ELSEVIER
Available online at www.sciencedirect.com
SCIENCE DIRECT®
Journal of Housing Economics 14 (2005) 336–354
JOURNAL OF HOUSING ECONOMICS
www.elsevier.com/locate/jhe

Mobility and optimal tenure choice

Süheyla Özyıldırım [a], Zeynep Önder [a,*], Abdullah Yavas [b]

[a] *Faculty of Business Administration, Bilkent University, Bilkent 06800, Ankara, Turkey*
[b] *Smeal College of Business Administration, The Pennsylvania State University, University Park, PA 16802, USA*

Received 17 September 2004
Available online 26 October 2005

Abstract

In this paper, we offer a dynamic model of the optimal tenure behavior of an individual who faces the possibility of moving multiple times during his lifetime. We also investigate the lifetime effects of such factors as income tax, property tax, transaction costs, and mortgage rates on the household's tenure choice. The agents in the model utilize a genetic algorithm, a probabilistic search approach, to determine their optimal lifetime tenure choice path. The agents are forward looking in that they anticipate such possible events as changes in jobs, marital status, household size, or dissatisfaction with current residence. Our results suggest several housing policy implications and explain some of the empirical findings in the literature.

JEL classification: D1; R21; D91; D83

Keywords: Tenure choice; Random mobility; Heuristic search

1. Introduction

Several empirical studies have established that tenure choice and mobility decisions are correlated.[1] In this paper, we offer a dynamic model of the optimal tenure behavior of an individual who faces the possibility of moving multiple times during his lifetime. We also

* Corresponding author. Fax: +90 312 2664958.
E-mail addresses: suheyla@bilkent.edu.tr (S. Özyıldırım), zonder@bilkent.edu.tr (Z. Önder), ayavas@psu.edu (A. Yavas).

[1] See, for example, Boehm et al. (1991), Ioannides (1987), and Ioannides and Kan (1996).

doi:10.1016/j.jhe.2005.09.002

investigate the lifetime effects of such factors as income tax, property tax, transaction costs, and mortgage rates on the household's tenure choice.

The decision to either own a house or rent one is by nature a discrete one. For this reason, we study, the optimal tenure choice of a household as a discrete time, discrete state Markov decision model, and analyze the effects of the tenure choice on the lifelong discounted utility of the individual. Discrete Markov decision models are analyzed using the dynamic programming principle and can be represented graphically as decision trees. The general prescribed procedure for choosing a decision from a decision tree employs backward induction analysis. However, the empirical studies on human cognition show that backward induction models perform poorly in predicting behavior of economic agents (Camerer et al., 1993; Gabaix and Laibson, 2000). In this paper, we replace the assumption of backward induction with a heuristic search procedure known as the genetic algorithm where the agents are forward looking and anticipate such possible future events as job relocation and changes in marital status and household size.

In addition to offering a new procedure to analyze the tenure choice problem, we also simulate the model utilizing various set of parameters obtained from historical data. We simulate the impacts of several economic and housing variables such as income tax, property tax, transaction costs, spread between mortgage and market interest rates, house price appreciation rate, and relative cost of renting on a randomly moving individual's tenure decision. The results suggest that the theoretical model and the forward looking solution procedure perform very well in terms of explaining the previous empirical findings in the literature about home ownership decisions of households.

The main conclusion of the model is that there is a strong relationship between home ownership decisions and the stage in the life-cycle in that older households act differently than middle-aged and younger households. Furthermore, the impact of changes in several factors on tenure choice seems to be different depending on the stage in the life-cycle. For example, an increase in income tax rate is projected to affect positively the home ownership of all households but it has less effect on old-aged households. Similarly, an increase in the home appreciation rate increases the home ownership rate in early ages but reduces the ownership rate of elderly. A decline in the market interest rate relative to the mortgage interest rate will have a positive impact on the home ownership rate at early ages but it will not have a significant effect on the home ownership rate of aged households. Transaction costs play a role in the tenure choice as well. An increase in transaction costs reduces the ownership rate, and middle-aged households are more sensitive to transaction costs than other age groups. If rents are high relative to house values, the household prefers to own at young ages, and as rents decline, the household's home ownership propensity declines significantly. We also find a negative relationship between property tax rates and home ownership rates regardless of age. Moreover, if the property taxes are increased, the lifetime discounted utility of the household decreases significantly.

Although tenure choice has been one of the most widely studied concepts in real estate literature, the majority of theoretical models of tenure choice do not consider the impact of the mobility of households, and hence fail to capture the intertemporal interactions between household characteristics, mobility, and the tenure decision. Early examples of theoretical models include Artle and Varaiya (1978), Ranney (1981) and Schwab (1982). The focus in Artle and Varaiya (1978) and Ranney (1981) is on the impact of a perfectly anticipated change in future house prices on current housing demand in the presence of capital imperfections. Households choose to own or rent based on where they are on their life-cycle path of income and how their tenure decision affects their desired path of consumption and asset accumulation. The point of Schwab (1982) is to show that imperfect capital markets cause inflation expectations and nominal interest rates to play a role in the demand for housing, but not to the extend argued in some of the earlier studies. The reason is that an increase in expected inflation causes an increase in the nominal interest rate and the nominal (constant) payment on a typical mortgage, thus increasing the real payments in initial years while reducing real payments in later years. Henderson and Ioannides (1983) highlight an externality involved in renting that makes it more attractive to own than to rent. The externality arises from the fact that the landlord cannot fully charge the tenant for the tenant's increased rate of utilization of the property (this externality results in over utilization of the property under rental tenure) and the tenant cannot collect from the landlord for improvements he makes on a unit. However, none of these models incorporates the possibility that the consumer may have to move in the future.

The need for a dynamic model of housing tenure choice is recognized in a later paper by Henderson and Ioannides (1989). However, they conclude that such a model would be too complicated to solve. Instead, they estimate tenure choice, consumption level and length of stay of households using several reduced-form models. Ioannides and Kan (1996) offer a dynamic discrete choice model that incorporates mobility of households in their tenure choice but the complexity of their setup prevents them from providing a closed-form solution. The mobility of households is also considered in the search model of van der Vlist et al. (2002). However, their focus is on the search of tenants for a rental unit, the matching between searching tenants and the existing supply of units by the landlords, and the resulting steady–state equilibrium. In a recent effort simultaneous to ours, Nichols (2003) uses a finite-horizon life-cycle model where housing is both a consumption and investment good. His objective is to show that the "over-investment puzzle" of housing is consistent with the rational behavior by agents. In addition to focusing on a different issue, the current model also differs from Nichols (2003) in its solution methodology for the tenure choice problem. To our knowledge, the current study is the first study to offer a dynamic life-cycle model of tenure choice employing a genetic algorithm and to utilize this model to explain the findings of the empirical literature. Instead of calculating the probability that the individual is an owner or renter, we derive the optimal tenure choice strategy from the discrete choice problem of forward looking individuals. Our approach is different from traditional models in the sense that individuals form their strategies by incorporating their average probability of move, average improvement on their income, appreciation of housing values etc. and make optimal choices.

