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Portfolio choices for homeowners

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Abstract

In this paper, I show that introducing frictions associated with housing into standard life-cycle models can partially resolve the portfolio choice puzzle. I calibrate a model in which a representative household endogenously transits from renting to mortgage-financed homeownership. The household can later adjust housing status either voluntarily or because of a forced move, by paying transaction costs. It is shown that homeownership crowds out stock market participation: risky owner-occupied housing substitutes for stocks while bonds provide liquidity. Young and middle-aged households, regardless of whether they are currently homeowners, hold much less stock than predicted by traditional models without housing.

JEL classification: G11; D10

Keywords: Portfolio choices; Homeownership

1. Introduction

Modern analysis of portfolio choices in incomplete markets has shown that given the historically prevailing equity premium, typical theoretical models with stochastic labor income but no other frictions predict 100% equity stockholding in households' financial portfolios. This is clearly inconsistent with what we observe. For instance, the 1998 Survey

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of Consumer Finance shows that the median household stockholdings are zero, even after taking into account the indirect holdings of stocks in mutual funds and defined contribution pensions. The gap between theoretical predictions and empirical evidence is referred to in the literature as "the portfolio choice puzzle," which is just the flip side of "the equity premium puzzle" in Mehra and Prescott [17].

Housing is a major investment for two thirds of US households. Nonetheless, most of the traditional literature ignores the single most important asset in many households' portfolios: a leveraged position in owner-occupied housing. In this paper, I explore the possibility that households' portfolio choices are tilted by this particular asset. The housing asset provides both consumption benefits and financial returns, but it is illiquid. Specifically, I study the interaction of the housing investment and financial asset investments in a dynamic life-cycle model. A representative household derives utility from housing consumption and nondurable goods consumption. The housing asset enters into a household's wealth in a complicated way because it involves mortgage debt, and is costly to adjust. Households use their wealth to pay for consumption, housing expenditures and to invest in real estate and financial assets. Wealth comes from an uncertain stream of labor income and from savings in both liquid and illiquid assets. A key element of my model is that the rent versus buy decision is endogenous. Households can avoid fixed mortgage payments and illiquid homeownership by renting, though with less utility than homeownership. This setting provides flexibility about the time at which households make housing investments, while also reducing distortions in financial asset investments relative to models with mandatory homeownership.

My main findings are summarized as follows. I find that young and middle-aged households, regardless of whether they are currently homeowners, have less stock holdings than predicted by traditional models without housing. Given the historical equity premium, the benchmark traditional model predicts that middle-aged households put 99% of their financial wealth in stocks, whereas the model here predicts that the ratio is only 48%. This qualitative result is robust to parameter choice. It implies that introducing frictions associated with housing into standard models can partially resolve the portfolio choice puzzle. I also investigate key factors that influence stockholdings. I find that homeowners' risky stockholdings are very sensitive to the degree of housing liquidity and the exogenous probability of moving. When the probability of a mandatory move is low, risky stockholdings exhibit a U-shape relative to transaction costs on housing adjustments; when the probability of a mandatory move is high, risky stockholdings decrease with transaction costs monotonically.

In addition to the contribution to the portfolio choice literature, the analysis has broader implications for real estate markets. The model presented in the paper generates an asymmetric response of home sales to price changes. Homeowners tend to hold rather than sell their houses when house prices are low. However, with the same level of transaction costs, they are more likely to sell their old houses and upgrade to more expensive ones when house prices are high. Since the housing asset provides a positive financial return on average, homeowners are better off waiting than selling when the idiosyncratic shock on the housing return is bad. This finding is consistent with the empirical study of the Boston condominium market by Genesove and Mayer [11].

This work is related to several strands of the literature. Grossman and Laroque [12] theoretically analyze the relation between housing and portfolio choices in the presence of adjustment costs. They find that the average fraction of wealth invested in risky assets falls as transaction costs rise. Henderson and Ioannides [14] and Brueckner [1] show that households might rationally over-invest in residential housing when the housing investment must be always at least equal to housing consumption. This inefficiency is the result of a rational balancing of consumption benefits and the portfolio distortion associated with housing investment. Flavin and Yamashita [8] posit that the consumption demand for housing creates a highly leveraged position for younger households, resulting in lower stock holdings. The model in Flavin and Yamashita [8] is static, with life-cycle effects captured through the exogenously given ratio of housing to net-worth. In this paper, the level of housing is endogenous in a dynamic life-cycle model, and the possibility of renting is included. Cocco [7] uses a life-cycle model to show that house price risks crowd out stockholdings, and the crowding out effect is larger for younger and poorer households.[1] Although broadly consistent with these findings, my analysis differs from previous studies along several dimensions. First, by analyzing portfolio differences between homeowners and renters, I can study a self-selected homeowner's investment behavior under the constraints imposed by holding a house. I can also look at whether the possibility of future homeownership alters a renter's financial portfolio. Second, previous studies assumed that each period the household can increase the level of mortgage debt up to some limit without incurring any cost. This assumption understates the risks associated with housing and mortgages. In my model, a household can costlessly reduce the size of its mortgage, but increasing the level of the mortgage is costly. Therefore, there is a liquidity demand for financial assets even when the fixed mortgage rate is higher than the rate of return on riskless bonds.

The paper is organized as follows. Section 2 presents the model and parameterization. In Section 3, I provide numerical solutions and conduct a simulation analysis of an investor's optimal decisions. Then, I investigate the sensitivity of the optimal decisions to various model parameters and interpret results. Section 4 provides concluding remarks.

2. The model

In this section, I present a model to study how risks associated with homeownership affect households' portfolio choices in financial markets. Homeowners, who constitute about two thirds of US households, typically hold a poorly diversified portfolio, where home equity is one of the most important assets. At the time of an initial purchase, a household may convert nearly all of its wealth into home equity, since housing by its nature is a lump-sum investment. The choice about how much housing and which house to buy is a joint consumption–investment decision. Once a house is bought, there is less flexibility on housing expenditures since transaction costs associated with frequent trades can be very large. When these costs are large enough to discourage selling, the owner faces fixed mortgage

[1] Due to forced housing investments, younger and poorer households have limited financial wealth to invest in stocks. Besides, there is a fixed cost to enter the equity market, thus housing investment crowds out stock market participation. The effect of fixed costs in equity markets is omitted from my model.

and tax payments. There are two main types of uncertainty associated with housing investments: the committed expenditure risk and the house price risk. A homeowner needs to make mortgage payments over a long horizon out of an uncertain stream of labor income, making the post-mortgage-payment income lower and more volatile. Home equity is the major proportion of homeowners' total wealth, so the uncertainty about the capital gain from the house could also create a hedging demand.

