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Following a panel of stayers: Length of stay, tenure choice, and housing demand

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Abstract

Due to moving and transactions costs, most housing buyers do not routinely move in response to small changes in income or housing price. In this paper, the "own–rent," "move–stay," and length-of-stay decisions are modeled as multi-period optimization in the presence of transactions costs. The empirical section uses the American Housing Survey to provide a unique 12-year panel of household stayers for the Detroit metropolitan area. Results indicate that income and value–rent measures in different years have separable and significant impacts on housing demand. Estimated full income elasticities are between 0.30 and 0.35.

Keywords: Housing demand; Tenure choice; Length of stay

1. Introduction

Recently, analysts have come to examine housing demand as a multi-period optimization in the presence of transactions costs. Goodman (2002) implemented such a model empirically by examining a single cohort of home-owners who had been in their dwelling units for eight or more years—looking at their demand and tenure choice as functions of multiple measures of prices and incomes. These income measures provided important insights into the estimation of demand for a group that did *not* adjust their housing consumption. It was a "snapshot" of housing demand, albeit a complex one based on a single group of stayers.

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Whereas the previous study examined a limited portion of a 1981 housing panel (those who owned and who remained in their homes in 1985 and 1989), this study looks at all of them. Some are renters and others are owners; some move after one year, and others stay the full 12 years. Most trivially, it extends the panel from eight to 12 years, which allows more moving and provides additional measures of income and price. Second, it provides for sequential estimation of demand for those who leave the sample, and for those who stay. Third, while the earlier work treated length of stay as exogenous to the model—this work introduces hazard analysis to that model to ascertain the determinants of length of stay. Fourth, this paper broadens an earlier definition of *expected demand* to provide a measure that attempts to bridge the micro- and the macroeconometric literatures that measure demand elasticity.

After briefly reviewing the literature, I provide a discrete time multi-period consumer optimization model with transactions costs. I then propose a general econometric framework for estimating the model, and present a panel household database that has been created and enlarged from the American Housing Survey (AHS). The primary finding is that in a multi-period model, the impacts of incomes and price variables from different periods are separable and significant. Length of stay has measurable and important effects.

2. Multiple period frameworks

Goodman (1989, 1990) derives a model in which the transactions costs of changing dwellings are essentially infinite. The two-period framework, while useful for exposition, ignores the decisions on how long to stay, and how often to move. Goodman (1995) links the static housing demand model to mobility analysis and considers a multi-period model that shows the equilibrium conditions, demonstrates that they are unique, and presents comparative statics.

Others have modeled transactions costs in adjusting activity levels. Hu (1980) considers the appropriate adjustments to capital stock when the transactions costs are large. In housing analysis, Muth (1974) examines moving costs in the context of long-term housing expenditures. For a consumer with perfect foresight who can access perfect capital markets, Amundsen (1985) shows how the optimal number of moves is related to moving costs, income, and preferences for housing, and he demonstrates, under simplified conditions, that the moves are equally spaced.[1]

These models do not address several aspects of housing analysis. The first is consumer choice under imperfect capital markets. The permanent income hypothesis suggests that consumers can easily borrow against future earnings, but “real life lenders” impose limits. The considerable literature on liquidity constrained

[1] Ai et al. (1990), Edin and Englund (1991), and Henderson and Ioannides (1989) conduct empirical studies on moving costs and housing demand.

borrowing (Duca and Rosenthal, 1993; or Jones, 1990, for example) suggests major capital market imperfections, particularly early in peoples' earning lives.

The second aspect involves linkages between demand and mobility. Most models view consumers either as purchasing housing services in equilibrium, or as moving when out of equilibrium. How are the two linked, and what indicators can be used to predict mobility? Most recently Haurin and Gill (2002) confirm that expected length of stay and the transactions costs of selling are very important to the ownership decision. They estimate the transaction cost of selling a home as the sum of 3% of the house value and 4% of household savings.

Third, consumers' optimal housing purchases may change over time, particularly with respect to life cycle variables such as family size, number of children, or retirement. A model permitting parameterization of the relative demands for housing and other goods to vary over time allows a more realistic characterization of the path of housing consumption.

Consider a consumer at time 0, optimizing over T periods, over housing consumption h_t (with price p_t) and consumption of all other goods c_t (with price 1). The transactions cost of moving each period is TC_t. If the consumer plans to move each period, assuming perfect capital markets, annual income y_t, transactions costs TC_t, interest rate r, and rate of time preference ξ, the optimization problem is:

$$\Lambda^* = \sum_{t=1}^{t=T} (1+\xi)^{1-t} U^t(h_t, c_t) + \lambda \left[\sum_{t=1}^{t=T} \left(\frac{y_t}{(1+r)^{t-1}} - \frac{p_t h_t}{(1+r)^{t-1}} - \frac{c_t}{(1+r)^{t-1}} - \frac{TC_t}{(1+r)^{t-1}} \right) \right]. \tag{1}$$

Without perfect capital markets the problem is:

$$\Lambda^{**} = \sum_{t=1}^{t=T} (1+\xi)^{1-t} U^t(h_t, c_t) + \sum_{t=1}^{t=T} \lambda_t (y_t - p_t h_t - c_t - TC_t). \tag{1'}$$

Staying in the same unit, providing $\bar{h}$ for the first T_m periods (where $T_m > 1$), permits the consumer to save moving costs, while incurring immobility costs (in terms of foregone utility):

$$\Lambda^* = \sum_{t=1}^{t=T_m} (1+\xi)^{1-t} U^t(\bar{h}, c_t) + \lambda \left[\sum_{t=1}^{t=T_m} \left(\frac{y_t}{(1+r)^{t-1}} - \frac{p_t \bar{h}}{(1+r)^{t-1}} - \frac{c_t}{(1+r)^{t-1}} \right) \right]. \tag{2}$$

or:

$$\Lambda^{**} = \sum_{t=1}^{t=T_m} (1+\xi)^{1-t} U^t(\bar{h}, c_t) + \sum_{t=1}^{t=T_m} \lambda_t (y_t - p_t \bar{h} - c_t). \tag{2'}$$

Given the multi-dimensional vectors of incomes, prices, and preferences, the consumer solves for:

1. Number of stays (alternatively number of moves), m.
2. Length of each stay (alternatively, number of periods between moves), $S_m = (T_m - T_{m-1})$, with the sum of all stays equaling the entire length of time the consumer purchases housing.
3. Housing consumed during each stay, $\bar{h}^{\mathrm{m}}$.
4. Non-housing consumption during each period, c_t.

For either (2) or (2′) each stay's multi-period equilibrium is summarized by Eq. (3) with the MU_t^y (marginal utility of income) weighted sum of differences between the marginal rate of substitution (MRS) and price ratio over the multi-period stay equaling 0.

$$\sum_{t=1}^{t=T_m} \mathrm{MU}_t^y \ (\mathrm{MRS}_t - p_t) = 0, \tag{3}$$

Each period's income and housing price, prices of other goods, and other sociodemographic characteristics, influence the housing quantity purchased during the *entire stay,* even for households that do not move.[2]

This, then, is a "certainty model," assuming that households look forward with respect to economic parameters, wealth accumulation, and changes in family size and structure. It contrasts with models in which staying households are periodically "out of equilibrium" as defined by single period equality of Eq. (3), due to changes in price or income (described in O'Sullivan, 2003, Chapter 17). It also contrasts with models that explicitly examine the impacts of uncertain events on housing choices (such as a simulation study by Chung and Haurin (2002)).

3. An econometric framework

This section provides a format for interpreting owner and renter demand in a unified framework. Goodman (1988, 1989) defines expected housing quantity as:

$$\text{Expected } Q = \text{Expected Owner } Q + \text{Expected Renter } Q,$$

$$H(Q) = fQ_{\mathrm{o}} + (1-f)Q_{\mathrm{r}}, \tag{4}$$

where f is a tenure choice probability, and f, Q_{o} and Q_{r} are functions of income y. He then totally differentiates (4) to get a "full elasticity" with respect to income where the η terms represent elasticities conditional on tenure choice:

$$\mathrm{Elas}_y^* = \frac{(1-f)\eta_{Q_{\mathrm{r}}y}Q_{\mathrm{r}}}{H(Q)} + \frac{f\eta_{Q_{\mathrm{o}}y}Q_{\mathrm{o}}}{H(Q)} + \left[1 - \frac{Q_{\mathrm{r}}}{H(Q)}\right]\eta_{fy}. \tag{5}$$

Consider a more detailed framework for following an initial panel of households, whether they own or rent *and* whether they move or stay:

[2] Equilibrium values of MU_t^y and MRS_t under perfect capital markets are not the same as the equilibrium values occurring when capital markets are imperfect.

$$\text{Expected } Q = \text{Expected Owner-stayer } Q + \text{Expected Renter-stayer } Q + \text{Expected Owner-mover } Q + \text{Expected Renter-mover } Q,$$

$$H(Q) = k_o^s Q_o^s + k_r^s Q_r^s + k_o^m Q_o^m + k_r^m Q_r^m, \tag{6}$$

where:

Q_o^s = housing demand for owner-stayers
Q_o^m = housing demand for owner-movers,

Q_r^s = housing demand for renter-stayers
Q_r^m = renter demand for renter-movers,

and k_o^s, k_r^s, k_o^m and k_r^m are probabilities of being in one of the four (tenure choice, mover–stayer) cells, recognizing that $k_o^s + k_r^s + k_o^m + k_r^m = 1$.