The remainder of the paper is organized as follows. The theoretical model is presented in the next section. Section 3 discusses the solution procedures. Numerical experiments and results appear in Section 4. The final section offers some policy implications of our results, especially for older households, and concludes.

2. The model

In this section, we develop a life-cycle model of household tenure choice with random mobility. The objective of a household is to maximize the expected discounted value of his lifetime utility. There is a positive probability that the household may have to move at any time. If he moves, he chooses his tenure, own or rent. Let the tenure choice at time period t

be represented by x_t and the mobility state by s_t where the discrete tenure choice is defined as

$$x_t = \begin{cases} 1 & \text{if household buys a house at time } t, \\ 0 & \text{if household rents a house at time } t \end{cases}$$

and the mobility state is described as

$$s_t = \begin{cases} 1 & \text{if household moves at time } t, \\ 0 & \text{if household does not move at time } t. \end{cases}$$

Then, the maximal expected value of the discounted lifetime utility, V, is

$$V = \max_{\{x_t\}_{t=1}^{T}} E\left[\sum_{t=0}^{T} \delta^t u(x_t, s_t) p(s_t; s_{t-1}, x_{t-1})\right], \tag{1}$$

where E is the expectation operator, $\delta > 0$ is the discount factor, T is the terminal period, $u(x_t,s_t)$ is the utility function for tenure choice of x_t in state s_t and $p(s_t;s_{t-1},x_{t-1})$ represents the state transition probabilities in each period from state s_{t-1} with tenure x_{t-1} to state s_t.

The representation of Eq. (1) assumes that future choices are made optimally. The part of the randomness in household's payoff function arises from the fact that state variables at time $t+1$ are observable only at time $t+1$, but not before. There is a possibility that household moves at time t ($s_t = 1$) and the probability of a move is a function of household characteristics such as, income, age, household size, marital status, race, and gender etc.

We assume that at time 0 an individual has a given initial endowment, ω_0, which is γ fraction of the value of the house h_0 that he currently lives in as an owner or a renter ($\omega_0 = \gamma h_0$). If an individual moves at time 1, he has to make a tenure choice. If he decides to own a house at time 1, he uses initial endowment as downpayment and obtains a mortgage to finance the rest of the house value. On the other hand, if he decides to be a renter at time 1, he invests his initial endowment at the market interest rate, i. This decision will be made every time he moves. Otherwise, he will stay in his current residence as either a renter or an owner. If the household does not move at time t ($s_t = 0$), the utility function for the renter with annual income, y_t and annual rent, e_t, is

$$u(x_t = 0, s_t = 0) = (y_t + \mathrm{i}\omega_t)(1 - \tau) - e_t$$

and for the owner with annual income y_t:

$$u(x_t = 1, s_t = 0) = (y_t - \theta h_p - R_t)(1 - \tau) - (M - R_t),$$

where τ and θ are the income and property tax rates, respectively. h_p represents the value of the house purchased at time $p < t$. Here, it is assumed that property taxes are calculated based on the historical house value. M represents the owner's constant mortgage payment which includes interest payment, R and the repayment of the principal:

$$M = \frac{h_p - \omega_p}{[(1/r) - (1/r)(1/(1+r))^N]},$$

where N is the term of the mortgage, r is the mortgage interest rate and the difference between the value of the house purchased, h_p, and the existing endowment of the individual,

ω_p (downpayment), represents the loan amount.[2] As captured in the utility functions above, a renter has an extra interest income, $\mathrm{i}\omega_t$ whereas an owner has a tax deduction advantage on property tax and mortgage interest payments.

A household that moves ($s_t = 1$) will incur transaction costs. These costs include attorney fees, closing costs, moving expenses, etc. Thus, the utility functions for the mover can be written as follows:

if the new unit is rented,

$$u(x_t = 0, s_t = 1) = (y_t + \mathrm{i}\omega_t)(1 - \tau) - e_t - c_t$$

and if the new unit is purchased,

$$u(x_t = 1, s_t = 1) = (y_t - \theta h_t - R_t)(1 - \tau) - (M - R_t) - o_t,$$

where c_t and o_t are transaction costs incurred by renter and owner, respectively.

The endowment of the household depends on the remaining mortgage balance when he sells his house at time $k \leqslant t$ and the appreciation of the house value over years

$$\omega_t = \begin{cases} [h_{t-1}(1 + a_t)] - b_t & \text{if } x_{t-1} = 1, \\ h_p[(1 + a_{p+1})(1 + a_{p+2}) \cdots (1 + a_k)] - b_k & \text{if } x_{t-1} = 0, \quad x_p = 1, \quad p < t, \quad k \leqslant t, \\ \omega_0 & \text{if } x_{t-j} = 0, \quad j = 1, \ldots, t, \end{cases}$$

where $a_t \geqslant -1$ is the house appreciation rate and b_t represents the remaining mortgage balance at time t. b_t can be expressed as a function of mortgage payments M, mortgage interest rate r, mortgage term N, and the time passed since the individual purchased the house, $t-p$

$$b_t = M[(1/r) - (1/r)(1/(1 + r))^{N-(t-p)}].$$

Clearly, if an individual has never been an owner, b_t will be zero.[3]

Fig. 1 depicts the decision tree of a representative household in two periods with the respective utility functions $u(x_t, s_t;\ x_{t-1}, s_{t-1})$ in each mobility state and tenure choice. Although we illustrate only the case where household moves and lives in an owner-occupied house at time 0, our analysis will include the case where the household moves and lives in a rental house at $t = 0$ as well. In the figure, rectangular boxes, and circles represent decision nodes and states respectively. Table 1 shows how utility functions, endowments, mortgage payments, and mortgage balances of a household are calculated at each decision node. Because of the dynamic nature of the model, all of these functions depend on the current and previous states and tenure.

[2] To simplify the problem, it is assumed that individuals take out fixed rate mortgages and are not allowed to refinance. Note that if the house value is less than the endowment ($h_t < \omega_t$) then there will be no mortgage payment, $M = 0$.

[3] Note that our formulation ignores the potential influence of housing wealth accumulation. The primary reason for not incorporating wealth accumulation in our model is that it would make the already complicated model drastically more complicated and very difficult to solve.