2.1. Dynamic setup

I consider a partial equilibrium model where households take all prices as given. I assume that a household lives for five periods in this discrete time life-cycle model. A household comes into each period with labor income and carried-in assets, including financial assets and possibly a real estate asset. The model incorporates the observed life-cycle pattern of household behavior. A representative household lives in a rental house early in life while accumulating wealth. Starting from the second period, the household can choose to buy a house or continue to rent. To buy a house, a down payment is required and the rest of the cost can be financed with a mortgage. In the following periods, the household can choose its housing status again; if acquiring a new house or switching back to a rental house, it must pay a transaction cost to sell the old house. At any time when a household wants to buy a house, the available house price is bounded below. Hence the poorest households cannot be homeowners because there are no houses inexpensive enough for them to invest in. This minimum price constraint implies that households with lower income rent. A decision to rent also arises when poorer households are not eligible for a mortgage loan due to income constraints, or when lower income households cannot take advantage of the tax benefit from the mortgage interest deduction. The minimum price constraint serves as a proxy for all these types of factors that are not explicitly modeled. Setting the minimum price constraint to zero relaxes this constraint.

In each period, a household derives utility from nondurable good consumption C; and housing consumption h. Preferences are assumed to be time separable such that

$$U_0 = E\left[\sum_{t=1}^{5} \beta_t U(C_t, h_t)\right], \quad \text{where} \quad U(C_t, h_t) = \frac{(C_t^{\alpha} h_t^{1-\alpha})^{1-\rho}}{1-\rho}. \tag{1}$$

ρ is the coefficient of relative risk aversion. The parameter α determines consumption shares in a static model. A household is able to freely adjust the level of nondurable consumption in every period. When a household lives in an owner-occupied house, its housing consumption is assumed to be partially tied to the initial purchase price. The price of a house is denoted by H. The correspondence between housing consumption and house prices for an owner is: $h_t = a_2 H_t + bH\tau$. The subscript τ means the house is purchased in period τ, so the initial value of the house is $H\tau$. If $\tau < t$, the initial value $H\tau$ may not equal the current value H_t. When a household lives in a rental house, its housing consumption only depends on the current value of the house: $h_t = (a_1 + b)H_t$. Both a and b are nonnegative constants.

Housing consumption is assumed to depend on both the initial and the current market value of the house because both are determinants of the utility, or service flow, from the house. Once a house is bought, the size and major features of the house are determined and cannot be adjusted easily. Hence a homeowner receives a portion of the service flow at a level based on the purchase price. On the other hand, if the neighborhood improves, homeowners typically have access to better schools, libraries, and surrounding communities. The value of the house increases, and so does the service flow or utility from the house. Therefore, it is assumed that housing consumption also changes with the market price of the house.

To distinguish the utility of owner and rental housing, I set two different levels of $a \in \{a_1, a_2\}$, where $a_1 < a_2$. An owner has a_2; while a renter has a_1. In other words, owners derive more utility than renters for the same level of housing. There are many reasons to buy rather than rent. Public policy may benefit owners at the expense of renters with tax subsidies. Moral hazard problems are avoided in owner-occupied housing. Households may have idiosyncratic tastes regarding their houses that the rental market does not satisfy, for instance, a demand for purple carpet. Homeowners are able to invest to their own specifications. For all these reasons, an owner derives more consumption services holding market value constant. This parameter influences how much benefit a marginal household must get from owning a house versus renting to make owning optimal, given the lack of liquidity and diversification associated with owning.

2.2. Budget constraints

2.2.1. An ex ante renter's budget constraints

A household's wealth comes from stochastic labor income $\tilde{y}_t$, income from financial assets, and possibly a housing asset. There are two financial assets in the economy: a riskless bond B with gross return r, and a risky stock S with gross return $\tilde{s}$. Each period a household invests in financial assets after it pays for consumption and housing. When a household rents in the previous period, wealth W_t is a sufficient statistic for past actions in the current period maximization problem where

$$W_t = S_{t-1} \cdot \tilde{s} + B_{t-1} \cdot r + \tilde{y}_t. \tag{2}$$

A renter can buy a house or continue to rent. Let δ_t^n be the decision variable for the renter, or the "nonowner": $\delta_t^n = 1$ indicates buying, $\delta_t^n = 0$ indicates renting. A renter's budget constraints are:

$$\begin{aligned} W_t = {}& \left(1 - \delta_t^n\right)\left[C_t^{\mathrm{r}} + rent \cdot H_t^{\mathrm{r}} + S_t^{\mathrm{r}} + B_t^{\mathrm{r}}\right] \\ & + \delta_t^n\left[C_t^{\mathrm{b}} + \left(D_t + m \cdot H_{t,t}^{\mathrm{b}} + \mu_{t,t}\right) + \left(S_t^{\mathrm{b}} + B_t^{\mathrm{b}} + P_{t,t}^{\mathrm{b}}\right)\right], \end{aligned} \tag{3}$$

$$D_t = d \cdot H_{t,t}^{\mathrm{b}}, \qquad M_{t,t} = (1-d) \cdot H_{t,t}^{\mathrm{b}} \qquad \mu_{t,t} = F\left(H_{t,t}^{\mathrm{b}}, d, r_m, L\right), \tag{4}$$

$$h_t^{\mathrm{r}} = \left(1 - \delta_t^n\right)\left[(a_1 + b) \cdot H_t^{\mathrm{r}}\right] + \delta_t^n\left[(a_2 + b) \cdot H_{t,t}^{\mathrm{b}}\right], \tag{5}$$

$$H_{t,t}^{\mathrm{b}} \geqslant H_m, \qquad M_{t,t} \geqslant P_{t,t}^{\mathrm{b}} \geqslant 0, \qquad C_t, h_t, S_t, B_t \geqslant 0. \tag{6}$$

The superscripts r or b indicate that choice variables are selected subject to the decision to rent or buy.

When a renter chooses to rent again, he must decide on the price of the rental house, nondurable good consumption and how to allocate remaining wealth between stocks and bonds. When a renter wants to buy a house, the house price must exceed a minimum level: H_m. He must have enough savings for a down payment D_t, which is proportional to the house price $H^{\mathrm{b}}_{t,t}$. The rest of the cost is financed by a mortgage loan in the amount of $M^{\mathrm{b}}_{t,t}$. For all variables with two time subscripts, the first subscript is the current time, and the second subscript is the house purchase time. Housing payments are proportional to house prices. In order to rent, a household pays the housing expense ($rent\, H_t$), which is proportional to the current value of the house. *rent* is a fixed rental rate. To buy a house, a household pays the housing maintenance cost (mH_t), which represents the sum of property taxes, insurance costs, etc. The mortgage loan payment μ is a function of the house price $H^{\mathrm{b}}_{t,t}$, the required down payment rate d, the mortgage loan rate r_m, and the duration of the loan L. Mortgage payments include both principal and interest payments. Maintenance costs and interest payments on the loan are housing expenditures. Principal payments are a component of savings, but are mandatory—they are not as liquid as financial assets. After the household pays for consumption and housing, it can either invest the rest of its wealth in financial assets or prepay part of its mortgage. $P^{\mathrm{b}}_{t,t}$ is the prepayment variable. We know that any additional payments on a mortgage loan reduce the loan principal. Thus prepayments can be seen as a special kind of savings similar to lending. However, since the housing asset is costly to adjust, the prepayment is not as liquid as a bond. Allowing prepayment to be one of the choice variables also implies that the household can costlessly reduce the outstanding mortgage debt, which is consistent with practice. The mortgage prepayment is nonnegative ($P^{\mathrm{b}}_{t,t} \geqslant 0$) and it cannot exceed the mortgage liability ($P^{\mathrm{b}}_{t,t} \leqslant M_{t,t}$). Throughout the paper, it is assumed that default is never an option, or equivalently, the default penalty is infinite. In practice, default rates are low but positive, but I abstract from this complication to make the model tractable.