Totally differentiating (6), and concentrating on $k_o^s Q_o^s$:

$$\text{Elas}_y^* = \frac{dH}{dy}\frac{y}{H} = k_o^s \frac{Q_o^s}{H}\left[\frac{dQ_o^s}{dy}\frac{y}{Q_o^s} + \frac{dk_o^s}{dy}\frac{y}{k_o^s}\right] + \text{similar terms for } k_r^s,\ k_o^m \text{ and } k_r^m.$$

or:

$$\text{Elas}_y^* = \frac{dH}{dy}\frac{y}{H} = k_o^s \frac{Q_o^s}{H}\left[E_{Q_o}^s y + E_{k_o}^s y\right] + \text{similar terms for } k_r^s,\ k_o^m \text{ and } k_r^m. \tag{7}$$

The first term in brackets describes owner–stayers, the "standard" single equation demand elasticity. Adding the second term (change in probability of being in the owner–stayer category) shows what happens in the owner–stayer category over time.

This analytical framework links the cross-section and time series literatures on income elasticities. The time series work such as Muth (1960) or Reid (1962) looks at annual aggregates, which internalize tenure and moving adjustments and finds elasticities of +1.0 or higher. The cross-section literature, which either examines movers or stayers, generally in place, finds elasticities much smaller than +1.0. By deconstructing some of the adjustments for a panel of stayers, this article attempts to bridge the theoretical and empirical differences between the literatures.

4. Hazard analysis

One of the major features of a model of stayers involves length of stay, which is jointly determined with prices, income, and preferences. Goodman (2002) models length of stay as endogenous, yet it is important to address its role.

The goal is to characterize the length of the observed stay, denoted by T. The cumulative distribution of T is:

$$F(t) = \int_0^t f(s)\,ds = \text{ Prob } (T \leqslant t), \tag{8}$$

where s represents length of stay, and $f(s)$ is a probability density function (PDF). The survival function $S(t)$ is the probability that a stay will still be in progress at length t:

$$S(t) = 1 - F(t) = \text{Prob}(T > t). \tag{9}$$

To address the probability that the stay will end in the next interval, Δt, define hazard rate $\lambda(t) = f(t)/S(t)$ as the instantaneous rate of termination for a stay still in progress at length t.

The functions also estimate median lengths of estimated durations. Both the *hazard* function and the *survival* function (from Eq. (8)) provide important information. The hazard function indicates whether one can expect the stay to end with higher or lower probability as duration increases.

Most standard statistical software provides distributions including exponential, Weibull, log-normal, and log-logistic. Following Peng et al. (1998) these distributions are subsets of the generalized F distribution with the following density function and survival function:

$$f(t; s_1, s_2) = (s_1 e^w/s_2)^{s_1}(1 + s_1 e^w/s_2)^{-(s_1+s_2)} B(s_1, s_2)^{-1}/(t\sigma), \tag{10}$$

$$S(t; s_1, s_2) = \int_0^{s_2(s_2+s_1 e^w)^{-1}} x^{s_2-1}(1-x)^{s_1-1} B(s_2, s_1)^{-1} \mathrm{d}x, \tag{11}$$

where $w = (\log\ t - \mu)/\sigma$. Also, $-\infty < \mu < \infty$, $\sigma > 0$, s_1, $s_2 > 0$, and B is the beta function.

This function subsumes most common alternatives, including the following special cases:

Weibull if $s_1 = 1, s_2 \to \infty$,	Lognormal if $s_1, s_2 \to \infty$
Exponential if $s_1 = 1, s_2 \to \infty, \sigma = 1$,	Log-logistic if $s_1 = s_2 = 1$

Extended generalized gamma (EGG) if $s_1 \to$ or $s_2 \to \infty$.

From here one estimates the length of stay $\log T$, where W is an error term:

$$\log T = X'\beta + \sigma W,\ \text{or}\ T = \exp(\log T) = e^{X'\beta}e^{\sigma W}. \tag{12}$$

5. Sequential bivariate probit

Testing the theoretical model presents challenges. One would desire to follow a panel of households over time, seeing some move, possibly several times, and some stay. The theoretical model does not explicitly model tenure choice, so any empirical housing work must address issues of owning as opposed to renting, particularly regarding the roles of moving and transactions costs.

The database covers households in the Detroit metropolitan area in 1981, 1985, 1989, and 1993. Beginning with a sample of 1981 households:

1. Were they owners or renters?
2. Did they stay in the dwelling unit from one year to the next?

3. Conditional on (1) and (2), how much housing did they own (rent) during their stay?

Estimating consumer behavior suggests a joint relationship between housing tenure (own/rent) and the move/stay decision. Shelton (1968) and others since have modeled the economic factors that lead renters to shorter (implicitly more likely to move in any time interval) housing tenures than owners. A bivariate probit model (Catsiapis and Robinson, 1982; Ermisch, 1996; Greene, 2000; Maddala, 1983) will estimate the joint relationship for tenure f and probability of staying g at a *given* time:

$f = 1$ if and only if the household owned, with $f = 0$ referring to renter housing.

$g = 1$ if and only if the household "stays," with $g = 0$ otherwise.[3]

Goodman (2002) uses this method to estimate 1989 housing demand by households who were in the sample in 1981 and 1985.

Owners: $f = f$ (Income, Prices, Demographics, Length of Stay) + ε_f

Stayers: $g = g$ (Income, Implicit immobility costs, Demographics, Length of Stay) + ε_g

The estimated correlation of errors ε_f and ε_g is ρ. The specific variables are discussed in Section 6.

The current project is more ambitious. Fig. 1 follows all households (owners and renters) who started in the 1981 panel. For all of the 1981 households, I estimate length of stay as of 1981. Subsequent to 1981 these households either moved or stayed. The movers have left the sample, so I estimate their 1981 demand during their stay based on the 1981 incomes, prices and demographics. This provides fractions that moved, and demand elasticities, to be applied to Eq. (7).

For 1985, the process is repeated. For the remaining households from the 1981 cohort, I re-estimate 1985 length of stay (which must now be at least 4 years). Again, subsequent to 1985 these households either moved or stayed, and I estimate the movers' demand during their stay based on the 1981 and 1985 values of incomes, prices, and demographics. The process is repeated for 1989 (similar to Goodman, 2002), with three rounds of information on prices and incomes, and for 1993, with four rounds of information.

This leads to following set of full elasticities, using Eq. (7). To account for the panel nature of the sample, add parameters $s^{\mathrm{s}}_{\mathrm{o}}$, $s^{\mathrm{s}}_{\mathrm{r}}$, $s^{\mathrm{m}}_{\mathrm{o}}$, and $s^{\mathrm{m}}_{\mathrm{r}}$ that indicate the share of the entire cohort estimated as of 1981, 1985, 1989, and 1993. Hence:

$$\begin{aligned} H(Q) &= s^{\mathrm{s}}_{\mathrm{o}}k^{\mathrm{s}}_{\mathrm{o}}Q^{\mathrm{s}}_{\mathrm{o}} + s^{\mathrm{s}}_{\mathrm{r}}k^{\mathrm{s}}_{\mathrm{r}}Q^{\mathrm{s}}_{\mathrm{r}} + s^{\mathrm{m}}_{\mathrm{o}}k^{\mathrm{m}}_{\mathrm{o}}Q^{\mathrm{m}}_{\mathrm{o}} + s^{\mathrm{m}}_{\mathrm{r}}k^{\mathrm{m}}_{\mathrm{r}}Q^{\mathrm{m}}_{\mathrm{r}} \\ &= \sum_{j=81,85,89,93} s^{\mathrm{s}}_{\mathrm{o},j}k^{\mathrm{s}}_{\mathrm{o},j}Q^{\mathrm{s}}_{oj} + \sum_{j=81,85,89,93} s^{\mathrm{s}}_{\mathrm{r},j}k^{\mathrm{s}}_{\mathrm{r},j}Q^{\mathrm{s}}_{rj} + \sum_{j=85,89,93} s^{\mathrm{m}}_{\mathrm{o},j}k^{\mathrm{m}}_{\mathrm{o},j}Q^{\mathrm{m}}_{\mathrm{o},j} \\ &\quad + \sum_{j=85,89,93} s^{\mathrm{m}}_{\mathrm{r},j}k^{\mathrm{m}}_{\mathrm{r},j}Q^{\mathrm{m}}_{\mathrm{r},j} \end{aligned}$$

or:

[3] Strictly speaking, f and g are continuous latent variables and the observable dichotomous ones are defined relative to these variables' crossing the zero threshold or not. This is analogous to comparing staying costs (in foregone utility) with moving costs, for the move-stay decision, and comparing owner and renter costs, for the tenure choice decision.