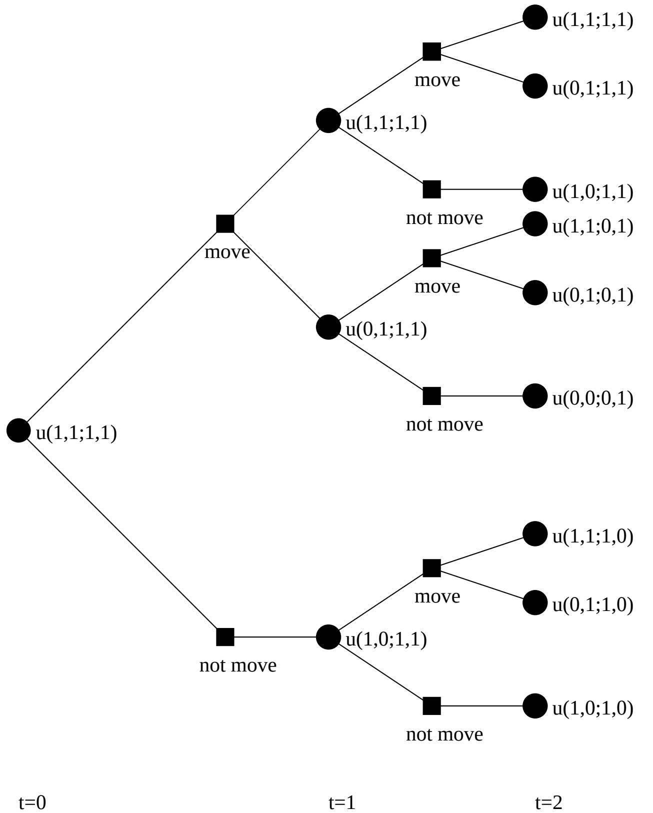

Fig. 1. Decision tree of a representative household that lives in an owner-occupied house at $t = 0$.

3. Solution procedure

We present our model to predict optimal dynamic tenure choice of an individual over his lifetime as a decision tree. The general prescribed procedure for choosing an action from a decision tree employs backward induction analysis that entails three fundamental consistency principles: dynamic, consequential, and strategic (Busemeyer and Townsend, 1993; Hammond, 1976; Sarin and Wakker, 1998). Intuitively dynamic consistency requires the decision-maker to follow through the plans to the end. Consequential principle requires the decision-maker to focus solely on the future events and final consequences given the current state of events, and strategic consistency is the union of the first two. These assumptions provide the foundation for working backward search procedures. However, recent empirical studies on human decision making show that backward induction analysis may be unsuitable for emotionally laden decisions (see Busemeyer et al., 2000; Camerer et al., 1993; Gabaix and Laibson, 2000). For this reason, we assume that our households solve their tenure choice problem by looking forward. Our approach is to specify the optimal tenure path that will be taken at each period as the household moves through the decision tree from the

Table 1
Summary of the tenure choice model[a]

Time	Utility function $u(x_t, s_t;\ x_{t-1}, s_{t-1})$	Mortgage payment	Interest payment	Endowment	Initial mortgage balance
0	$u(1{,}1;1{,}1) = (y_0 - \theta h_0 - R_0)(1-\tau) - (M_0 - R_0)$	$M_0 = (h_0 - \omega_0)A(N)$[b]	$R_0 = b_0 r$	$\omega_0 = \gamma h_0$	$b_0 = M_0 A(N)$
1	$u(1{,}1;1{,}1) = (y_1 - \theta h_1 - R_1)(1-\tau) - (M_1 - R_1)$	$M_1 = (h_1 - \omega_1)A(N)$	$R_1 = b_1 r$	$\omega_1 = h_0(1+a_1) - M_0 A(N-1)$	$b_1 = M_1 A(N)$
1	$u(0{,}1;1{,}1) = (y_1 + \mathrm{i}\omega_1)(1-\tau) - e_1$	—	—	ω_1	—
1	$u(1{,}0;1{,}1) = (y_1 - \theta h_0 - R_{01})(1-\tau) - (M_0 - R_{01})$	M_0	$R_{01} = b_{01} r$	—	$b_{01} = M_0 A(N-1)$
2	$u(1{,}1;1{,}1) = (y_2 - \theta h_2 - R_2)(1-\tau) - (M_2 - R_2)$	$M_2 = (h_2 - \omega_2)A(N)$	$R_2 = b_2 r$	$\omega_2 = h_1(1+a_2) - M_1 A(N-1)$	$b_2 = M_2 A(N)$
2	$u(0{,}1;1{,}1) = (y_2 + \mathrm{i}\omega_2)(1-\tau) - e_2$	—	—	ω_2	—
2	$u(1{,}0;1{,}1) = (y_2 - \theta h_1 - R_{12})(1-\tau) - (M_1 - R_{12})$	M_1	$R_{12} = b_{12} r$	—	$b_{12} = M_1 A(N-1)$
2	$u(1{,}1;0{,}1) = (y_2 - \theta h_2 - R_{2'})(1-\tau) - (M_{2'} - R_{2'})$	$M_{2'} = (h_2 - \omega_{2'})A(N)$	$R_{2'} = b_{2'} r$	$\omega_{2'} = \omega_2$	$b_{2'} = M_{2'} A(N)$
2	$u(0{,}1;0{,}1) = (y_2 + \mathrm{i}\omega_1)(1-\tau) - e_2$	—	—	ω_1	—
2	$u(0{,}0;1{,}0) = (y_2 + \mathrm{i}\omega_1)(1-\tau) - e_2$	—	—	ω_1	—
2	$u(1{,}1;1{,}0) = (y_2 - \theta h_2 - R_{2''})(1-\tau) - (M_{2''} - R_{2''})$	$M_{2''} = (h_2 - \omega_{2''})A(N)$	$R_{2''} = b_{2''} r$	$\omega_{2''} = h_0(1+a_2)(1+a_1) - M_0 A(N-2)$	$b_{2''} = M_{2''} A(N)$
2	$u(0{,}1;1{,}0) = (y_2 + \mathrm{i}\omega_{2''}(1-\tau) - e_2$	—	—	$\omega_{2''}$	—
2	$u(1{,}0;1{,}0) = (y_2 - \theta h_0 - R_{02})(1-\tau) - (M_0 - R_{02})$	M_0	$R_{02} = b_{02} r$	—	$b_{02} = M_0 A(N-2)$
⋮	⋮	⋮	⋮	⋮	

[a] For illustration transaction costs are suppressed.

[b] $A(N)$ represents present value of annuity of \$1 per period for N periods, defined as $A(N) = [(\frac{1}{r} - \frac{1}{r(1+r)^N}]$. Depending on the previous mobility and tenure status, we have different values of bs, Ms, and R in each period.

initial node to terminal node. Instead of planning the action at the terminal node and working backwards to the beginning, we propose a decision algorithm working forward over time. Yet, we assume that our decision-maker is sophisticated à la Hammond (1976) anticipates future choices and chooses the best path from amongst those that are available to him. Thus, the sophisticated choice path will be dynamically consistent.