A renter's problem is also subject to nonnegativity constraints: both nondurable good consumption and housing consumption must be nonnegative. These constraints are automatically satisfied by the constant relative risk averse utility function. Financial asset investments are also assumed to be nonnegative, since households cannot issue bonds or stocks at market rates.

2.2.2. *An ex ante homeowner's budget constraints*

For a homeowner, the optimal level of housing is a joint consumption-investment decision. When a household is a homeowner in the previous period, its wealth includes stocks, bonds and a house net of the associated mortgage debt:

$$W_t = LW_t + (H_{t,\tau} - M_{t,\tau}) = [S_{t-1} \cdot \tilde{s} + B_{t-1} \cdot r + \tilde{y}_t] + (H_{t,\tau} - M_{t,\tau}), \tag{7}$$

$$H_{t,\tau} = \tilde{r}_{h,t-\tau} \cdot H_{\tau,\tau}. \tag{8}$$

Financial assets and labor income are components of liquid assets LW_t. $H_{\tau,\tau}$ is the initial purchase price of the owner-occupied house, $\tilde{r}_{h,t-\tau}$ is the stochastic gross return on the housing asset between time t and τ. The mortgage debt balance $M_{t,\tau}$ depends on the initial purchase price of the house $H_{\tau,\tau}$, the down payment rate d, the mortgage interest rate r_m, the loan term, and all previous prepayments. I assume a fixed mortgage rate. The constant mortgage rate implies no refinancing due to interest rate changes. Since there is no interest rate risk or default risk, the mortgage is risk-free. The difference between the mortgage interest rate r_m and the risk-free bond rate r reflects an assumed spread between borrowing and lending rates in the partial equilibrium system.

Although home equity is part of the household's wealth, it is illiquid. Unless the house is sold, this part of wealth cannot be used for consumption. Equivalently, it is assumed that a homeowner cannot costlessly re-borrow against the home equity in order to consume or invest in financial markets. When a homeowner makes additional payments to reduce his mortgage liability, his equity in the house and total wealth increase; however, liquid wealth does not necessarily increase. Since only liquid wealth can be used costlessly to smooth consumption, stock and bond investments are more liquid alternatives to cushion labor income uncertainty. This assumption distinguishes prepayments from bonds even when the mortgage interest rate is assumed to equal the risk-free rate r. When the mortgage rate is higher than the risk-free rate, there is a tradeoff between liquidity and return.

The assumption of high refinancing costs differs from some related studies of the interaction between housing investments and portfolio choices. For example, Cocco [7] and Yao and Zhang [20] both assume that the refinancing cost is zero. In this paper, the refinancing cost is the same as the housing adjustment cost. In practice, the cost is somewhere in between. I use the high-end assumption since the state contingent cost of borrowing may be higher than what people think. In real life, few households borrow on margin to invest in the equity market. The time when people want to borrow is most likely the time when they need liquidity, i.e., adverse income or investment shocks. For instance, in case of unemployment or facing a large drop on house prices, it is hard to get a second mortgage. From a modeling perspective, assuming the refinancing cost to be zero makes prepayments strictly preferred to bonds.[2] The portfolio choice problem is irrelevant for any homeowner who has positive mortgage debt. In the model presented here, there is an embedded liquidity demand for bonds, which allows the portfolio choice problem to be addressed. Relaxing the assumption of high refinancing costs weakens the applicability of the results. However, in work not shown here, the model is recalibrated with zero refinancing cost. It turns out that relaxing this constraint does not qualitatively change the results.

A homeowner has three choices: (1) sell his house and buy a new one; (2) sell his house and rent; (3) stay with the existing house. The first two choices involve selling a house. Selling the house incurs a transaction cost. The transaction cost is assumed to be a percentage of the existing house's market price. This assumption accommodates the fact that sellers usually pay about a 7% commission fee. Plus, there are moving costs, search costs, etc. Let δ_t^0 denotes a homeowner's decision variable of selling versus staying: $\delta_t^0 = 1$ means selling, $\delta_t^0 = 0$ means staying with the existing house. Upon selling, a homeowner liquidates his house by paying transaction costs. Then, the optimal decision on consumption and investment depends on the total after-house-sale wealth W_t^λ,

$$W_t^\lambda = LW_t + H_{t,\tau} \cdot (1 - \lambda) - M_{t,\tau}. \tag{9}$$

λ is the transaction cost parameter. Conditional on $\delta_t^0 = 1$, an ex ante homeowner's optimal solution set depends only on W_t^λ , and his budget constraints look exactly the same as those of a renter's, which are shown in the previous section.

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[2] See, for example, Cocco [7]. In order to address the portfolio choice problem, Cocco [7] assumes that a household must hold a liquid portfolio proportional to the current nondurable goods consumption.

If a homeowner decides to stay with his existing house ($\delta_t^0 = 0$), his current period expenditures are constrained by liquid wealth,

$$LW_t = C_t^{\mathrm{s}} + (m \cdot H_{t,\tau} + \mu_{t,\tau}) + \left(S_t^{\mathrm{s}} + B_t^{\mathrm{s}} + P_{t,\tau}^{\mathrm{s}}\right), \tag{10}$$

$$h_t^{\mathrm{b}} = a_2 \cdot H_{t,t}^{\mathrm{b}} + b \cdot H_{t,\tau}^{\mathrm{b}}, \tag{11}$$

$$M_{t,t} \geqslant P_{t,t} \geqslant 0; \quad \mu_{t,\tau} = F\left(H_{t,\tau}^{\mathrm{b}}, d, r_m, L\right). \tag{12}$$

The superscript s indicates that decision variables are conditional on $\delta_t^0 = 0$. Maintenance costs and mortgage payments are necessary parts of current housing payments. The mortgage loan payment $\mu_{t,\tau}$ does not depend on previous prepayments.[3] As is generally the case in practice, previous prepayments, do not resize the mortgage payment. However, prepayments reduce the principal, thus shortening the time to pay off the loan. After consumption and housing payments, the homeowner can invest in stocks and bonds or pay down mortgage debt. Housing consumption is a weighted-average of the initial house price and the current house price.

