	1 if age 70–74, 0 otherwise
BLACK	1 if black, 0 otherwise
MALE	1 if male, 0 otherwise
MAR	1 if married, 0 otherwise
SWORK	1 if second household worker, 0 otherwise
NCENT	1 if North Central region, 0 otherwise
SOUTH	1 if South region, 0 otherwise
WEST	1 if West region, 0 otherwise
CAL	1 if California, 0 otherwise

NYC	1 if New York City region (NY–NJ–CT), 0 otherwise
DC	1 if Washington, D.C. region, 0 otherwise

Demand

Variable	Definition
Y^P	permanent income
Y^T	transitory income
Y	measured income ($Y = Y^P + Y^T$)
RATIO	owner to renter price ratio
VALRENT	value-rent ratio
HHSIZE	household size
BLACK	1 if black, 0 otherwise
MALE	1 if male-headed household, 0 otherwise
AGE	age of household head
MAR	1 if married, 0 otherwise

REFERENCES

1. R. Barnes and R. Gillingham, Demographic effects in demand analysis: Estimation of the quadratic expenditure system using microdata, *Rev. Econom. Statist.*, **66**, 591–601 (1984).
2. G. E. P. Box and D. R. Cox, An analysis of transformations, *J. Roy. Statist. Soc. Ser. B*, **26**, 211–243 (1964).
3. R. V. Butler, Cross-sectional variation in the hedonic relationship for urban housing markets, *J. Reg. Sci.*, **20**, 439–453 (1980).
4. G. G. Cain, The challenge of segmented labor market theories to orthodox theory: A survey, *J. Econom. Lit.*, **14**, 1215–1257 (1976).
5. A. Dougherty and R. Van Order, Inflation, housing costs, and the consumer price index, *Amer. Econom. Rev.*, **72**, 154–164 (1982).
6. J. R. Follain, Jr., Does inflation affect real behavior: The case of housing, *South. Econom. J.*, **48**, 570–582 (1982).
7. A. C. Goodman and M. Kawai, Permanent income, hedonic prices and demand for housing: New evidence, *J. Urban Econom.*, **12**, 214–237 (1982).
8. A. C. Goodman and M. Kawai, Replicative evidence on the demand for owner-occupied and renter housing, *South. Econom. J.*, **50**, 1036–1057 (1984).
9. A. C. Goodman and M. Kawai, Functional form, sample selection and housing demand, *J. Urban Econom.*, **10** (1986).
10. W. M. Gorman, Tricks with utility functions, *in* "Essays in Economic Analysis" (M. J. Artis and A. R. Nobay, Eds.). Cambridge Univ. Press, Cambridge (1976).
11. W. H. Greene, *LIMDEP*, Greene, Brooklyn (1985).
12. B. W. Hamilton, Capitalization of intrajurisdictional differences in local tax prices, *Amer. Econom. Rev.*, **66**, 743–753 (1976).
13. J. J. Heckman, Sample selection bias as a specification error, *Econometrica*, **47**, 153–161 (1979).
14. J. J. Heckman and S. Polachek, Empirical evidence on the functional form of the earnings–schooling relationship, *J. Amer. Statist. Assoc.*, **69**, 350–354 (1974).
15. J. F. Kain and J. M. Quigley, "Housing Markets and Racial Discrimination, Columbia Univ. Press, New York (1975).

16. L.-F. Lee and R. P. Trost, Estimation of some limited dependent variable models with application to housing demand, *J. Economet*, **8**, 357–382 (1978).
17. P. Linneman, Some empirical results on the nature of the hedonic price function for the urban housing market, *J. Urban Econom.*, **8**, 47–68 (1980).
18. S. K. Mayo, Theory and estimation in the economics of housing demand, *J. Urban Econom.*, **11**, 95–116 (1981).
19. R. S. Phillips, "Metropolitan Housing Capitalization Rates: Explaining Intertemporal and Cross-Sectional Variation," University of California, San Diego (1984).
20. R. A. Pollak and T. J. Wales, Demographic variables in demand analysis, *Econometrica*, **49**, 1533–1551 (1981).
21. H. S. Rosen, Housing decisions and the U.S. income tax: An econometric analysis, *J. Public Econom.*, **11**, 1–24 (1979).
22. S. Rosen, Hedonic prices and implicit markets: Product differentiation in pure competition, *J. Politic. Econom.*, **82**, 34–55 (1974).
23. R. M. Schwab, Inflation expectations and the demand for housing, *Amer. Econom. Rev.*, **72**, 143–153 (1982).
24. J. C. Weicher, K. E. Villani, and E. A. Roistacher, "Rental Housing: Is There a Crisis?" Urban Institute Press, Washington, DC (1981).