The empirical studies have also demonstrated that people tend to simplify problems and solve them using selective heuristic search techniques. Since real life problems are generally multitudinous, the trial, and error search would simply not work for complex systems and that the search must be highly selective (Gabaix and Laibson, 2000; Simon et al., 1986). In this study, we use an alternative approach known as the genetic algorithm (GA), a probabilistic search approach, to examine the optimal tenure choices of an individual over lifetime. To derive a dynamically consistent solution for the model, we have to apply complete enumeration where GA handles efficiently since the search will be stochastic and directed (Goldberg, 1989). GA is founded on the ideas of evolutionary processes and operates on a population of candidate solutions to a well-defined problem (for a more detailed description of GA procedure, see Appendix A).

3.1. Time aggregation

In the model, we assume that individuals make buy or rent decisions whenever they move ($s_t = 1$). The factors that cause individuals to move are characterized as random events, such as changes in jobs, changes in marital status, changes in household size, or dissatisfaction with current residence (Muth, 1974). It should be noted, however, that if an individual has to move and make a tenure choice at each period, the decision tree becomes very large within a short period of time. For instance, for our particular problem, an individual will face more than 1.5 million decision nodes if these random events, i.e., moves, are realized 13 times over the lifetime. The tractability of such a decision tree would be very difficult for an individual looking forward at $t = 0$. In our numerical experiment, we assume that an individual starts to move and makes his first tenure choice at age 25 and lives until age 75. Then, we aggregate our 50-year model into five mobile periods. In determining the number of moves that a household makes over lifetime, we consider the results of previous studies on the average number of times US households move and how long they stay in their residences over their lifetime. For example, Ioannides (1987) calculates that the average length of stay is 142.35 months. It suggests that individuals will move approximately five times over a 50-year period. Thus, in our proposed model, the individual will face five random events of move with estimated probabilities. Furthermore, since older households stay longer in their current dwellings (Muth, 1974), we assume that a household will decide to move or not every 5 years until age 35. The length of stay increases to 10 years after age 35. Hence, at age 25–35, the random event of one move happens within a five-year interval and thereafter, within a ten-year interval until age 75. So, in our model, the length of stay is determined primarily by life-cycle characteristics, such as marital status, age and occupation, that are exogeneous to tenure choice. The last tenure decision will be made at age 65 and the household will live in that residence for the remaining ten years. At age 75, the owner will liquidate

Table 2
Time dependent parameters

Age	Income ($)	House value[a] ($)	Rent[b] ($)	Probability of move	
				$x_{t-1} = 1$	$x_{t-1} = 0$
25–30	32,649	65,000	4062.5	—	—
30–35	41,078	80,000	5000.0	0.149518	0.357189
35–45	51,896	95,000	5937.5	0.128494	0.317879
45–55	63,685	125,000	7812.5	0.092154	0.242906
55–65	62,259	115,000	7187.5	0.063551	0.176615
65–75	52,736	105,000	6562.5	0.044376	0.127988

[a] Income and house value are the mean income and house value.
[b] On average, house value is 16 times of rent.

his house while renter has already liquidated his house and both move to a nursing home and die at age 76.[4]

3.2. Parameter selection

Based on the historical data and current observations in the US markets, we utilize the following set of parameters: property tax rate, $\theta = 0.02$; income tax rate, $\tau = 0.19$; market interest rate, $i = 0.06$; mortgage interest rate, $r = 0.07$; house price appreciation rate, $a = 0.02$; discount factor, $\delta = 0.95$; and downpayment, $\gamma = 0.2$.[5] Homeowners pay legal and realtor fees at the time they move out of their homes whereas renters do not have to pay these fees. The transaction costs for renters include security deposits of one or two month's rent, search costs to find a new house and moving costs (DiPasquale and Wheaton, 1996). Therefore, we assume that three percent of the house value and two months rent can be taken as transaction costs for owners and renters, respectively.

The probability of a move $p(s_t = 1; s_{t-1}, x_{t-1})$, is estimated at each decision node using a sample of households from 1990 to 1993 panel study of income dynamics (PSID) datasets. The moving probabilities depend on previous tenure status, household wealth, demographic characteristics, such as, age, and work status characteristics, and they decline as households get older (see Table 2 and Table B.1 in Appendix B). Current renters have higher probability of moving than current owners do as found in several studies (for example, see Ioannides and Kan, 1996; Kan, 2000).

In our numerical experiments, some parameters change over time as reported in Table 2. Average household income, house value and rent at different age groups are estimated

[4] Although the model does not explicitly incorporate any bequest motives, one can modify the model to assume that individuals leave some/all of their wealth available at age 75, accumulated in their houses through principal payments and appreciation in house value, to their heirs. This will not change the results of the paper as long as we assume that the utility of consumption from a dollar is the same as the utility from leaving a dollar to one's heirs.

[5] These values are calculated as follows: Property tax rate is the average property tax rate in several US cities in 1992. The market interest rate is the interest rate on the 30-year US Treasury-bills. Mortgage interest rate is the average interest rate on fixed rate mortgages. House price appreciation rate is calculated from the changes in the median house values in the US over the decade between 1990 and 2000. Most of these values are obtained from the Statistical Abstracts of the United States. Since there is a jump in the cost of mortgage when the downpayment is less than 20% (due to mortgage insurance requirement), we assume a loan-to-value ratio of 80%.

from PSID datasets. Furthermore, as age increases, income of household increases first but then it declines after certain age. This relationship also holds for the rent paid and the value of the house purchased (DiPasquale and Wheaton, 1996). In calculating the average rent, we assume that households will buy a house with a value 16 times of their annual rent. Since Poterba (1992) reports that this user cost (ratio of house value to annual rent) increased from 13.3 to 15.1 over the last decade (1980–1990) and the real rent has not changed much but house values have appreciated after 1990, we take a value of 16 as a user cost in our base case.

4. Numerical experiments

The life-long optimal tenure choices of an individual using benchmark parameters and the sensitivity analysis using six different simulations are reported in Table 3. In the analysis of forward-looking decision-making, there are two sets of results for each experiment depending on the initial tenure status of the household (either owner, $x_0 = 1$ or renter, $x_0 = 0$ at age 25). Thus, the impact of changes in income tax, property tax, house appreciation rates, transaction cost, rents, and spread between mortgage and market interest rates on the optimal tenure path of an individual has been numerically examined. The ratios in the table represent the probability of owning a house if a move occurs, conditional on the initial tenure choice made at age 25.

According to the model, an individual who moves at age 30–35 (or $t = 1$) makes only one tenure decision. In our numerical experiment, it is found that the optimal choice will be to buy a house regardless of the previous tenure at age 25 (as captured by the ratio 1/1 in Table 3). Assuming that the ownership rate at age 25–30 is 36.5%,[6] the result that all of the movers become homeowners increases the expected home ownership rate at age 30–35 to 59.18%[7] regardless of the changes in economic and policy variables.