2.3. Dynamic optimization

Each period, a household's state depends on its housing status, carried-in wealth W, realized labor income y, the stock return s and possibly the stochastic return on the housing asset r_h. I denote the expected lifetime utility of a renter at period t as $V_t^R(W(s, y))$. Similarly the expected lifetime utility of a homeowner at period t is $V_t^0(LW(s, y), H(r_h), M)$. I assume that stochastic asset returns follow a finite-state Markov chain, with conditional transition probabilities given by the matrix $\prod[\omega', \omega] = [\pi_{\omega',\omega}]$, where $\pi_{\omega',\omega} = \Pr(\omega_{t+1} = \omega' \mid \omega_t = \omega)$.$\omega$ describes a state of both stock returns and housing asset returns,[4] $\omega = \{s = \bar{s}, \underline{s}; r_h = \overline{r_h}, \underline{r_h}\}$, i.e., returns can be either high or low in any period.

Each period, a homeowner must decide whether to sell his existing house. This is a financial and personal decision. Homeowners change houses for many nonfinancial reasons, such as job relocation, changes of marital status or family size, etc. To capture turnover caused by these factors, I introduce a new state variable e, representing exogenous moving shocks: $e = 1$ indicates that a homeowner is forced to sell his existing house for exogenous reasons, $e = 0$ otherwise. Let the transition probability matrix be $\prod[e', e] = [\pi_{e',e}]$, where $\pi_{e',e} = \Pr(e_{t+1} = e' \mid e_t = e)$, $e = 0, 1$. In practice the probability of exogenous moving may be correlated with asset returns. For example, during recessions when asset returns are low, people are more likely to lose their jobs and therefore forced to move. For simplicity, however, the moving shock is assumed to be orthogonal to asset return innovations in the model. The optimization problem for a renter can be expressed as

$$V_t^R(W_t) = \max\Big\{U_t(C_t, h_t) + \beta E\Big[\max\Big(V_{t+1}^R(W_{t+1}), V_{t+1}^0(LW_{t+1}, H_{t+1,t+1}, M_{t+1,t+1})\Big)\Big]\Big\} \tag{13}$$

[3] The only exception is when the remaining mortgage balance is less than the required per period mortgage load payment, since previous prepayments reduce the mortgage principal.

[4] If a household does not own a house, ω only represents stock returns.

subject to (2)–(6). The optimization problem for an owner can be expressed as

$$\begin{aligned} &V_t^0(LW_t, H_{t,\tau}, M_{t,\tau}) \\ &\quad = \max\Big\{U_t(C_t, h_t) + \beta E\Big[\max\Big(V_{t+1}^R(W_{t+1}), V_{t+1}^0(LW_{t+1}, H_{t+1,\tau}, M_{t+1,\tau}), \\ &\qquad\qquad V_{t+1}^0(LW_{t+1}, H_{t+1,t+1}, M_{t+1,t+1})\Big)\Big]\Big\} \end{aligned} \tag{14}$$

subject to (7)–(12). The last part in expression (14) is different from expression (13) since a homeowner has the choice of staying with his existing home.

Given the existence of a solution to this finite concave optimization problem subject to linear constraints, the solution can be obtained by backward induction. However, a general analytical solution is not available, so numerical techniques will be used to derive solutions under various parametric assumptions.

2.4. Parameterization

2.4.1. Labor income

A household is assumed to be born at age 20 and to die at age 80. Its 60 years of life are divided into 5 periods. The first three periods each has 10 years, and the last two periods each has 15 years. The household works in the first 4 periods (age 20–65). The last period is the retirement period (age 65–80). The labor income process has two components, a deterministic mean and a stochastic shock. The mean labor income each period is calculated from an estimate of the median age-earnings profile from the PSID. The annual income measure is multiplied by an annuity factor to obtain an estimate over a multi-year period. Carroll and Samwick [4] estimated permanent and transitory labor income variance measures from the PSID. Following their work, the labor income shock is constructed over each period by multiplying the annual income variance measure to the length of the period. Note that this setting ignores possible serial correlation in labor income, thus understating labor income risk. Increasing the labor income risk by assuming positive serial correlation may further reduce optimal holdings of risky assets and strengthen the results.

2.4.2. Returns

There are three assets in this economy, two financial assets and one real estate asset. The annual risk-free bond return is set to be 3%. It is compounded appropriately for the number of years represented. Both the stock return and the financial rate of return on housing are stochastic. Campbell, Lo and MacKinlay [2] used historical data from 1889 to 1994 to estimate risks and returns in equity markets. They found the mean stock return is 7.69%, and the standard deviation of log stock returns is 0.1674. In calibrating the model, I use a mean stock return of 8% with a standard deviation of 18%. As a first approximation, I assume annual returns are i.i.d. log normal in order to get multi-year returns. To keep the dimensionality of the problem low, I set two levels of $\tilde{s}$ to capture the whole distribution.

Flavin and Yamashita [8] estimate the average annual return on real estate assets from 1968–1992 to be 6.59% with a standard deviation of 0.1424. This return includes capital gains from housing investment and the imputed rent minus costs.[5] Cocco [7] uses self-assessed values of residential houses in the PSID to construct a house price index. He found the average housing return from 1970 to 1992 is 1.6% per year. Cocco [7] also compares the house price index constructed from PSID to other house price indices such as the Conventional Mortgage Home Price Index (CMHPI) constructed by Freddie Mac, and the House Price Index (HPI) constructed by the Office of Federal Housing Enterprise Oversight. It is shown that the correlations between the annual percentage changes in the PSID index and the annual percentage changes in the HPI and CMPHI indices are high: 0.922 and 0.871, respectively. In the model here, the financial rate of return on housing should be lower than that in Flavin and Yamashita [8] since $\tilde{r}_h$ only measures capital gain on housing investment. However, virtually all of the stochastic part of the return comes from capital gains. I use a mean of 2% with a standard deviation of 12% for the return on housing assets. Following Flavin and Yamashita [8], I also assume the correlation between $\tilde{r}_h$ and $\tilde{s}$ is zero.[6]

2.4.3. Housing

The required house down payment rate is set at 20% of the house price in the model $(d = 20\%)$. Though there have been down payment rates as low as 5% in recent years, not all households qualify. Even those that do qualify have to pay a mortgage insurance fee.

The mortgage loan is assumed to have a fixed 30-year term. I assume that there is a competitive mortgage market in which the fixed mortgage loan rate is r_m. In general, mortgages require a higher rate than bonds because they bear long-term interest rate risk, default risk and prepayment risk due to the embedded call option. Most papers in the literature estimate that the average annual difference between T-bill and mortgage rates is between 2.29 and 3.01%. Since in my model, there is no default risk or interest rate risk, the mortgage rate premium should be zero in the absence of other transaction costs. Nevertheless, I use a mortgage rate premium of 1.5% to proxy for a borrow-lend spread and the cost of monitoring real estate assets. This gives an annual mortgage rate of 4.5%.

The transaction cost on housing adjustments is assumed to be 10% of the house sale price in the base model. It reflects a sales commission of 7% plus search and moving costs. The minimum purchase price of a house is assumed to be three times the median annual labor income of households aged between 30 and 40. The annual exogenous moving shock is assumed to be 2%, hence for a 10-year period the probability of a forced move is 18.3%.[7] I will do comparative analysis with respect to transaction costs and exogenous moving shocks in later sections.