For households who started in the 1981 database

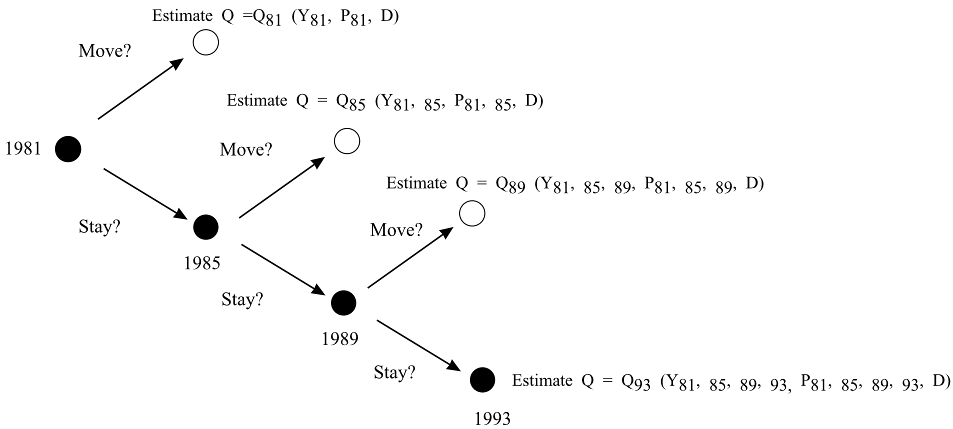

Fig. 1. Selection model.

$$\begin{aligned}
\mathrm{Elas}^{*}_{y} &= \frac{\mathrm{d}H}{\mathrm{d}y}\frac{y}{H} \\
&= \underbrace{\sum_{j=81,85,89,93} \frac{s^{\mathrm{s}}_{\mathrm{o}} k^{\mathrm{s}}_{\mathrm{o}} Q^{\mathrm{s}}_{\mathrm{o}}}{H}\left[E_j^{Q^{\mathrm{s}}_{\mathrm{o}} y} + E_j^{k^{\mathrm{s}}_{\mathrm{o}} y} + E_j^{s^{\mathrm{s}}_{\mathrm{o}} y}\right]}_{\text{[a. Owner-stayer]}} + \underbrace{\sum_{j=81,85,89,93} \frac{s^{\mathrm{s}}_{\mathrm{r}} k^{\mathrm{s}}_{\mathrm{r}} Q^{\mathrm{s}}_{\mathrm{r}}}{H}\left[E_j^{Q^{\mathrm{s}}_{\mathrm{r}} y} + E_j^{k^{\mathrm{s}}_{\mathrm{r}} y} + E_j^{s^{\mathrm{s}}_{\mathrm{r}} y}\right]}_{\text{[b. Renter-stayer]}} \\
&\quad + \underbrace{\sum_{j=85,89,93} \frac{s^{\mathrm{m}}_{\mathrm{o}} k^{\mathrm{m}}_{\mathrm{o}} Q^{\mathrm{m}}_{\mathrm{o}}}{H}\left[E_j^{Q^{\mathrm{m}}_{\mathrm{o}} y} + E_j^{k^{\mathrm{m}}_{\mathrm{o}} y} + E_j^{s^{\mathrm{m}}_{\mathrm{o}} y}\right]}_{\text{[c. Owner-mover]}} \\
&\quad + \underbrace{\sum_{j=85,89,93} \frac{s^{\mathrm{m}}_{\mathrm{r}} k^{\mathrm{m}}_{\mathrm{r}} Q^{\mathrm{m}}_{\mathrm{r}}}{H}\left[E_j^{Q^{\mathrm{m}}_{\mathrm{r}} y} + E_j^{k^{\mathrm{m}}_{\mathrm{r}} y} + E_j^{s^{\mathrm{m}}_{\mathrm{r}} y}\right]}_{\text{[d. Renter-mover]}}. \qquad (7')
\end{aligned}$$

In a full panel that followed both movers and stayers one could estimate all four impacts in Eq. (7′). Analysts who examine movers only measure impacts [c] and [d]. Focusing on stayers, I will be measuring impacts [a] and [b], realizing that as detailed as these are, they are but partial effects.

6. Full model

The analysis uses a seven-equation model. The first two equations establish instruments for permanent income (one equation each for owner and renter) and housing price (again, one equation each for owner and renter). The third equation estimates length of stay in the dwelling. The fourth and fifth equations jointly estimate tenure choice (owner–renter status) and mover–stayer status. The sixth and seventh equations estimate owner and renter housing demand, respectively, conditional on staying in the same dwelling unit.

Permanent income estimates follow the cross-sectional method proposed by Goodman and Kawai (1982), as return r_h on human capital vector $\boldsymbol{H}$ and return r_n on non-human capital vector $\boldsymbol{N}$:

$$Y^P = r_h\boldsymbol{H} + r_n\boldsymbol{N}. \tag{13}$$

Substituting Eq. (12) into the identity that current income Y equals the sum of its permanent (Y^P) and transitory (Y^T) components, or $Y = Y^P + Y^T$, yields:

$$Y = r_h\boldsymbol{H} + r_n\boldsymbol{N} + u. \tag{14}$$

Here, predicted value of the regression on human capital variables including age, education, gender, and race, and non-human capital variables including financial assets, is taken as permanent income. In a single period model, the residual u is treated as transitory income Y^T.

Error term u may contain systematic components attributable to unmeasured luck, skills or effort. These components cannot be identified in cross-sectional regressions, but they can be estimated for households with more than one observation. For those in the sample two, three, or four years, $\bar{u}_2 = (\hat{u}_{81} + \hat{u}_{85})/2$, $\bar{u}_3 = (\hat{u}_{81} + \hat{u}_{85} + \hat{u}_{89})/3$, or $\bar{u}_4 = (\hat{u}_{81} + \hat{u}_{85} + \hat{u}_{89} + \hat{u}_{93})/4$ were calculated, respectively. Systematic effects $\bar{u}_2$, $\bar{u}_3$, or $\bar{u}_4$ were then added to fitted values of wage Eq. (14) for each year as permanent income, and subtracted from $\hat{u}$ as transitory income.

Housing prices use hedonic price equations following the formula:

$$\log V = v_0^o + \sum v_0^o x_k + v_G^o G + \zeta_o, \tag{15a}$$

$$\log R = v_0^r + \sum v_0^r x_k + v_G^r G + \zeta_r, \tag{15b}$$

where $V(R)$ = the value (rent) of the dwelling unit, depending on vector X of housing attributes, and location G. House and rent price indices are calculated over geographic areas G for standardized bundles X^* such that $P_o^G = V(X^*, G)$ and $P_r^G = R(X^*, G)$.

The specification of tenure choice follows Goodman (1988).

$$\textit{Owners}:\ f = \mu_Y Y + \mu_P\left(\frac{P_o}{P_r}\right) + \mu_V\left(\frac{V}{R}\right) + \sum \mu_D D + \mu_L L + \varepsilon_f. \tag{16a}$$

$$\textit{Stayers}:\ g = \alpha_Y Y + \sum \alpha_\sigma \sigma + \sum \alpha_D D + \alpha_L L + \varepsilon_g. \tag{16b}$$

The correlation of ε_f and ε_g is denoted by ρ.

For (16a), all else equal, increased income Y and length of stay L are likely to predict owner housing, and the D terms such as household size, age, gender or race of head may reflect tastes. Goodman distinguishes between the owner–renter price ratio P_o/P_r, and the value–rent ratio V/R. For comparable dwelling units with attributes X^*, an increase (decrease) in $P_o(X^*)/P_r(X^*)$ is expected to predict renter (owner) status.

In contrast, V/R is derived to reflect expected housing investment returns; a high (low) V/R is expected to predict owner (renter) status for specific dwelling units (Goodman, 1988). Through a well-specified function, one can reconstruct any renter (owner) unit as if it were owned (rented). Since hedonic coefficients can be interpreted as the sums of replacement costs (Rosen, 1974) and quasi-rents (Kain and Quigley, 1975), a set of high quasi-rents for a specific bundle suggests a market-indicated expectation for capital gain. Holding relative prices for standardized units constant, the value–rent ratio compares units for investment potential.

Eq. (16b) follows the theoretical derivation of Eq. (3), which implies that differences over time in explanatory variables such as income and housing price may impose higher staying costs. The σ terms refer to "spreads" of incomes, prices, and value–rent ratios, variables D referring to sociodemographic variables that may reflect tastes, and L refers to length of stay in the residence. Since it is postulated that owners are more likely to stay, the simultaneity between home ownership and staying in place is estimated in an expected positive correlation ρ between f and g.