In the second period, age 35–45, the individual faces two cases. The first case occurs if he does not move in the first period, but moves in the second period and has to choose his tenure. Similarly, the second case occurs if he moves in both the first and the second periods. The results indicate that the household is better off by owning in one case and renting in the other case (as captured by the ratio 1/2),[8] thus giving rise the expected home ownership rate for the 35–45 age group to 61.87%, as reported in the third column of the table.

At ages 45, 55, and 65, a household faces with 4, 8, and 16 tenure decisions, respectively, depending on his mobility in the current time periods. Since optimal decisions are found to be same across different scenarios until age 45, we will concentrate on the results after 45. In addition to the tenure choice, we present the utility gains or losses relative to the base case in each experiment.[9]

[6] *Source.* US Census Bureau, Statistical Abstracts of the United States (2000).

[7] The probability of home ownership at age 30–35 is the summation of three joint probabilities: p(own at 30–35, move at 30–35, own at 25–30), p(own at 30–35, not move at 30–35, own at 25–30), and p(own at 30–35, move at 30–35, rent at 25–30). Hence, $p(\text{own at } 30\text{–}35) = [(1)(0.149518)(0.365)] + [(1)(1 - 0.149518)(0.365)] + [(1)(0.149518)(1 - 0.365)] = 0.5918$. See Table 3 for further explanations.

[8] There is only one exception. When the appreciation rate is zero, it is found that the owner individual at age 25 will rent a house in both cases. Their expected ownership rate is 57.63%.

[9] The base case corresponds to the discounted utility of the household under the initial parameters specified in Section 3.2.

Table 3
Numerical results

Age	Income taxes (%)											
	16			19			22			25		
	$p(x_t=1 \mid s_t=1,x_0)$[a]		p(own)[b]	$p(x_t=1 \mid s_t=1,x_0)$		p(own)	$p(x_t=1 \mid s_t=1,x_0)$		p(own)	$p(x_t=1 \mid s_t=1,x_0)$		p(own)
25–30	1	0	36.5%	1	0	36.5%	1	0	36.5%	1	0	36.5%
30–35	1/1	1/1	59.18	1/1	1/1	59.18	1/1	1/1	59.18	1/1	1/1	59.18
35–45	1/2	1/2	61.87	1/2	1/2	61.87	1/2	1/2	61.87	1/2	1/2	61.87
45–55	0/4	0/4	56.17	0/4	0/4	56.17	2/4	1/4	61.33	4/4	1/4	64.18
55–65	0/8	0/8	52.60	4/8	3/8	57.28	8/8	3/8	63.89	8/8	8/8	70.51
65–75	9/16	6/16	53.85	10/16	4/16	57.70	9/16	11/16	65.85	9/16	13/16	72.21
Utility gain	3.87%	4.18%					−3.86%	−4.18%		−7.70%	−8.35%	
	House value appreciation rate (%)											
	0			2			3			4		
	$p(x_t=1 \mid s_t=1,x_0)$		p(own)	$p(x_t=1 \mid s_t=1,x_0)$		p(own)	$p(x_t=1 \mid s_t=1,x_0)$		p(own)	$p(x_t=1 \mid s_t=1,x_0)$		p(own)
45–55	0/4	0/4	52.32	0/4	0/4	56.17	4/4	4/4	71.13	3/4	4/4	69.70
55–65	0/8	0/8	48.99	4/8	3/8	57.28	4/8	7/8	73.33	4/8	7/8	72.17
65–75	0/16	0/16	46.82	10/16	4/16	57.70	6/16	7/16	72.79	7/16	10/16	72.60
Utility gain	−1.45%	−0.52%					1.30%	0.56%		3.11%	1.45%	
	Spread between mortgage and market interest rates ($r-i$) (%)											
	0.5			1.0			1.5			2.0		
	$p(x_t=1 \mid s_t=1,x_0)$		p(own)	$p(x_t=1 \mid s_t=1,x_0)$		p(own)	$p(x_t=1 \mid s_t=1,x_0)$		p(own)	$p(x_t=1 \mid s_t=1,x_0)$		p(own)
45–55	0/4	0/4	56.17	0/4	0/4	56.17	3/4	1/4	62.79	3/4	2/4	65.07
55–65	0/8	0/8	52.60	4/8	3/8	57.28	6/8	4/8	65.05	8/8	4/8	68.16
65–75	8/16	6/16	53.70	10/16	4/16	57.70	8/16	5/16	65.00	9/16	12/16	69.89
Utility gain	0.06%	0.11%					−0.04%	−0.11%		−0.07%	−0.21%	

	Transaction cost of owner (= c * House value) (%)											
	$c=3$			$c=4$			$c=5$			$c=6$		
	$p(x_t=1 \mid s_t=1, x_0)$		p(own)	$p(x_t=1 \mid s_t=1, x_0)$		p(own)	$p(x_t=1 \mid s_t=1, x_0)$		p(own)	$p(x_t=1 \mid s_t=1, x_0)$		p(own)
45–55	0/4	0/4	56.17	0/4	0/4	56.17	0/4	0/4	56.17	0/4	0/4	56.17
55–65	4/8	3/8	57.28	1/8	1/8	54.01	0/8	0/8	52.60	0/8	0/8	52.60
65–75	10/16	4/16	57.70	8/16	5/16	54.65	3/16	3/16	51.84	1/16	1/16	50.79
Utility gain				−0.12%	−0.05%		−0.23%	−0.10%		−0.35%	−0.15%	
	Rent (=House value/ d)											
	$d=15$			$d=16$			$d=17$			$d=18$		
	$p(x_t=1 \mid s_t=1, x_0)$		p(own)	$p(x_t=1 \mid s_t=1, x_0)$		p(own)	$p(x_t=1 \mid s_t=1, x_0)$		p(own)	$p(x_t=1 \mid s_t=1, x_0)$		p(own)
45–55	3/4	2/4	65.07	0/4	0/4	56.17	1/4	0/4	57.59	0/4	0/4	56.17
55–65	8/8	8/8	71.24	4/8	3/8	57.28	0/8	0/8	53.93	0/8	0/8	52.60
65–75	10/16	13/16	73.05	10/16	4/16	57.70	4/16	3/16	53.24	1/16	1/16	50.79
Utility gain	−0.11%	−0.78%					0.11%	0.71%		0.22%	1.34%	
	Property taxes (%)											
	2.00			2.50			2.75			3.00		
	$p(x_t=1 \mid s_t=1, x_0)$		p(own)	$p(x_t=1 \mid s_t=1, x_0)$		p(own)	$p(x_t=1 \mid s_t=1, x_0)$		p(own)	$p(x_t=1 \mid s_t=1, x_0)$		p(own)
45–55	0/4	0/4	56.17	0/4	0/4	56.17	0/4	0/4	56.17	0/4	0/4	56.17
55–65	4/8	3/8	57.28	0/8	0/8	52.60	0/8	0/8	52.60	0/8	0/8	52.60
65–75	10/16	4/16	57.70	3/16	3/16	51.84	1/16	1/16	50.79	0/16	1/16	50.64
Utility gain				−0.68%	−0.26%		−1.02%	−0.39%		−1.36%	−0.52%	

[a] Each cell represents the probability that a household owns ($x_t = 1$) given that he moves ($s_t = 1$) if he starts as an owner or a renter at age 25–30 ($x_0 = 1,0$). For example, in the first column, on age 55–65 with 16% income tax rate, the household makes eight tenure decisions depending on his previous moves. It is found that he decides to rent in all of the cases (i.e., 0/8).