The rental parameter *rent* should be determined by the equilibrium rate of return for the owner of the rental unit, assuming a competitive rental market. However, I have not

[5] Costs include property tax and the maintenance cost.

[6] Introducing a positive correlation between stock returns and housing returns will strengthen my result because of the substitution and hedging effect.

[7] Assume that the annual mandatory moving shock is $p = 2\%$, during a 10-year period, the probability of a forced move is $p_{10\text{-year}} = 1 - (1 - p)^{10} = 18.3\%$. Note that households can also move voluntarily, the implicit annual moving rate would be higher than 2%.

pursued this issue. The rental rate is assumed to be 7%.[8] Housing consumption parameters a and b are set as $a_1 = 0.4$; $a_2 = 0.5$; $b = 0.5$.[9] Recall that the parameter a reflects the difference in housing consumption service between owners and renters.

The coefficient of relative risk aversion is $\rho = 5$ and the weight for nondurable goods consumption is set at $\alpha = 0.7$. The discount factor β is assumed to be $1/(1.03)$ on an annual basis, or 0.744 on a 10-year basis.

3. Numerical results

The representative household solves a dynamic problem of maximizing expected utility subject to budget and nonnegativity constraints. The problem cannot be solved analytically, so I solve the model by standard numerical techniques. First, the optimal consumption, portfolio and housing rules are derived. Once decision rules are obtained, statistical averages are derived by simulation.

3.1. Life-cycle portfolio choices for renters versus homeowners

In this section, I present summary statistics of households' consumption and asset allocations from the simulation. I first discuss predictions from the model with owner-occupied housing. Then I compare the results to the predictions of a benchmark model without owner-occupied housing.

When calibrating the model, all households are restricted to rent in the first period. Starting from the second period at age 30, households can choose to invest in owner-occupied housing. The trade offs are between the higher utility from ownership, the portfolio diversification benefit from adding housing assets and transaction costs, and the illiquid and lumpy nature of ownership. Once a household optimally chooses to own or rent, its consumption and asset portfolios are determined conditional on its housing status.

Table 1 reports summary statistics from the simulated data. Households are categorized by self-selected housing status and by age. All numbers are statistical means in thousands of dollars adjusted annually. Policy rules solved from the model give statistical means of labor income, consumption, house price, stocks, bonds and prepayments. Cash-on-hand is the residual wealth after households consume and make mandatory housing payments. For renters, it is the value of financial assets. For homeowners, it is the sum of financial assets and prepayments. The ratios of risky stocks to cash-on-hand are reported last.

Part A of Table 1 shows calibration results for renters. The first row presents the renter's population. The probability of being a renter decreases over time since more households

[8] Rental rates vary a lot depending on the location and the quality of the unit. According to the Housing Statistics of the United States (1999), in 1995, the median price for specified housing units in the United States is $77,500, the median monthly rent is $435. This gives a monthly rental return of 0.561%, or 6.95% on an annual basis. Calculated this way, the average annual rental rate from 1993 to 1997 is 7.00%. This statistic is used in the base model, though the author acknowledges its impreciseness. In addition, by setting the rental rate at 7%, the model is able to produce the aggregate homeownership rate matched with the real data.

[9] More discussion on these parameters is provided in Section 3.4.

Table 1
Life-cycle portfolio choices for households

	Age 20–30	30–40	40–50	50–65	65–80
Part A: Renters					
Prob(renter)	100.0%	41.4%	15.2%	4.6%	36.4%
Labor income	18.00	22.99	26.44	17.93	5.05
Consumption	12.55	14.05	16.99	13.03	14.10
House price	90.12	102.39	123.76	103.52	107.84
Stock	0.0	2.62	5.14	6.17	–
Bond	0.0	0.04	1.29	4.84	–
Cash-on-hand	0.0	2.67	6.44	11.01	–
Stock/cash-on-hand		98.47%	79.91%	56.04%	–
Part B: Homeowners					
Prob(owner)	0.0%	58.6%	84.8%	95.4%	63.6%
Labor income	–	28.58	31.92	23.53	5.70
Consumption	–	17.76	18.88	18.30	15.88
House price	–	126.63	199.36	230.37	190.18
Prepayment	–	0.01	1.53	1.64	
Stock	–	0.00	2.88	5.08	
Bond	–	0.00	1.50	1.43	
Cash-on-hand	–	0.01	5.90	8.16	
Stock/cash-on-hand	–	0.00%	48.81%	62.25%	

Notes. This table reports summary statistics from the simulation. Households are categorized by their self-selected housing status and age. All numbers are mean values in thousands of dollars adjusted annually. Policy rules solved from the model give statistical means of labor income, consumption, house price, stocks, bonds and prepayments. Cash-on-hand is what is left after households consume and make mandatory housing payments. For renters, it is the value of financial assets. For homeowners, it is a sum of the value of financial assets and the voluntary house prepayment. The transaction cost on housing adjustments is assumed to be 10%. The annual exogenous moving shock is assumed to be 2%.

save enough to buy. The probability of renting drops from 41% for the 30–40 age group, to 5% for the 50–65 age group. However, for the 65–80 age group, the renter population increases to 36%. As a whole, the model provides reasonable predictions on the life-cycle pattern of homeownership rates and aggregate homeownership.[10]

Labor income is the primary source of households' wealth. The average labor income first increases with age, and then drops sharply after retirement. The expected humped pattern of labor income over the life cycle creates a savings demand for both renters and homeowners. Both implied average consumption and house price are smooth as expected. The risky stock to cash-on-hand ratio is decreasing over a renter's lifetime. This is because the precautionary savings demand is higher when a household becomes older. Jagannathan and Kocherlakota [15] and Heaton and Lucas [13] point out that future labor income, although risky, serves more like a riskless asset. The lower bound of expected future labor income can be considered as a risk-free bond. When a household is relatively young and poor, it saves very little and invests a high fraction of savings in risky stocks. As the house-

[10] The limitation of the model to predict the homeownership rate among the elderly is discussed in Section 3.4.

hold ages, its financial wealth increases and the expected future labor income decreases, so that the implicit holdings of the riskless asset in the form of future labor income become less important relative to financial wealth. Thus we see a shift in asset allocations towards riskless bonds. The decreasing stock-to-cash-on-hand ratio along the life cycle depends crucially on the assumption that future labor income shocks are uncorrelated with risky asset returns. If the correlation is positive, future labor income would be more like a risky asset and we would expect the relative risky stockholdings to increase (or decrease less) as the household gets older.