As an example, consider demand estimates for 1989 (panel year 3). Conditional on "staying" until 1989, and moving before 1993, owner and renter housing demand are:

$$q^{\text{own}} = \left[\sum_{i=1}^{i=3} \eta^{\text{P}}_{yi} Y^{\text{P}}_i + \eta_{pi} P_{oi} + \eta_{vi} (V/R)_i\right] + \sum_k \eta_{kD_3} D_k + \eta_{f_3}\lambda_{f_3} + \eta_{g_3}\lambda_{g_3} + \omega_{o_3}, \tag{17a}$$

$$q^{\text{rent}} = \left[\sum_{i=1}^{i=3} \delta^{\text{P}}_{yi} Y^{\text{P}}_i + \delta_{pi} P_{ri}\right] + \sum_k \delta_{kD_3} D_k + \delta_{f_3}\lambda_{f_3} + \delta_{g_3}\lambda_{g_3} + \omega_{r_3}. \tag{17b}$$

Multiple measures of income, housing price, and value–rent ratio are included for each of the three years. Selection adjustments λ_f and λ_g are derived from Eqs. (16a) and (16b).[4]

Variables such as income are used in several stages of the estimation so it is important to show how they are used to calculate marginal impacts and elasticities. Expected housing demand is multiplies the probability of being an owner-stayer (renter-stayer) by the amount of housing demanded by those who are owner-stayers (renter-stayers). Following Greene, identify the tenure choice regression as f and the mover–stayer regression as g. Then let vector $\mathbf{x} = \mathbf{x}_f \cup \mathbf{x}_g$ and let $\boldsymbol{\beta}'_f\mathbf{x}_f = \boldsymbol{\gamma}'_f\mathbf{x}$, and $\boldsymbol{\beta}'_g\mathbf{x}_g = \boldsymbol{\gamma}'_g\mathbf{x}$.[5]

The bivariate probability reflecting, for example, owner-stayer status is:

$$\text{Prob}[f = 1, g = 1] = \Phi_b\left\lfloor \boldsymbol{\gamma}'_f\mathbf{x}, \boldsymbol{\gamma}'_g\mathbf{x}, \boldsymbol{\rho}\right\rfloor, \tag{18}$$

[4] The 1993 demand regressions use only λ_f. Because the panel ends in 1993, all of those remaining, by definition, are stayers.

[5] As a result of these transformations, $\boldsymbol{\gamma}'_f$ contains all the non-zero elements of $\boldsymbol{\beta}'_f$ and possibly some zeros in the positions of variables in $\mathbf{x}$ that appear only in the other equation; $\boldsymbol{\gamma}'_g$ is defined similarly (Greene (2000, p. 851)).

and the expected housing demand (ED) for owner-stayers is:

$$\begin{aligned}\mathrm{ED} &= [\text{Prob. of observing an owner-stayer}]\ [\text{Demand by owner-stayers}] \\ &= \Phi_b\left\lfloor \boldsymbol{\gamma}_f'\mathbf{x}, \boldsymbol{\gamma}_g'\mathbf{x}, \boldsymbol{\rho}\right\rfloor \left\lfloor q_i^{\mathrm{own}} | q_i^{\mathrm{own}} \text{ is observed}\right\rfloor \\ &= \Phi_b\left\lfloor \boldsymbol{\gamma}_f'\mathbf{x}, \boldsymbol{\gamma}_g'\mathbf{x}, \boldsymbol{\rho}\right\rfloor \left\lfloor \boldsymbol{\eta}'\mathbf{x}_i + \eta_{\lambda f}\lambda_f + \eta_{\lambda g}\lambda_g\right\rfloor. \end{aligned} \tag{19}$$

Eq. (19) provides two demand elasticities of interest. The first is the conditional elasticity of owner-stayers, which (following Greene) consists of two components. The direct effect of variable x on the mean of q_i^{own} is η. In addition a variable such as income Y, which appears in one or more probability equations, will influence q_i^{own} through its presence in λ_f and λ_g.[6] The effect of a 1% income increase on q_i^{own}, for example, is:

$$\begin{aligned}\Delta q_i^{\mathrm{own}} = &\left\lfloor \boldsymbol{\eta}'\mathbf{x}_i^{(Y=1.01Y_0)} + \eta_{\lambda f}\lambda_f^{(Y=1.01Y_0)} + \eta_{\lambda_g}\lambda_g^{(Y=1.01Y_0)}\right\rfloor \\ &- \left\lfloor \boldsymbol{\eta}'\mathbf{x}_i^{(Y=Y_0)} + \eta_{\lambda f}\lambda_f^{(Y=Y_0)} + \eta_{\lambda g}\lambda_g^{(Y=Y_0)}\right\rfloor. \end{aligned} \tag{20}$$

The derived percentage change in $\Delta q_i^{\mathrm{own}}$ thus represents the income elasticity.

The second elasticity relates to changes in explanatory variables on the entire expected demand (ED) expression. An income increase, for example, may affect the probability of being an owner-stayer as well as the conditional elasticity of owner-stayers. Starting with Eq. (19):

$$\begin{aligned}\text{Pct.}\,\Delta\mathrm{ED} = &\ \text{Pct.}\Delta[\text{Prob. of observing owner-stayer}] \\ &+ \text{Pct.}\Delta[\text{Demand by owner-stayers}]. \end{aligned} \tag{21}$$

The impact on demand by owner-stayers comes from Eq. (20).

The impact of variable x on the probability of being an owner-stayer is:

$$\frac{\partial \Phi_b}{\partial x} = \phi(w_f)\Phi\left[\frac{w_g - \rho w_f}{\sqrt{1-\rho^2}}\right]\gamma_f + \phi(w_g)\Phi\left[\frac{w_f - \rho w_g}{\sqrt{1-\rho^2}}\right]\gamma_g, \tag{22}$$

where γ_f and γ_g are the coefficients from the tenure choice and the mover–stayer equations, respectively.[7] This "expected value" formulation from Eqs. (19) to (22) compares panels of owner-stayers, for example, with earlier specifications that look at aggregate expenditures of owners (some movers and some stayers) over time.

It follows that one should model a permanent income increase in the panel setting (for example) as one-dollar increase in each of the four years. Similar effects, using

[6] Greene signs $(\partial E[y_i|z_i^* > 0])/(\partial x_{ik})$ in a conventional probit model, where z^* is the selection parameter and y is the dependent variable conditional on selection. In an e-mail, Greene wrote that $\partial E[y_i|f_i^*, g_i^* > 0]/\partial x_{ik}$ is exceedingly difficult to sign, but calculating the incremental impacts depends only on the ability to evaluate λ_f and λ_g at incremental levels of the explanatory variables.

[7] Let $h_f = 2f - 1$ and $h_g = 2g - 1$, $h_f = 1$ if $f = 1$, and -1 if $f = 0$; similarly for $g = 1$ or 0. Then $z_j = \boldsymbol{\beta}_j'\mathbf{x}_j$; and $w_j = h_j z_j$, for $j = f, g$.

multiple measures of housing price or value–rent ratio, can be derived for other "economic" variables. Estimating separate significant coefficients for income in different years within the same equation would provide separate effects over time, as predicted by the theoretical model.

7. Sample

The American Housing Survey (AHS) provides details on both the dwelling units and the households within them that are not available in other databases.[8] Moreover, the methods developed are replicable on AHS databases for other metropolitan areas.

The AHS follows dwelling units (each with a unique identification number) rather than households. The fundamental criterion for following households asks when the household moved into the unit. Suppose 1981 Household A (HA) lived there since 1978. Looking at the same house in 1985, if the 1985 household also lived there since 1978, and matched on age of household head and other consistency criteria, it was assumed to be HA for both 1981 and 1985, and that HA had been there for 7 years. The process was repeated for the 1989 and the 1993 panels.

If HA is also identified for 1989, then the household lived in the dwelling unit for 11 years (since 1978). If, however, in looking at the same dwelling unit for 1989, the current household has been there since 1987, I assume that HA moved from the dwelling unit in 1987 after living there 9 years, and Household B (HB) moved into the dwelling unit in 1987, and has been there for 2 years. HBs are not used in this article.

Due to confidentiality concerns the AHS does not provide geographic identifiers on its publicly available files. As a result, dwelling unit location in a metropolitan area is limited to central city, suburb (within the central county), or county indicators. For example, all houses in the city of Detroit have the identical unit price for 1981, and identical unit prices for 1985, 1989, and 1993.[9]

Detroit MSA surveys were available for at four-year intervals from 1973 through 1993, but due to survey changes, the study was limited to 1981, 1985, 1989, and 1993. Some dwelling units were rotated out of the survey, so the demand analyses used only households from dwelling units included in all four years. Thus households outside of Wayne (the central county), Macomb, and Oakland Counties (the three 1981 counties) were not used. With no reason to believe that units were systematically rotated out of the sample, there is no reason to assume selection bias.

One of the major premises is that households continue to live in the same unit, consuming the same quantity of housing. Even with "perfect" measurement, housing quantity may change within the same unit due to renovation or depreciation.

[8] This feature contrasts with a database like the Panel Survey on Income Dynamics (PSID) that is explicitly panel, but which contains only limited housing data, and even less geographic detail.

[9] Unit prices do change from period to period. Inclusion of additional metropolitan areas in this estimation process would presumably alleviate lack of price variation.

Housing quantity is calculated by dividing estimated value by the price of housing estimated from Eqs. (15a) and (15b), yielding (for four years) q_{81}, q_{85}, q_{89}, and q_{93}. This process does not constrain q_{81}, q_{85}, q_{89}, and q_{93} to equal each other, so the arithmetic average of the four is used as housing quantity.

The multi-year demand analyses were based on a sample of 1099 households who started in the 1981 sample, and whose dwelling unit remained in the sample through 1993. Approximately 18% of the 1981 sample households were black and about 64% of the households were married. Mean household head age was 47.2 years, and mean household length of stay was 11.75 years. Summary measures of income and price are discussed below.