[b] The p(own) columns represent the expected ownership rate. It is calculated using the following formula: p(own at l) = p(own at l |move at l, own at l–1) p(move at l |own at l–1) p(own at l–1) + p(own at at l |move at l, rent at l–1) p(move at l |rent at l–1) p(rent at l–1) + p(own at at l |not move at l, own at l–1) p(not move at l |own at l–1) p(own at l–1) where l=30–35, 35–45, 45–55, 55–65, 65–75, and p(own at 25–30) = 36.5%.

The first experiment examines the effect of income tax rate on the optimal tenure choice. Several empirical studies have found that tax deductibility of mortgage interest payments and property taxes have substantial positive influence on home ownership (Aaron, 1970; Green and Vandell, 1999; Rosen, 1979; Rosen and Rosen, 1980; Rosenthal, 1988). Since tax deductibility reduces the effective cost of owning, this benefit would increase with the income tax rate. For the base case, where income tax rate is 19%, when household moves by ages 65–75, he will have a 0.625 (i.e., 10/16) probability of owning if he started as an owner at ages 25–30. This probability decreases to 0.25 (i.e., 4/16) if he started as a renter. Hence, the expected home ownership rate at ages 65–75 will be 57.70%. The simulation results suggest that if income tax rate increases, a representative household is more likely to become a homeowner at the ages of 45–55 and 55–65. However, in old ages (after 65) since real income of household declines (see Table 2), an increase in income tax rate will reduce the tax benefits of mortgage payments and subsequently reduce home owning propensity of moving aged households. Consequently, the tax deductibility of interest is worth less to the older households, as in Aaron (1970). Although tax benefits of owning increase, the lifelong discounted utility of the household declines as income tax rate increases.

The simulation results for the impact of a change in house price appreciation rate suggest that if there is no appreciation in house values, the household would prefer to be a renter. If house values appreciate, he chooses to be a homeowner in early ages as found by Nakagami and Pereria (1991) and Rosen et al. (1984). As house values continue to increase, if he moves, he prefers to sell his house and rent instead of owning. This slightly reduces the conditional probability of home ownership in old ages. Although the growth in house prices increases the proportion of owner–occupiers for the relatively young households (45–55), this increase will depend on the access the household has to a mortgage loan market. Ranney (1981) shows that consumers respond differently to changes in prices depending on the constraints in the mortgage market. Since older households have higher accumulation of equity than young households, they will choose to own even at low house price appreciation rates. For example, when the house value appreciation rate is two percent, even if the household did not own at ages 45–55, the conditional probability of owning increases to 0.50 (0.38) (i.e., 4/8 (3/8)) at ages 55–65 and changes to 0.625 (0.25) at ages 65–75 if the household was owner (renter) at age 25–30. Additionally, the discounted utility of the household increases as the house price appreciation rate increases.

The third simulation analyzes the impact of a change in the spread between the market and mortgage interest rates instead of the level of interest rates. Since Schwab (1982) shows that there is no clear-cut relationship between demand for housing and real interest rates, inflation rate and nominal interest rate, and Kan (2000) reports no significant influence of nominal interest rates on tenure choice, we examine the spread between the market and mortgage interest rates instead of the level of interest rates. If the spread is low, the opportunity cost of buying a house will be high and individuals prefer to be a renter instead of owning a house when they move. As spread increases, it is observed that the household becomes renter at ages between 45 and 55 but he is more likely to be an owner at ages above 55. This can be explained by the difference in the cost of owning for different age groups. At ages 55–65, real income of household is similar to that at ages 45–55 ($63,685 vs $62,259, see Table 2) but households prefer lower priced properties at ages 55–65 (the house value purchased at ages 45–55 is $125,000 vs $115,000 at ages 55–65, see Table 2). Therefore, even though mortgage interest rates increase relative to the market interest rate, the impact on ownership cost will be lower for the 55–65 age group than for the 45–55 age group. Hence, mover households at ages 55–65 still prefer owning a house instead of renting although households at ages 45–55 prefer to rent, as proposed by Kearl (1979). As spread increases more, all households prefer to own and invest in a house rather than to invest at the market interest rate and rent a house. Similar to Schwab (1982), we also find that discounted utility loss due to the increase in the spread is very small. As the opportunity cost of owning increases, the expected ownership probability declines for all age groups.

Transaction costs are assumed to be a certain percentage of the value of the house purchased. Since a household in the 45–55 age group purchases the highest value houses, he will incur the highest transaction costs. Therefore, he is better of renting than buying. However, a household at ages between 65 and 75 is more likely to own even at slightly higher transaction costs since he purchases a less expensive house ($105,000). In addition, we observe that if transaction costs increase, the probability of owning decreases for all age groups. These findings support Rosenthal (1988) that if transaction costs are high, individuals prefer to stay in rental housing because of the increase in the cost of owning. This result is also supported with the decline in expected home ownership rates with the increase in transaction cost at almost all age levels. The discounted utility of the household is slightly affected from the changes in transaction costs since these costs are paid only when the household moves.

We also found that if rents are high relative to house values (e.g., $d = 15$), the mover household is more likely to become a homeowner at relatively young ages whereas if rents decline, he prefers to be a renter immediately. However, at old ages, the household is more likely to be a home owner although rents decline relative to house values since there are offsetting tax benefits. In this experiment, the impact of changes in rents on lifelong discounted utility of the renter is noticeably higher than that of the owner.

When we study the impact of property taxes, we observe that in the base case, households at ages 45–55 choose to rent when they move. This finding confirms the actual lower rate of ownership in this age group.[10] As property taxes increase, the households prefer to be renter in general. To be more specific, none of the households that moves in age groups 45–55 and 55–65 prefers to be an owner if property taxes are above two percent. The reason for this behavior can be explained by the fact that property taxes are based on the acquisition value of the house.[11] Hence, the tendency to purchase high-priced houses and higher probability of moving at ages 45–65 relative to ages 65–75 result in adverse impact of property taxes on ownership propensity. Moreover, the discounted utility of the households declines as the property taxes increase.

The numerical results suggest that income tax rate is the most important factor that affect the utility of households. The sensitivity of utility to the changes in the income tax rate can be explained by the fact that an individual is required to pay income taxes regardless of the tenure choice or mobility. The other costs are paid either when the individual becomes an owner or when he moves.