Part B of Table 1 reports simulation results for homeowners. It shows the average labor income for homeowners is higher than that of renters. This is a selection effect due to the down payment requirement and minimum house price constraint. Homeowners maintain a fairly smooth consumption pattern during their lifetime. Consumption and housing increase as homeowners accumulate more wealth. Homeowners hold a large amount of housing compared to financial assets. This is because the housing asset provides consumption services as well as investment benefits. In addition, the housing asset serves as collateral to borrow against future labor income. Therefore, it is attractive especially for young households, who have less labor income and thus want to borrow. This result is consistent with the theoretical predictions in Chah, Ramey and Starr [6] that if durable good expenditures can be debt-financed, consumers optimally increase their durable good holdings in anticipation of higher future income. Although homeowners hold fewer bonds relative to financial assets than renters, it does not necessarily mean that homeowners are seeking higher return and risk in their financial portfolios. Homeowners can use their cash-on-hand to prepay part of their mortgages. Since the mortgage has a higher interest rate than bonds, prepayments can be seen as long-term bonds that offer a higher interest rate (equal to the mortgage rate) but less liquidity. Although prepayments contribute to the principal on the house, it is not a risky investment since the mortgage is risk-free by assumption. Homeowners still hold some bonds since the mortgage debt and prepayments are attached to the house, which is less liquid than financial assets. When homeowners do not sell their houses, they cannot take the home equity to smooth their consumption. Bonds have a liquidity advantage over prepayments although they offer a lower interest rate.

These results suggest that homeowners' asset allocations depend not only on the risk and return characteristics of various assets, but also on the relative liquidity of different types of assets. Many young homeowners between age 30 and 40 have no savings in financial assets. They are still relatively poor and they convert all of their wealth into housing assets as first time buyers. Housing investments crowd out stock investments. As homeowners get older, the average stock-to-cash-on-hand ratio rises: for those between age 40 and 50, the average stock-to-cash-on-hand ratio is 48.8%. This fraction is still much lower than the average risky stock ratio of renters in the same age group. For renters between age 40 and 50, the average stock-to-cash-on-hand ratio is 79.9%. Homeowners hold a large amount of wealth in risky housing assets, which typically are also highly leveraged. Hence their asset portfolios are already risky. In addition, the committed mortgage debt makes after-mortgage-payment labor income lower and more volatile. Therefore homeowners are more risk averse towards the liquid wealth allocations. This result suggests homeownership risks have a negative impact on middle-aged households' risky stock holdings. For households at age between 50 and 65, a typical homeowner's risky stockholdings are proportionally similar to (or a little more than) those of a typical renter. This is because during this period, homeowners on average have less mortgage liability. Since a large proportion of homeowners' assets are in the form of housing, the home equity (house value net of debt) is relatively more important in their wealth. The lower bound on the home equity can be seen as a substitute for riskless bonds. Therefore, homeowners can afford more risk in their liquid financial portfolio during this period.

Note that "renters" in Table 1 are not lifetime renters who do not ever own houses or who do not ever want to own houses. Rather, renters include households who are saving for down payments on future home purchases, or those who are forced to move out of their houses due to exogenous moving shocks, etc. The optimal portfolio choices of these renters may still be slanted by potential home purchases. To analyze whether these homeownership-related constraints affect renters' financial portfolios, I consider a benchmark model where homeownership is not a choice for households. In other words, the benchmark model is a traditional portfolio choice model without housing investments. All settings are the same as in the base model presented in Section 2 except that households are forced to rent in each period.

The simulated optimal consumption and asset holdings are presented in Table 2. Obviously, models that do not recognize the difference between owning and renting homes cannot predict homeownership rates over the life cycle. Compared to "renters" in Table 1, lifetime renters in the benchmark model do not expect homeownership in future. It turns out that they hold proportionally more risky stocks in their portfolios. For instance, lifetime renters aged between 40 and 50 invest almost entirely in stocks in the benchmark model, while "renters" in the base model with potential ownership housing invest about 80% liquid wealth in stocks. This result shows that the mere possibility of homeownership makes renters more risk averse towards liquid asset investments. Homeowners' risky stockholdings are even lower, only 49% at age 40–50. This suggests that homeownership crowds out stock market participation, especially for young and middle-aged households, who might be saving for a future home, or who might have large holdings of housing and mortgage relative to wealth in their portfolios. This result is consistent with Flavin and Yamashita [8]

Table 2
Life-cycle portfolio choices for households: Benchmark model w/o investment housing

	Age				
	20–30	30–40	40–50	50–65	65–80
Labor income	18.00	28.01	32.97	23.70	5.41
Consumption	12.55	19.47	18.93	16.09	17.10
House price	90.12	139.83	135.91	110.73	122.74
Stock	0.00	0.19	5.24	5.41	
Bond	0.00	0.00	0.01	4.23	
Cash-on-hand	0.00	0.19	5.25	9.64	
Stock/cash-on-hand	–	100.00%	99.87%	56.08%	

Notes: This table reports simulation results from a benchmark model without housing investments. In other words, all households are forced to rent. All parameter values are the same as those for the statistics in Table 1. All numbers are mean values adjusted annually. Policy rules solved from the benchmark model give statistical means of labor income, consumption, house price, stocks and bonds. Cash-on-hand is the sum of the value of financial assets.

and Cocco [7]. Therefore, frictions associated with homeownership can help to partially resolve the portfolio choice puzzle.

3.2. Comparative analysis of homeowners' stockholdings

Homeowners would like to maintain optimally balanced consumption and investment portfolios of both housing and financial assets. However, transaction costs on housing adjustments alter the benefit of re-optimization and thus affect the optimal financial portfolio. In this section, I study how transaction costs and mobility affect homeowners' choices of financial assets. Portfolio choices for homeowners between age 40 and 50 are of most interest here because during this period, homeowners have savings in financial assets, and there is a trade-off between prepayments with a higher interest rate and bonds with liquidity.

Table 3 presents homeowners' asset allocations between age 40 and 50, conditional on different levels of transaction costs. The first part of the table reports homeowners' asset portfolios, including shares of stocks, bonds and the long-term asset—housing. The mortgage debt ratio is the ratio of mortgage debt to the value of all assets. The prepayment-to-house ratio shows the relative size of the prepayment. The stock-to-cash-on-hand ratio measures the value of stocks relative to liquid wealth after consumption and mandatory housing payments. As the transaction cost on housing increases, homeowners on average hold less housing and more financial assets. Less housing investment also leads to less mortgage debt so the mortgage debt ratio is decreasing. The prepayment-to-house ratio is increasing with transaction costs. This is because the higher interest rate on the mortgage dominates the liquidity demand of bonds. The next part of the table reports how homeowners allocate their residual liquid wealth, or cash-on-hand. A homeowner can use cash-on-hand either to invest in stocks and bonds or to pay down the mortgage debt. I focus on the stock-to-cash-on-hand ratio because prepayments are also an investment choice. There are two effects that may drive the stock-to-cash-on-hand ratio. When

Table 3
Homeowners' asset allocations conditional on transaction costs

	Transaction cost					
	0%	10%	15%	20%	25%	30%
Asset share						
Stock (%)	11.71	11.83	11.54	12.19	12.39	13.96
Bond (%)	5.20	6.17	6.37	7.02	6.66	7.17
House (%)	83.10	82.00	82.09	80.79	80.95	78.88
Mort. debt ratio (%)	65.75	65.06	64.48	63.95	62.73	58.71
Prepayment/house (%)	7.17	7.66	8.37	8.98	9.65	10.78
S/(S+B) (%)	69.25	65.76	64.43	63.45	65.05	66.06
S/cash-on-hand (%)	51.21	48.81	46.56	46.06	46.13	47.10