8. Results

8.1. Income and price

Separate owner and renter permanent income regressions were estimated for each year for *all* households in the AHS database (rather than simply those who stayed in the same unit) that year. The estimating regression is:

$$\begin{aligned}\text{Wage Income} &= Y - r_n \boldsymbol{N} \\ &= r_0 + r_1(\text{AGE}) + r_2(\text{EDUC}) + r_3(\text{DEM}) + u, \qquad (14')\end{aligned}$$

where $r_n\boldsymbol{N}$ nets out non-wage returns to non-human capital (interest, rents, and dividends), which were measured in dollars. Parameters r_1 refer to a cubic function of age of household head, r_2 to levels of education (high school, some college, college degree, and graduate work), and r_3 to demographic variables such as gender, race, marital status, and presence of a second worker. The regressions (available from the author on request) were estimated in nominal (1981, 1985, 1989, or 1993) dollars; all results were subsequently deflated to real (1982–1984) dollars. Sample sizes for the auxiliary regressions were as follows:

	1981	1985	1989	1993
Permanent income—owners	3051	3072	1654	2325
Permanent income—renters	1267	2126	1004	1269
Owner hedonic price	2261	2972	1591	2218
Renter hedonic price	1257	2098	986	1259

Returning to Table 1, mean sample real income increased from \$23,590 in 1981 to \$42,390 for those that remain in 1993. Permanent real income rose similarly, from \$21,910 in 1981 to \$32,060 in 1993. Households who were in the sample for all four periods had mean annual real transitory income of \$10,330.

Housing prices and value–rent ratios were derived from hedonic price regressions estimated in semi-log form (Thibodeau, 1992). Separate regressions were estimated

Table 1
Values for variables

	1981	1985	1989	1993
Current income/yr ($1000)	**23.59**	**33.97**	**39.05**	**42.39**
	15.08	25.16	25.86	28.02
Permanent income/yr ($1000)	**21.91**	**28.58**	**31.90**	**32.06**
	32.89	35.31	28.24	20.64
Transitory income/yr ($1000)	**1.68**	**5.44**	**6.94**	**10.33**
	24.17	20.42	14.11	13.07
Owner price ($1000)	**43.91**	**40.21**	**43.29**	**42.88**
	7.11	9.23	10.64	11.47
Renter price($1000)	**0.36**	**0.41**	**0.37**	**0.37**
	0.04	0.04	0.04	0.04
Value–rent	**133.46**	**113.52**	**149.45**	**137.13**
	34.88	31.55	50.75	45.68
Relative (P_o/P_r)	**119.63**	**97.91**	**116.58**	**113.00**
	10.04	17.18	19.48	21.66
N	1099	701	455	356

Standard deviations below means.
All monetary values in $ (1982–1984).

by year, and for differing tenures, but geographic submarkets were modeled solely with binary variables. The 1980s saw considerable population loss in the City of Detroit relative to the rest of the metropolitan area, indicated by steep house price discounts (32.2, 46.1, 49.4, and 53.6%) for the four years.

Renter hedonic price regressions were also estimated for 1981, 1985, 1989, and 1993. City of Detroit rents were not as steeply discounted, although they were 18.2, 17.1, 22.5, and 22.2% less than surrounding areas, in the four years, respectively.

The price indices used the arithmetic mean of owner and renter bundles as X^*. Indices P_o and P_r apply the Duan (1983) "smearing" factors s_o and s_r, with $s = (\sum \exp(\hat{\zeta}_i))/n$, where $\hat{\zeta}_i = y_i - x_i\hat{\beta}$, to retransform semi-log estimates from Eqs. (15a) and (15b):

$$P_o^G = s_o \exp(v_0^o + \sum v_k^o x_k^* + v_G^o G), \quad P_r^G = s_r \exp(v_0^r + \sum v_k^r x_k^* + v_G^r G). \qquad (23)$$

Value-rent ratios for individual units are created by statistically matching owner units with renter units with the same characteristics using (15a) and (15b). Because the vectors of characteristics were allowed to vary by dwelling unit, there was considerably more variation in value–rent ratios than in housing prices.

Both owner and renter prices (per unit) remained constant in real terms over the 12-year period. The Detroit metropolitan area was in a "zero-growth" state during that time period, and for the most part any growth was occurring in outlying counties that were not covered by the AHS for the entire 12-year period. The relative prices and relative value–rent ratios reflect generally accepted industry norms of the value reflecting 10–12 years of monthly rents.

8.2. Duration models

Table 2 presents the duration models for each of the four years, 1981, 1985, 1989, and 1993. Households had a minimum length of residence of 1 year in 1981, 5 years, in 1985, 9 years in 1989, and 13 years in 1993.

From the nature of the optimizing process in Eqs. (1)–(3), it is appropriate to include the "spread" variables to indicate deviation from single-period equilibrium. For households (still) in the sample, it is likely that the larger spreads would be related to shorter stays (i.e., negative signs), and increased probabilities of moving. After several specifications, squared difference of income, price ratio (owner–renter) and value–rent ratio were chosen such that for variable z, over n periods,

Table 2
Length of stay

	1981	1985	1989	1993
Constant	**−0.39600**	**−4.68501***	**3.47074***	**3.17982***
	0.23555	1.46114	0.38603	0.39743
YP	**0.00365***	**−0.00394***	**−0.00116**	**−0.00335***
	0.00178	0.00109	0.00083	0.00104
SIGYP		**0.00017**	**−0.00005**	**−0.00002**
		0.00016	0.00012	0.00010
YT	**0.00472***	**−0.00399***	**0.00022**	**−0.00020**
	0.00217	0.00170	0.00148	0.00155
SIGYT		**0.00006**	**−0.00004**	**0.00003**
		0.00008	0.00008	0.00007
PP	**−0.00481***	**0.03567***	**−0.01529***	**−0.01051***
	0.00215	0.01161	0.00287	0.00273
SIGP		**0.00835***	**−0.00250***	**−0.00222**
		0.00218	0.00099	0.00122
VR	**0.00248***	**0.00487***	**0.00503***	**0.00226***
	0.00074	0.00081	0.00042	0.00051
SIGVR		**−0.00011***	**−0.00010***	**−0.00000**
		0.00004	0.00002	0.00003
MAR	**0.11351***	**0.00480**	**−0.04293**	**−0.04796**
	0.04176	0.03249	0.03166	0.03338
AGE	**0.09449***	**0.08028***	**0.02614***	**0.03501***
	0.00638	0.00738	0.00660	0.00726
AGESQ	**−0.00063***	**−0.00056***	**−0.00010**	**−0.00019***
	0.00006	0.00007	0.00006	0.00006
BLACK	**−0.03774**	**−0.20182***	**−0.15241**	**−0.14272***
	0.05805	0.05085	0.05521	0.05822
σ	**0.57971***	**0.41996***	**0.31015***	**0.25096***
	0.01254	0.01142	0.01222	0.01289
λ	0.0899	0.0574	0.0431	0.0359
p	1.7250	2.3812	3.2242	3.9848
Median	8.9940	14.9326	20.7093	25.2174
N	1099	694	455	356

Standard errors below coefficients.
* Significant at 5% level.

$\mathrm{SIGz} = \sum_{k=1}^{n}(z_k - \bar{z})^2/n$, where n is the number of times the household appeared in the sample. There are no spread variables for those households who appear only in the 1981 sample.

The Weibull distribution is presented for the four years. Across the years it was most reliable in converging to solution although it was not always the best by likelihood ratio criteria.[10] Greene shows that Weibull survival function $S(t) = \mathrm{e}^{-(\lambda t)^p}$ yields hazard function $H(t) = \lambda p(\lambda t)^{p-1}$, so $p > 1$ indicates increasing hazard, or positive duration dependence. Parameter p significantly exceeds 1 in all four years, so for each of the four years, the stay is more likely to end, the longer it is at time t.

Permanent income has a mixed impact. It has a positive impact on length of stay in 1981, but negative impacts the next three years. Transitory income has similar impacts. One might expect a negative impact on length of stay if transactions costs are fixed, or if they rise more slowly than the cost of the housing bundle, as they would become a smaller proportion of a larger income. Housing price has important impacts. Except for 1985, the more expensive owner housing is relative to renter housing, the shorter the length of stay. Similarly, value–rent ratio has a positive (and significant impact on each length of stay). This is consistent with the premise that the better the investment the housing is, the longer people stay in it.

Regarding sociodemographic impacts, black households have systematically shorter stays across all four years. Married households have longer lengths of stay for 1981 and 1985, and shorter lengths of stay for 1989 and 1993. The age impacts are significantly non-linear, increasing the lengths of stay at a decreasing rate, although they are always positive.

The spread variables (permanent income, transitory income, price ratio, and value–rent ratio) available for 1985, 1989, and 1993, have mixed results. The income spread terms are all insignificant. The price spread terms have mixed impacts. Increased spread in the value–rent ratio has the expected negative impact on length of stay for all three years; increased owner–renter price ratio has a negative impact for two of the three.