[10] For example, in 1998, the home ownership rates were 23.9 and 19.5% for households with ages 35–44 and 45–54, respectively. *Source.* US Census Bureau, Statistical Abstracts of the United States (2000).

[11] This assumption might affect the results because O'Sullivan et al. (1995) show that if property taxes are based on acquisition value, the likelihood of home ownership among infrequent movers will increase but frequent movers will more likely rent.

5. Conclusions

The objective of this paper has been to offer an alternative theoretical model of the lifetime tenure choice problem. In the model, the household with random mobility solves its tenure choice problem by looking forward and maximizing its lifetime utility. We also simulate the model utilizing parameter values obtained from historical data. We examine the impact of such variables as income tax, property tax, transaction cost, house price appreciation rate, relative cost of renting, and spread between mortgage and market interest rates on the household's tenure decision. The results indicate that the theoretical model and the forward looking solution procedure perform very well in terms of explaining the previous empirical findings in the literature about tenure choice of households, thus suggesting that individuals act quite rationally in their choice of home ownership status.

In this study, we have investigated the tenure choice of households under the assumption that the probability of a move by a household is dependent of whether they own or rent but independent of the length of stay in the current unit. However, as argued in a recent study by Goodman (2002), the tenure choice is correlated with the length of stay in the current unit. One extension of the current model would be to correlate the mobility rate with the current ownership status and to incorporate residence time in the analysis of tenure choice.

Appendix A. A simple GA algorithm

Genetic algorithm is based on the principle of evolution—survival of the fittest. A population of potential solutions undergoes a sequence of unary (mutation type) and high order (cross over) transformations. These solutions/individuals strive for survival: a selection scheme, biased towards fitter individuals, and selects the next generation. After some number of generations, the program converges and generates the optimum solution. GA is often more attractive than gradient search methods because it does not require complicated differential equations. It needs only evaluation or fitness function to distinguish between different solutions/individuals. For example, in most of the economic modeling, the fitness function is either utility or profit function.

To clarify the search procedure used in this paper, we present a two-period version of the problem. As illustrated in Fig. 1, since there are two move states, there would be three tenure decisions, x during the lifetime of the household. x_i takes binary values: 1 for owner and 0 for renter. If at $t = 0$, household is owner, $x_0 = 1$, then

t	i	x_{t-1}	s_{t-1}	s_t	$x_i(s_t;\ x_{t-1}, s_{t-1})$
1	1	Owner	Move	Move	(owner,renter)
2	2	Owner	Move	Move	(owner,renter)
2	2	Renter	Move	Move	(owner,renter)
2	3	Owner	Not-move	Move	(owner,renter)

Since households do not make any choice if they do not move, we did not report the not-move states. In our tenure choice model, the discounted lifelong utility function detailed in Table 1 is used to measure the fitness, f of the candidate solutions of the problem:

$$\max_{x_i \in 0,1} f = u(x_0 = 1) + \delta[p_1\Theta_1 + (1 - p_1)\Theta_2],$$

where

$$\begin{aligned}
\Theta_1 &= x_1[u(x_1;\, x_0 = 1) + \delta[p_2\Theta_3 + (1 - p_2)\Theta_4]],\\
&\quad + (1 - x_1)[u(1 - x_1; x_0 = 1) + \delta[p_2\Theta_5 + (1 - p_2)\Theta_6]],\\
\Theta_2 &= u(x_0 = 1; \text{not move at } t = 0) + \delta[p_2\Theta_7 + (1 - p_2)\Theta_8],\\
\Theta_3 &= x_2u(x_2;\, x_1 = 1) + (1 - x_2)u(1 - x_2;\, x_1 = 1),\\
\Theta_4 &= u(x_1 = 1, \text{not move at } t = 1),\\
\Theta_5 &= x_2u(x_2;\, x_1 = 0) + (1 - x_2)u(1 - x_2;\, x_1 = 0),\\
\Theta_6 &= u(x_1 = 0, \text{not move at } t = 1),\\
\Theta_7 &= x_3u(x_3;\, x_0 = 1) + (1 - x_3)u(1 - x_3;\, x_0 = 1),\\
\Theta_8 &= u(x_0 = 1, \text{not move at } t = 1)
\end{aligned}$$

and p_i denotes the probability of move at $t = i$, and δ is the discount factor. Starting with any random solution as an initial population, say, $x_1 = x_2 = x_3 = 0$, GA guides the search for optimum solution. Although we have a two-period problem, the recursion inherent in the model complicates the fitness function remarkably. GA works iteration by iteration generating and testing a population of solutions. The current population are carried through into a new population depending on the fitness values or discounted lifelong utility function. Due to this operation called reproduction, a candidate solution with better fitness value gets larger number of copies in the next iteration. This strategy emphasizes the survival-of-the-fittest (natural selection) concept of the genetic algorithms. In our problem, candidate population of solutions for three tenure choices, x_i, are substituted to the fitness function and the ones with higher values are selected for further transformations.

As mentioned earlier, this approach is different from classical search methods. In classical methods of optimization the rule is deterministic where movement is from one point in the search space into another point based on some transition rule. However, in GAs probabilistic operators progress the search. In order to explore new solutions in the search space, crossover and mutation are applied as additional genetic operators to reproduction. A simple crossover follows reproduction in a few steps. First, newly reproduced strings are paired together at random. Then, an integer position along every pair of strings is selected uniformly at random. Finally based on the probability of crossover, the paired strings undergo crossing over at the integer position along the string. As an arbitrary example, consider two strings $y = 000111$ and $z = 111000$ of length six mated at random. If the random draw chooses position three ($y = 000|111$ and $z = 111|000$), the resulting crossover yields two new strings, $y^* = 111111$, and $z^* = 000000$. By combining reproduction and crossover, we exchange information and combine portions of good quality solutions. Reproduction and crossover give GAs most of their search power. Third operator mutation is simply an occasional random alteration of a string position based on the probability of mutation.[12] The mutation operator in general helps in avoiding the possibility of mistaking a local extreme for a global one. Genetic algorithms combine partial strings to form new solutions that are possibly better than their predecessor. This kind of methodology is

[12] In our numerical experiments, we use publicly available GA package GENESIS (version 5.0) with default parameters: crossover rate = 0.6 and mutation rate = 0.001.

strictly inductive when compared with other search methods, which are mostly deductive. Holland (1975) schema theorem places the theory of genetic algorithm on rigorous footing by calculating a bound on the growth of useful similarities. The fundamental principle of GA is to make good use of these similarity templates.

Appendix B. Estimation of moving probabilities

In determining the moving probabilities, the model by Boehm et al. (1991) is estimated using a sample of 9406 households selected from the 1990 to 1993 Panel Study of Income Dynamics. The following logit model is used in the estimation of the moving probability for owners and renters.