Notes. This table presents the asset allocations of homeowners aged between 40 and 50, conditional on different levels of transaction costs. The first part of this table reports homeowners' asset portfolios, including shares of stocks, bonds and the long-term asset—the owner-occupied house. The mortgage debt ratio is the ratio of mortgage debt to the value of all assets. The prepayment-to-house ratio shows the relative size of prepayments. The stock-to-cash-on-hand ratio measures the value of stocks relative to liquid wealth after consumption and mandatory housing payments. The annual moving shock is assumed to be 2%.

transaction costs are relatively low, few households alter their rent/buy decision. Within a certain range, when transaction costs go up, a homeowner may want to save more in the riskless bond to pay for the increasing potential adjustment cost. However, when the level of transaction costs passes a certain threshold, the probability of housing adjustment is lowered. Homeowners expect to hold their houses for a longer period of time, which leads to less precautionary demand. In Table 3, the stock-to-cash-on-hand ratio exhibits a U-shape. For relatively low transaction costs (between 0–20%), the precautionary savings demand dominates, risky stock holdings are negatively correlated with transaction costs. The stock-to-cash-on-hand ratio is 51% in the no transaction cost case, but only 46% in the 20% transaction cost case. When the transaction cost is higher than 20%, homeowners anticipate less chance of housing adjustments, and thus have less incentive for precautionary savings to pay for the transaction cost. Risky stockholdings increase with the transaction cost. When the transaction cost increases to 30%, the risky stock ratio goes back to 47%.

Results in Table 3 also depend on the assumed probability of moving shocks. When the probability of a forced move is low, most homeowners move voluntarily due to con-

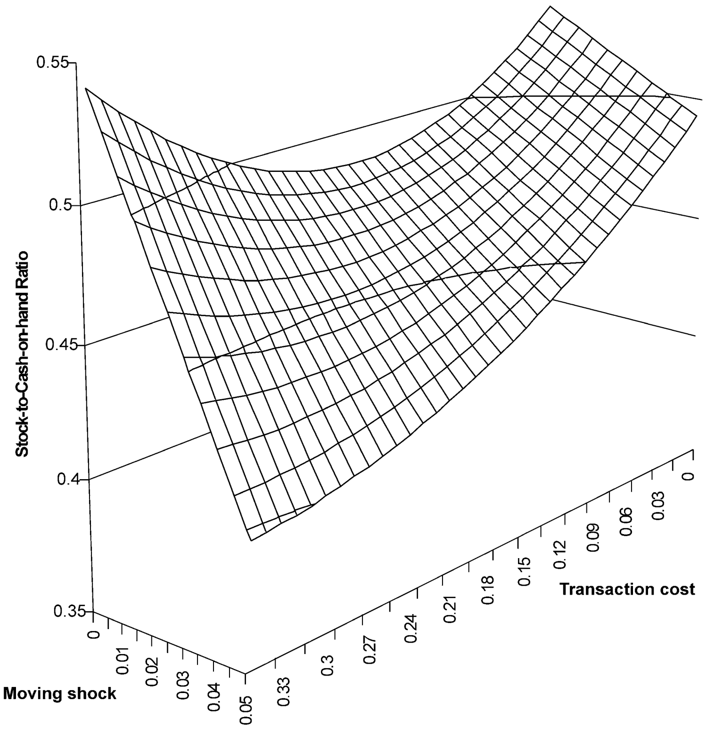

Fig. 1. Risky stock holdings for homeowners. *Notes*: This figure presents the stock-to-cash-on-hand ratio on a three-dimensional graph. The two independent axes are the annual exogenous moving shock and the housing transaction cost, respectively. It is shown that when the probability of mandatory moving is low, there is a U-shape of risky stock holdings along the transaction cost line; however, when the probability of mandatory moving is high, stock holdings monotonically decrease with transaction costs. In all levels of transaction costs, risky stock holdings decrease with the assumed probability of mandatory move.

sumption and investment balancing. However, when the probability of mandatory moving is high, more homeowners are forced to sell their houses and pay the transaction cost. Therefore, a higher exogenous moving rate should induce more renting and more precautionary savings. Figure 1 presents the stock-to-cash-on-hand ratio on a three-dimensional graph. The two independent axes are the annual exogenous moving shock and the housing transaction cost, respectively. When there is no transaction cost and no mandatory move, stockholdings peak at 53.5%; however, when transaction cost is 30% and the probability of annual mandatory moving is 5%, stockholdings drop to 38.5%. The shape of the risky stockholding curve changes with the assumed probability of annual moving shocks. When the probability of a forced move is low, there is a U-shape of risky stockholdings along the transaction cost line. The risky stock ratio increases in the higher transaction cost cases. As explained earlier, this is because homeowners can choose to hold housing assets for a longer period of time, so that they do not need more precautionary savings in bonds for transaction cost payments. However, if the probability of mandatory moving is high, all homeowners face a higher probability of forced transaction cost payments, the U-shape is gone, and stock holdings monotonically decrease with transaction costs. A higher transaction cost makes homeowners invest in a more conservative manner. From another aspect, at all levels of transaction costs, the stock-to-cash-on-hand ratio is decreasing with exogenous moving shocks. Furthermore, a higher transaction cost makes the slope steeper. When there is no transaction cost, in the absence of mandatory move, homeowners on average put 53.5% of liquid wealth in risky stocks; when the probability of an annual forced move rises to 5%, the ratio drops to 49%. The downward slope is due to the housing investment constraints other than the direct transaction cost, such as the down payment requirement. When the transaction cost is 30%, risky stock holdings drop from about 52% with no moving shocks, to about 38.5% with a 5% annual moving shocks. As a whole, the graph shows that the lumpy nature of housing investments and the mobility help to explain the low equity holdings among homeowners.

3.3. Remarks on homeowners' housing choice

This study also provides some insight into households' housing choices. In this section, I look at how different types of exogenous shocks influence homeowners' ex post housing decisions. Table 4 reports statistics of ex ante homeowners' next period housing choices conditional on different types of exogenous shocks. Part A of the table gives the distribution of homeowners' housing choice in the next period, and Part B shows how exogenous shocks affect homeowners' future housing choices. The left four columns show how ex ante homeowners make housing decisions for the 40–50 age period: 55% stay with their existing houses, 45% upgrade to more expensive ones, and none downgrade or switch to rental. We know from Table 1 that about 58% of households choose to be homeowners between age 30 and 40. They are most likely to be in the higher income class. Part A in Table 4 suggests that these homeowners will continue to be homeowners under current parameter values.