8.3. Bivariate selection

This section follows the panel's transition from one sample to the next. Fig. 2 presents the set of transitions from a sample of 1099 households (75.2% owner) in 1981 to 353 households that remained by 1993. Of the original 826 identifiable owners, 29.4%, or 238 moved between 1981 and 1985. Of the original 258 identifiable renters, 62.0%, or 160 moved between 1981 and 1985. These percentages are consistent with long-standing estimates of owner and renter mobility. The tall bar in 1985 is comprised of the 1981 total less the moving owners and renters. Subsequent years are treated similarly with 15 of the 1,099 original households classified as "missing" with

[10] For 1981 the Weibull distribution had the highest log-likelihood value. For 1985 and 1989 the log-logistic distribution had the highest value, and for 1993 the log-normal distribution had the highest value. The differences were not large, and since the Weibull distribution is easy to interpret, it is used here. The gamma distribution did not converge.

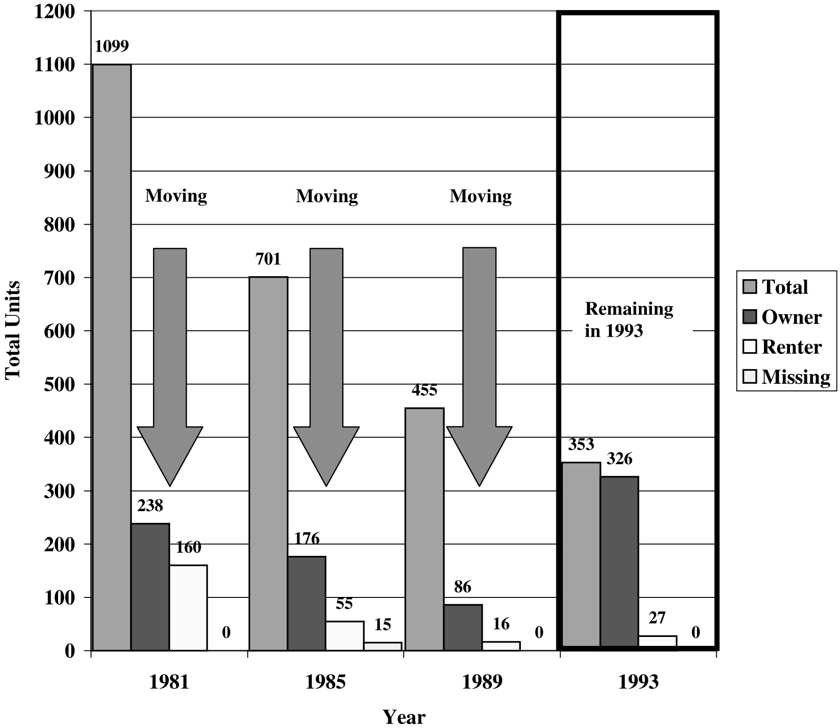

Fig. 2. Total units and owner/renter demands by year.

respect to tenure choice. The final estimates in 1993 describe a sample of 326 owner-stayers, and 27 mover–stayers.

Three sequential bivariate probit models indicate: (1) 1981 tenure and 1985 stayer status; (2) 1985 tenure and 1989 stayer status; and (3) 1989 tenure and 1993 stayer status. All of the 1993 households are stayers, so the final equation is a conventional tenure choice probit model.

Looking at Table 3, the 1981 and 1985 models are the strongest, probably because sample attrition (more renters move) leads to smaller sample sizes for the 1989 and 1993 models. For 1981 and 1985, the model correlations are positive and significant with $\rho_{81} = 0.272$ and $\rho_{85} = 0.229$. For the 1989 sample $\rho_{89} = -0.007$ and is not statistically significant.

For the tenure choice equations, both permanent and transitory incomes have significant and substantive importance. Interestingly, the transitory component for the stayers has a larger impact than the permanent component in all three regressions in which it is used (it is omitted in 1989 to achieve convergence in estimation). In all four years married households are more likely to own; black households have mixed impacts from year to year.

This study confirms a finding from Goodman (2002) regarding age and homeownership. Most previous work, including the author's, found age to be positively

Table 3
Determinants of tenure choice and mover–stayer status

	TEN81	SURV85		TEN85	SURV89		TEN89	SURV93		TEN93
Constant	**−4.22188***	**−2.45858***	Constant	**−4.66475***	**0.23287**	Constant	**−5.40202***	**−0.21444**	Constant	**−4.18782**
	0.88681	0.68044		0.90869	4.35391		2.07286	2.61126		2.20184
YP81	**0.02545***	**0.00950***	YP85	**0.02363***	**−0.00164**	YP89	**0.01337***	**0.00051**	YP93	**0.02439***
	0.00515	0.00343		0.00282	0.00331		0.00684	0.00326		0.00975
YT81	**0.03195***	**0.01305***	YT85	**0.03838***	**−0.00317**				YT93	**0.03115**
	0.00713	0.00434		0.00642	0.00495					0.01730
MAR81	**0.94902***	**0.20089***	MAR85	**0.80715***	**0.01597**	MAR89	**0.97116***	**0.08464**	MAR93	**0.30920**
	0.12085	0.09316		0.16547	0.12415		0.33750	0.16290		0.28644
AGE81	**0.07295***	**0.07807***	AGE85	**0.07223***	**0.09617***	AGE89	**0.10052**	**0.06729**	AGE93	**0.09181**
	0.01896	0.01559		0.03310	0.02420		0.06085	0.03845		0.06840
AGESQ81	**−0.00078***	**−0.00074***	AGESQ85	**−0.00078***	**−0.00089***	AGESQ89	**−0.00105**	**−0.00065***	AGESQ	**−0.00087**
	0.00019	0.00015		0.00030	0.00022		0.00056	0.00033		0.00056
BLACK81	**−0.04057**	**0.13691**	BLACK85	**0.22410**	**−0.01933**	BLACK89	**0.62137***	**−0.23996**	BLACK93	**−0.18076**
	0.15543	0.13167		0.20668	0.16991		0.31666	0.23303		0.39813
HOWL81	**0.11341***	**0.01907***	HOWL85	**0.09200***	**0.01321***	HOWL89	**0.08870***	**0.00758**	HOWL93	**0.08293***
	0.01152	0.00559		0.01351	0.00605		0.02234	0.00874		0.02102
PP81	**0.02139***	**0.00358**	PP85	**0.02065***	**−0.01818**	PP89	**0.01690***	**−0.00756**	PP93	**0.00402**
	0.00726	0.00537		0.00625	0.03515		0.00789	0.01531		0.00860
VR81	**−0.00853***	**−0.00027**	VR85	**−0.00139**	**0.00042**	VR89	**0.00260**	**0.00203**	VR93	**0.00157**
	0.00198	0.00139		0.00399	0.00046		0.00404	0.00264		0.00388
			SIGYP85		**−0.00008**	SIGYP89		**−0.00001**		
					0.00056			0.00062		
			SIGYT85		**0.00002**	SIGYT89		**−0.00008**		
					0.00016			0.00507		
			SIGP85		**−0.00426**	SIGP89		**0.00004**		
					0.00662			0.00030		
			SIGVR85		**−0.00007**	SIGVR89		**−0.00011**		
					0.00012			0.00012		
$\rho(1,2)$		**0.27244***			**0.22854***			**−0.00720**		
		0.06917			0.10731			0.18969		
Max. age effect	46.52	52.92		46.38	54.04		47.88	51.50		53.02
N		1099			701			455		353
LL		−1006.90			−595.43			−311.48		−61.37

Standard errors below coefficients.
* Significant at 5% level.

related to ownership at all age levels. Here, controlling for length of stay in the residence, age effects (holding length of stay constant) peak in the residents' late 40s' with older residents increasingly likely to rent. This finding can be interpreted by adding the age and the length of stay impacts. Older households with shorter stays in the unit are more likely to rent. Those with longer stays are more likely to own.

The second part of the bivariate probit analysis examines the determinants of "staying." Controlling for tenure, length of stay is significantly related to stayer status in all the three stayer regressions. Age enters all three of the equations quadratically, and significantly. However, the age impact evaluated at the mean, positive for 1981 and 1985, is negative for 1989. This suggests that following a cohort over time, the households that preferred to stay at younger ages, prefer to move as they reach age 60 (the mean age for the 1993 sample).

Increased permanent income spread for 1985 and 1989 implies mover status, consistent with the model, although the coefficients are not significant. Similarly, variation in the value–rent ratio for 1985 and 1989 is also related to moving, but again without statistical significance.

8.4. Demand regressions

This section examines the demand equations, corrected for selection into the sample. The selection process provides owner sample sizes of 235, 170, 86, and 326 for the four years, respectively; it provides renter sample sizes of 154, 54, 16, and 27. Due to the small renter sample sizes, interpretation of rental results will be more tentative than the owner results.

The selection adjustments are important for all four years of owner regressions. The stayer adjustment is statistically significant for 1981 and 1985, with the tenure choice adjustment significant for 1989 and 1993. The tenure choice adjustment is significant for renters for 1981, but not for the other years. This is almost certainly due to small sample size (which increases the standard error) since the coefficient orders of magnitude are roughly similar to 1981. Like Ermisch (1996) for the owner regressions, the selection adjustments are positively related to quantity demanded.