Table B.1
Logit coefficients

Variable	Parameter estimate	Standard error
Intercept	−1.5211	0.2774
Previous tenure	−1.1508	0.0617
Income	3.6699	1.0302
Family Size	−0.1525	0.0205
Change in marital status	0.2562	0.0807
Married	0.1907	0.0911
Male	−0.3731	0.0857
White	0.5237	0.0593
Age	−9.2011	1.1025
Age squared	5.3212	1.1423
Years of education	−0.0059	0.0100
Professional occupation	0.3108	0.0579
Wife employed	−0.2559	0.0717
Job changed	0.7047	0.0692
Change in family size	0.5376	0.0310
Unemployed	−0.1959	0.0966
Log likelihood	4636.0424	

Definition of Variables:

Move	Dummy variable, takes a value of 1 if a household moved during the last two years, and 0 otherwise.
Previous tenure	Dummy variable, takes a value of 1 if a household was owner before the move.
Income	Annual family money income in terms of 1992 prices in 10,000 s.
Family size	Number of people in the family.
Change in marital status	Takes a value of 1 if there is a change in marital status.
Married	Takes a value of 1 for married households and 0 otherwise.
Male	Takes a value of 1 if head of household is male, 0 otherwise.
White	Takes a value of 1 if head of household is white, 0 otherwise.

Age	age of head of household in decades.
Years of education	Years of education completed by head of household.
Professional occupation	Takes a value of 1 if head of household is professional, technical, and kindred workers, managers, officials, and proprietors, and 0 otherwise.
Wife employed	Takes a value of 1 for married households. and spouse works full time, 0 otherwise.
Job changed	Takes a value of 1 if there is a change in the main employer of the head of household.
Change in family size	The absolute value of the change in family size over one year period following the tenure choice.
Unemployed	Takes a value of 1 if head of household is unemployed, and 0 otherwise.

References

Aaron, H., 1970. Income taxes and housing. Amer. Econ. Rev. 60, 789–806.
Artle, R., Varaiya, P., 1978. Life cycle consumption and homeownership. J. Econ. Theory 18, 38–58.
Boehm, T.P., Herzog, H.W., Schlottmann, A.M., 1991. Intra-urban mobility, migration, and tenure choice. Rev. Econ. Statist. 73, 59–68.
Busemeyer, J.R., Townsend, J.T., 1993. Decision field theory: a dynamic cognitive approach to decision making in an uncertain environment. Psychol. Rev. 100, 432–459.
Busemeyer, J.R., Weg, E., Barkan, R., Li, X., Ma, Z., 2000. Dynamic and consequential consistency of choices between paths of decision trees. J. Exp. Psychol. Gen. 129, 530–545.
Camerer, C.F., Johnson, E.J., Rymon, T., Sen, S., 1993. Cognition and framing in sequential bargaining for gains and losses. In: Binmore, K., Kirman, A., Tani, P. (Eds.), Frontiers of Game Theory. The MIT Press, Cambridge, MA.
DiPasquale, D., Wheaton, W.C., 1996. Urban Economics and Real Estate Markets. Prentice Hall, NJ.
Gabaix, X., Laibson, D., 2000. Bounded rationality and directed cognition. Harvard University, unpublished paper.
Goodman, A.C., 2002. Estimating equilibrium housing demand for stayers. J. Urban Econ. 51, 1–24.
Goldberg, D.E., 1989. Genetic Algorithms in Search, Optimization, and Machine Learning. Addison-Wesley, Reading, MA.
Green, R.K., Vandell, K.D., 1999. Giving households credit: how changes in the U.S. tax code could promote homeownership. Reg. Sci. Urban Econ. 29, 419–444.
Hammond, P.J., 1976. Changing taste and coherent dynamic choice. Rev. Econ. Stud. 43, 159–173.
Henderson, J.V., Ioannides, Y.M., 1983. A model of tenure choice. Amer. Econ. Rev. 73, 98–113.
Henderson, J.V., Ioannides, Y.M., 1989. Dynamic aspects of consumer decisions in housing markets. J. Urban Econ. 26, 212–230.
Holland, J.H., 1975. Adaptation in Natural and Artificial Systems. University of Michigan Press, Ann Arbor, MI.
Ioannides, Y.M., 1987. Residential mobility and housing tenure choice. Reg. Sci. Urban Econ. 17, 265–287.
Ioannides, Y.M., Kan, K., 1996. Structural estimation of residential mobility and housing tenure choice. J. Reg. Sci. 36, 335–363.
Kan, K., 2000. Dynamic modelling of housing tenure choice. J. Urban Econ. 48, 46–69.
Kearl, J., 1979. Inflation, mortgages, and housing. J. Polit. Econ. 87, 115–138.
Muth, R.F., 1974. Moving costs and housing expenditure. J. Urban Econ. 1, 108–125.
Nakagami, Y., Pereria, A.M., 1991. Housing appreciation, mortgage interest rates, and homeowner mobility. J. Urban Econ. 30, 271–292.
Nichols, J.B., 2003. A Life Cycle Model with Housing, Portfolio Allocation, and Mortgage Financing, Mimeo, University of Maryland.

O'Sullivan, A., Sexton, T.A., Sheffrin, S.M., 1995. Property taxes, mobility, and home ownership. J. Urban Econ. 37, 107–129.

Poterba, J.M., 1992. Taxation and housing: old questions, new answers. Amer. Econ. Rev. Papers Proceed. 82, 237–242.

Ranney, S.I., 1981. The future price of houses, mortgage market conditions, and the returns to homeownership. Amer. Econ. Rev. 71, 323–333.

Rosen, H.S., 1979. Housing decisions and the U.S. income tax: an econometric analysis. J. Public Econ. 11, 1–23.

Rosen, H.S., Rosen, K.T., 1980. Federal taxes and homeownership: evidence from time series. J. Polit. Econ. 88, 59–75.

Rosen, H.S., Rosen, K.T., Holtz-Eakin, D., 1984. Housing tenure, uncertainty, and taxation. Rev. Econ. Statist. 66, 405–416.

Rosenthal, S.S., 1988. A residence time model of housing markets. J. Public Econ. 36, 87–109.

Sarin, R.K., Wakker, P.P., 1998. Dynamic choice and non-expected utility. J. Risk Uncertainty 17, 87–119.

Schwab, R.M., 1982. Inflation expectations and the demand for housing. Amer. Econ. Rev. 72, 143–153.

Simon, H.A., G.B. Dantzig, R. Hogarth, et al. 1986. Decision Making and Problem Solving. In: Research Briefings 1986: Report of the Research Briefings Panel on Decision Making and Problem Solving. National Academy Press, Washington, DC.

van der Vlist, A.J., Rietveld, P., Nijkamp, P., 2002. Residential search and mobility in a housing market equilibrium model. J. Real Estate Finance Econ. 24, 277–300.