One of the key issues in this research is the appropriate specification of multiple year variables. Table 4(a) concentrates on the 1989 stayers, with potentially three income, price, and value–rent terms, and Table 4(b) on the 1993 stayers with potentially four income, price and value–rent terms. These regressions are compared to regressions using only the 1989 coefficients (4a) or only the 1993 coefficients (4b), and comparing the fit using either F tests. Both tests significantly reject the hypothesis that current year quantities are explained solely by current year parameters.[11]

In Table 4(a), for example, the permanent income coefficient for 1989 alone is 0.00579. When entered separately the 1981, 1985, and 1989 coefficients are

[11] In 1989, $F_{8,66} = 2.49$ with the critical (5%) value of 2.08. In 1993, $F_{12,305} = 2.53$ with a critical (5%) value of 1.78.

Table 4
Owner housing demand—parameter tests of multi-year models

(1) Current year		(2) Three years separate		(3) Three years—constrained	
(a) 1989					
Constant	**−1.30810***	Constant	**1.21864**	Constant	**0.30038**
	0.47021		0.77749		0.32941
		YP81	**0.00700***	YP818589	**0.00490***
			0.00315	Constrained	0.00088
		YP85	**0.00506**		
			0.00263		
YP89	**0.00579***	YP89	**0.00289**		
	0.00145		0.00210		
		YT81	**0.00594***	YT818589	**0.00518***
			0.00272	Constrained	0.00142
		YT85	**0.00414**		
			0.00209		
YT89	**0.00630***	YT89	**0.00792***		
	0.00273		0.00284		
		PO81	**0.00236**	PO818589	**−0.00100**
			0.03502	Constrained	0.00189
		PO85	**−0.10345***		
			0.03003		
PO89	**0.00865***	PO89	**0.07762**		
	0.00442		0.03650		
		VR81	**−0.00138**	VR818589	**0.00148***
			0.00130	Constrained	0.00043
		VR85	**0.00398***		
			0.00187		
VR89	**0.00294***	VR89	**0.00192***		
	0.00073		0.00089		
Demographic and selection variables					
R^2	0.52775		0.64080		0.52661
Adj R^2	0.47032		0.55101		0.47055
SER	0.24940		0.23293		0.25294
(b) 1993					
Constant	**0.30803**	Constant	**0.50675***	Constant	**0.14683**
	0.17931		0.22511		0.21035
		YP81	**0.00223**	YP81_93	**0.00294***
			0.00225	Constrained	0.00035
		YP85	**0.00376***		
			0.00163		
		YP89	**0.00176**		
			0.00178		
YP93	**0.00671***	YP93	**0.00147**		
	0.00124		0.00184		
		YT81	**0.00229**	YT81_93	**0.00339***
			0.00193	Constrained	0.00063
		YT85	**0.00563***		

Table 4 (*continued*)

(1) Current year		(2) Three years separate		(3) Three years—constrained	
			0.00141		
		YT89	**−0.00033**		
			0.00161		
YT93	**0.00399***	YT93	**0.00361***		
	0.00162		0.00174		
		PO81_93	**−0.00179***	PO81_93	**−0.00204***
			0.00090	Constrained	0.00091
PO93	**−0.00635***				
	0.00287				
		VR81	**−0.00260***	VR81_93	**0.00171***
			0.00090	Constrained	0.00022
		VR85	**0.00029**		
			0.00129		
		VR89	**0.00368***		
			0.00072		
VR93	**0.00563***	VR93	**0.00247***		
	0.00062		0.00088		
Demographic and selection variables					
R^2	0.50248		0.64640		0.55691
Adj R^2	0.48992		0.62688		0.54573
SER	0.27604		0.23272		0.26051

Standard errors below coefficients.
* Significant at 5% level.

0.00700, 0.00506, and 0.00289, respectively. When the separate coefficients are constrained to be constant, the constrained coefficient of 0.00490 is significant and gives a permanent income elasticity (0.00490, multiplied by three) that is more than twice as large as the single year's elasticity. Similar results occur for the four years summarized in Table 4(b).[12]

Looking at all of the demand regressions in Table 5, the owner income terms enter separately and significantly for all four years. A single income term is used for 1981, separate terms for 1985, and constrained coefficients for 1989 and 1993. The resulting income elasticities (particularly for 1985, 1989, and 1993), summing the permanent and transitory elasticities, are quite similar, at 0.407, 0.349, and 0.377, respectively.

The owner price effects were the correct sign for 1985, 1989, and 1993. (Goodman, 2002, also had problems with 1981 prices). Again constraining the elasticities to be the same across years, the price elasticities for 1985, 1989, and 1993 were −0.196, −0.107, and −0.289, respectively.

[12] The multi-year specifications are better than the single year specifications. Due to multicol linearity of income, price, and value–rent ratios, some of the multi-year coefficients are not stable. *F* tests on the coefficients reject equality of column (2) and column (3). However the resulting elasticities from column (3) were similar to column (2) and easier to interpret.

Table 5
Owner and renter housing demand

	Owner housing					Renter housing			
	1981	1985	1989	1993		1981	1985	1989	1993
Constant	**0.43274***	**0.18323**	**0.30038**	**0.14683**		**0.68206***	**0.81755***	**0.30666**	**0.25499**
	0.21863*	0.24772	0.32941	0.21035		0.15852	0.26155	0.66620	0.40842
YP81	**0.01174***	**0.00752***	***0.00490****	***0.00294****		**0.00098**	**0.00175**	***−0.00454****	***0.00190***
	0.00193	0.00257	*0.00088*	*0.00035*		0.00142	0.00329	*0.00206*	*0.00148*
YP85		**0.00688***	***0.00490***	***0.00294***			**0.00545**	***−0.00454***	***0.00190***
		0.00197	*0.00088*	*0.00035*			0.00328	*0.00206*	*0.00148*
YP89			***0.00490***	***0.00294***				***−0.00454***	***0.00190***
			0.00088	*0.00035*				*0.00206*	*0.00148*
YP93				***0.00294***					***0.00190***
				0.00035					*0.00148*
YT81	**0.00915***	**0.00639***	***0.00518****	***0.00339****		**−0.00057**	**0.00156**	***−0.00681***	***0.00230***
	0.00239	0.00242	*0.00142*	*0.00063*		0.00179	0.00254	*0.00427*	*0.00249*
YT85		**0.00997***	***0.00518***	***0.00339***			**0.00892***	***−0.00681***	***0.00230***
		0.00198	*0.00142*	*0.00063*			0.00396	*0.00427*	*0.00249*
YT89			***0.00518***	***0.00339***				***−0.00681***	***0.00230***
			0.00142	*0.00063*				*0.00427*	*0.00249*
YT93				***0.00339***					***0.00230***
				0.00063					*0.00249*
PO81	**0.00276**	***−0.00272***	***−0.00100***	***−0.00204****	PR81	**0.73286***	**3.27002**	***0.35542***	***0.45646***
	0.00433	*0.00222*	*0.00189*	*0.00091*		0.37213	3.36485	*0.29534*	*0.23988*
PO85		***−0.00272***	***−0.00100***	***−0.00204***	PR85		**−2.81491**	***0.35542***	***0.45646***
		0.00222	*0.00189*	*0.00091*			2.96147	*0.29534*	*0.23988*
PO89			***−0.00100***	***−0.00204***	PR89			***0.35542***	***0.45646***
			0.00189	*0.00091*				*0.29534*	*0.23988*
PO93				***−0.00204***	PR93				***0.45646***
				0.00091					*0.23988*
VR81	**0.00128**	**−0.00333***	***0.00148****	***0.00171****					
	0.00086	0.00117	*0.00043*	*0.00022*					
VR85		**0.01036***	***0.00148***	***0.00171***					
		0.00128	*0.00043*	*0.00022*					
VR89			***0.00148***	***0.00171***					
			0.00043	*0.00022*					
VR93				***0.00171***					
				0.00022					
BLACK	**−0.02544**	**−0.01807**	**−0.04481**	**−0.00119**		**0.01623**	**−0.00702**	**−0.02357**	**−0.00286**
	0.07119	0.07881	0.09656	0.00204		0.03386	0.05629	0.09243	0.00253
MAR	**0.08458**	**0.05119**	**0.04575**	**0.00410**		**−0.03627**	**0.02451**	**1.12968***	**0.07956**
	0.05738	0.06983	0.07810	0.08561		0.03456	0.05924	0.14660	0.10069
AGE	**0.00264**	**0.00174**	**0.00103**	**0.06019**		**−0.00223***	**−0.00079**	**−0.00399**	**0.04958**
	0.00157	0.00188	0.00251	0.05469		0.00072	0.00095	0.00212	0.09121
LAM_TEN	**0.03134**	**0.16161**	**0.42799***	**0.63794***		**−0.15915***	**0.11368**	**−0.21461**	**0.06476**
	0.05282	0.10106	0.17368	0.16619		0.05430	0.09276	0.25697	0.09865
LAM_SUR	**0.01296***	**0.03316***	**0.09741**			**0.01764**	**−0.03858**	**−0.35607**	
	0.00648	0.01583	0.07345			0.09184	0.13931	0.22633	
SER	0.32822	0.29934	0.25294	0.26051		0.14673	0.12203	0.08600	0.15831
R^2	0.31404	0.59743	0.52661	0.55691		0.27219	0.32042	0.95383	0.31776
Adj R^2	0.28660	0.56666	0.47055	0.54573		0.23203	0.14244	0.90106	0.06641
N	235	170	86	326		154	54	16	27
E_y	0.2419	0.4071	0.3487	0.3767		0.0081	0.1509	–	0.1570
E_p	+	−0.1965	−0.1072	−0.2893		+	+	+	+

Standard errors below coefficients.
* Significant at 5% level.

The 1993 regression may provide the best test of the multi-year optimization model. Both permanent and transitory incomes have significant impacts. The price elasticity is statistically significant, and the value–rent ratio is positively related to quantity demanded as expected. The owner–renter selection adjustment is also significant, although over 90% of the households are owner households.

9. Expected demand and full elasticities

This section examines the full elasticities that accompany an increase in income. These include impacts on tenure choice and mover–stayer status, plus the impact of income on quantity demanded holding all of them constant. Returning to Eq. (7′) the elasticity calculated is:

$$\begin{aligned}\mathrm{Elas}_y^* &= \frac{\mathrm{d}H^{\mathrm{s}}}{\mathrm{d}y}\frac{y}{H^{\mathrm{s}}}\\ &= \underbrace{\sum_{j=81,85,89,93} \frac{s_{\mathrm{o}}^{\mathrm{s}} k_{\mathrm{o}}^{\mathrm{s}} Q_{\mathrm{o}}^{\mathrm{s}}}{H^{\mathrm{s}}}\left[E_j^{Q_{\mathrm{o}}^{\mathrm{s}}y} + E_j^{k_{\mathrm{o}}^{\mathrm{s}}y} + E_j^{s_{\mathrm{o}}^{\mathrm{s}}y}\right]}_{\text{[a. Owner-stayer]}} + \underbrace{\sum_{j=81,85,89,93} \frac{s_{\mathrm{r}}^{\mathrm{s}} k_{\mathrm{r}}^{\mathrm{s}} Q_{\mathrm{r}}^{\mathrm{s}}}{H^{\mathrm{s}}}\left[E_j^{Q_{\mathrm{r}}^{\mathrm{s}}y} + E_j^{k_{\mathrm{r}}^{\mathrm{s}}y} + E_j^{s_{\mathrm{r}}^{\mathrm{s}}y}\right]}_{\text{[b. Renter-stayer]}},\end{aligned} \tag{7''}$$

since movers cannot be followed. Table 6 provides a worksheet that traces the impacts of a long-term 1% income increase in permanent and transitory income.

Table 6 begins with baseline values of owner and renter fractions f and the percentage of stayers, which starts as 1.0 in 1981. The 1981 housing quantity is calculated as a weighted average of the four owner (or renter) regressions for those whose demand was measured in 1981, 1985, 1989, and 1993, respectively. Measure $E(Q)$ weights housing quantity by percentages of owners and renters, and $H(Q)$ weights $E(Q)$ by the percentage of stayers, here 1.0.

The 1985 housing quantity drops those households that moved between 1981 and 1985, so while $E(Q)$ may rise with income, $H(Q)$ falls due to sample attrition. The 1989 and 1993 baseline measures are calculated similarly.

From Eq. (7″), the impact of a 1% increase in income is related to elasticities in percent owner f, percent stayer g, and share s. There are major changes in probability of owning/renting, and smaller changes in the probability of staying in the house. Changes in sample shares are calculated in the table, but since they are small, their elasticities are not shown.

Table 6, part c, shows the full impact of a 1% increase in income, and its component parts. The partial impacts vary from 0.228 in 1989 to 0.435 for 1985 quantity. The full elasticity for stayers is 0.312.

The conceptual interpretation of the numerous impacts on observed housing demand is as important as the measurements. Income and household age have complicated impacts on length of stay, tenure choice, the mover–stayer decision, and on quantity demanded. Moreover, even with the complicated interactions, these calculations only represent those who *stayed*! It is almost certain that the omitted mover

Table 6
Full elasticities and their components f, owner probability; g, stayer probability

	f	g	Q	$E(Q)$	$H(Q)$
(a) Expected demand—baseline					
1981					
Owner	0.7637	1.0000	1.2062	1.1313	1.1313
Renter	0.2363	1.0000	0.8890		
1985					
Owner	0.8605	0.6379	1.2125	1.1635	0.7422
Renter	0.1395	0.6379	0.8616		
1989					
Owner	0.9111	0.4140	1.2208	1.1852	0.4907
Renter	0.0889	0.4140	0.8207		
1993					
Owner	0.9235	0.3212	1.2184	1.1878	0.3815
Renter	0.0765	0.3212	0.8191		
Sum					2.7457
(b) Elasticities with respect to 1% income increase					
1981					
Owner	0.1578	0.0000	0.2930		
Renter	−0.5098		0.0222		
1985					
Owner	0.0466	0.1424	0.3002		
Renter	−0.2877		0.1026		
1989					
Owner	0.0155	−0.0508	0.2929		
Renter	−0.1585		−0.0207		
1993					
Owner	0.0358	0.0034	0.2766		
Renter	−0.4327		0.1265		
(c) Expected demand with 1% income increase					
1981					
Owner	0.7649	1.0000	1.2098	1.1344	1.1344
Renter	0.2351		0.8892		
1985					
Owner	0.8609	0.6388	1.2161	1.1669	0.7454
Renter	0.1391		0.8624		
1989					
Owner	0.9113	0.4138	1.2243	1.1885	0.4918
Renter	0.0887		0.8206		
1993					
Owner	0.9238	0.3212	1.2217	1.1912	0.3826
Renter	0.0762		0.8201		
Sum					2.7542
	Partial 1981			0.2768	
	Partial 1985			0.4348	
	Partial 1989			0.2275	
	Partial 1993			0.2832	
Full elasticity					0.3116

elasticities [c] and [d] are positive, because movers respond to increased income with increased purchases. As a result the elasticity of demand over the entire 12 year period for the entire starting panel of 1,099 households is probably considerably larger than the value of 0.312 that was measured for the stayers.

10. Conclusions

This article continues a line of research in which the explicit mover–stayer decision is modeled as an equilibrium decision. The American Housing Survey has been processed to provide a unique 12-year data panel with very good household and unmatched housing data.

This study adds to earlier work by explicitly modeling length of stay in the dwelling unit. Careful analysis of length of stay allows researchers to distinguish between effects that are related to age, and those that are related to housing tenure, and the decision to move or stay.

These results provide an important test of the theory that that income and value–rent measures in different years have separable and significant impacts on housing demand. For individual groups of stayers, the conditional (Table 5) income elasticities are between 0.24 and 0.41. Price impacts on demand are less helpful, in part because of difficulties in measuring housing price using the AHS in a single metropolitan area, even over a period of 12 years. However, the four-period average price elasticities are plausible.

Renter data also provide useful results in looking at tenure choice and mover–stayer behaviors. The demand results are circumscribed by the fact that renter mobility yields very small samples of long-term stayers, with often unstable parameter and standard error estimates.

When the panels are combined (Table 6), the full income elasticity is slightly higher than 0.31, although elasticities for individual years are as high as 0.43. Increased income, leading to the choice of owner—rather than renter housing, increases housing demand separately from the impacts of tenure-specific income increases.

From a policy perspective the separable income impacts help interpret key features of demand side programs such as housing vouchers that have been proposed to address inadequate housing for the poor. Goodman (1989) notes that repeated analyses using individual data have found income elasticities to be less than +1.0 and most analyses from the Experimental Housing Allowance Program (EHAP) project found them to be closer to 0 than to +1.0. The general appraisal was that the EHAP experiments were too short in duration, that the income subsidies were not necessarily viewed as permanent, or that moving costs constrained adjustment.[13]

The owner and renter demand estimates verify criticisms that naïve cross-section methods, as well as single year income measures tend to underestimate responsiveness to income changes. For longer-staying households, one-year income increases,

[13] Bradbury and Downs (1982) and Friedman and Weinberg (1982) provide good EHAP summaries.

even if fully expected, would provide very small impacts on housing demand unless they became permanent. For income subsidies and/or vouchers to influence housing demand, they must be expected, and they must be long-term.

Moreover, measuring the full impacts of income or price changes at the microeconometric level requires an intensive modeling effort that is largely internalized within the aggregate measures that are generally available with time-series data. Neither is necessarily "right" or "wrong." For those seeking the impacts of increases in national income measures on housing expenditures, the macro-measures are appropriate. If one wants to know how much individuals' housing demand will change with targeted voucher or income subsidy programs, the macro-measures will not do—detailed microeconometric estimates such as those provided here are essential.

Variable list

Length of stay and discrete choice models

YP_	permanent income ($1000 for a given year)
YT_	transitory income ($1000 for a given year)
AGE_	age of household head
AGESQ_	age of household head squared
BLACK_	1 if black; 0 otherwise
MAR_	1 if married; 0 otherwise
PP_	owner-renter price ratio
VR_	value-rent ratio
SIGYP_	variance of permanent income
SIGYP_	variance of transitory income
SIGVR_	variance of value–rent
SIGP_	variance of owner–renter ratio
HOWL_	length of residence
TEN_	1 if owner; 0 otherwise
SURV_	1 if stayed; 0 otherwise

Demand—additional parameters

PO_	owner price
PR_	renter price
LAM_TEN_	selection parameter from tenure choice probit
LAM_STAY_	selection parameter from selection (mover–non-mover) probit

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