Part B in Table 4 presents the distribution of homeowners' ex post housing choices conditional on ex ante shocks. For instance, of those homeowners who get a positive shock on housing investments, 37% choose to stay with their existing houses, while 63% choose to

Table 4
Homeowners' housing choice

Housing choice next period	Age 40–50 Rent (%)	Age 40–50 Stay (%)	Age 40–50 Upgrade (%)	Age 40–50 Downgrade (%)	Age 50–65 Rent (%)	Age 50–65 Stay (%)	Age 50–65 Upgrade (%)	Age 50–65 Downgrade (%)
Part A								
Summary probability	0.0	54.55	45.45	0.0	1.20	73.60	16.00	9.20
Part B								
w/o Moving shock	–	61.36	38.64	–	0.00	90.20	9.31	0.49
w/Moving shock	–	0.00	100.00	–	6.52	0.00	45.65	47.83
High income	–	32.73	67.27	–	0.00	73.47	19.18	7.35
Low income	–	81.82	18.18	–	2.35	73.73	12.94	10.98
High housing return	–	37.04	62.96	–	0.40	65.20	24.80	9.60
Low housing return	–	75.56	24.44	–	2.00	82.00	7.20	8.80
High stock return	–	40.00	60.00	–	0.78	74.42	16.28	8.53
Low stock return	–	50.00	50.00	–	1.65	72.73	15.70	9.92

Notes: This table reports the relationship between housing choices and exogenous shocks for ex ante homeowners. The transaction cost on housing adjustments is assumed to be 10%. The annual exogenous moving shock is assumed to be 2%.
Part A: Distribution of homeowners' ex post housing choice.
Part B: Statistics of the distribution of homeowners' ex post housing choice, conditional on ex ante shocks. For instance, for homeowners who get a bad shock on housing investments, 76% of them choose to stay with their existing houses, whereas 24% choose to upgrade.

upgrade; of those who get a negative shock, 76% choose to stay with their existing houses, while 24% choose to upgrade. Among homeowners who get high income shocks, 67% upgrade to more expensive houses, 33% stay with existing houses; among homeowners who get low income shocks, only 18% upgrade to more expensive houses, 82% stay with existing houses. Since homeowners between age 30 and 40 are first-time home buyers, and they have almost no financial assets, stock returns do not play a big role in determining the ex post housing choices.

Results here show that income shocks and house price shocks are important factors that affect homeowners' housing decisions. Clearly, homeowners with bad income shocks or bad housing returns are more likely to stay with existing houses than those who get good income shocks or good housing returns. This result is quite intuitive. The adjustment cost is more affordable to higher income homeowners. Since housing is the biggest investment in homeowners' portfolios, positive returns increase homeowners' wealth considerably. By liquidating the house, homeowners can realize a capital gain even after paying the transaction cost. However, when a homeowner gets a negative return on the housing asset, selling may not be a good idea. The capital loss and the adjustment cost can be large. A homeowner is more likely to bear the consumption distortion by holding the current house and waiting for the next innovation on the housing return, which on average is positive.

As a whole, homeowners who upgrade their houses are more likely to be those who get good income shocks and/or high housing returns, while bad housing returns and/or bad income shocks discourage selling. There is an interesting asymmetry of homeowners' selling behavior: when house prices go up, homeowners take the profit from the housing investment and upgrade; however, when prices drop, homeowners tend to hold the house and wait. This asymmetry had been noted in the literature. Case and Shiller [5] suggest that sellers who expect positive future returns in the housing market may have a reduced willingness to sell their properties in a down market. Genesove and Mayer [10] also suggest that an owner's equity position in the house determines his selling behavior. They showed that an owner with a high loan-to-value ratio sets a higher reservation price for his property and expects a longer waiting time in the market. The result in this paper is consistent with these findings. A seller relies on the proceeds from the sale of his existing home to purchase or rent the next house. If the housing price has fallen, owners have limited home equity. They choose not to sell because if they do, they would have little money left for a new house. Waiting for the price to appreciate is optimal so long as the option value of waiting exceeds the cost. In this paper, the long run return on housing has a positive mean, which enhances the option of waiting. The positive average return on housing is the essential factor that induces the asymmetry in the upgrade/downgrade decision. Why housing prices do not adjust to clear markets, however, cannot be addressed in a partial equilibrium model; further research based on general equilibrium models is needed in this area.

The right four columns of Table 4 report similar statistics for ex ante homeowners making housing decisions for the 50–65 age period. Most people continue to be owners between age 50 and 65. Even homeowners who are forced to sell their houses for exogenous reasons are generally rich enough to make new down payments and meet other requirements to invest in owner-occupied housing. About 9% of homeowners downgrade their houses. These are homeowners with bad income shocks who want to take out savings in housing assets to smooth consumption. Renting occurs with an exogenous moving shock plus low wealth.

Housing choices also depend on the assumed level of transaction cost. In work not shown here, I study the effect of transaction cost on homeownership. As expected, the homeownership ratio decreases with transaction costs. Keeping the probability of exogenous moving shocks fixed, when the housing adjustment cost goes up, more people choose to rent; among homeowners, fewer choose to move. In the high transaction cost cases, homeowners expect to hold their houses for a long period of time so that owning a house is still worthwhile since the owner-occupied house provides higher housing consumption and a positive financial return.

3.4. Discussion of model and robustness check

It has been shown that the model with homeownership can partially explain the observed low stockholdings among US households. However, the model also has some limitations which need to be discussed.

The model predicts that self-selected renters would invest more of their savings in stocks than homeowners. This is counterfactual. In the actual data such as the Survey of Consumer Finances, homeowners have proportionally more invested in stocks than renters. This might be because in real life, homeowners generally are wealthier and more educated than renters. In addition, homeowners usually have more disciplined savings behavior.[11] It is possible that renters' lack of stockholdings could also be explained by a small fixed cost associated with equity market participation. Cocco [7] shows that introducing a fixed cost to enter the stock market will lower the rate of stock market participation. Liu and Loewenstein [16] provide explicit necessary and sufficient conditions under which an investor might optimally never buy stocks subject to transaction costs. In the analysis presented here, I abstract from the fixed cost to equity market participation for model tractable reasons.

Although the model can provide reasonable predictions on the aggregate homeownership rate, it does not match the homeownership rate among the elderly. From the 1998 Survey of Consumer Finances data, the homeownership rate of households over 65 years old is 78%. The model implies the homeownership rate for households at age 65–80 is 64%. Calibrating models to the ownership patterns of older households is complicated. To date no life-cycle model has explained the high homeownership rate among the elderly. The gap between evidence and predictions on homeownership among the elderly can be reduced by adding a bequest motive in the model or by modifying the preference parameters for the elderly. Caplin [3], Sheiren and Weil [18] and Shiller and Weiss [19] discuss some economic and psychological factors that can help to explain why older households may prefer to stay with their existing owned houses—typical factors include transaction costs, moral hazard, health problems and mobility. These complications are abstracted from the model.

In this paper, the assumption that housing consumption depends partly on the current house price in addition to the purchase price is different from some previous dynamic housing models. In order to check whether this assumption would influence the main re-

[11] See, for example, Fratantoni [9].

sult, I did the following robustness checks. In the current model, the housing consumption of a homeowner is: $h_t = a_2 \cdot H_{t,t} + b \cdot H_{t,\tau}$, the housing consumption of a renter is: $h_t = a_1 \cdot H_t + b \cdot H_t$, where $a_1 < a_2$. Letting $b = 0$ would make housing consumption depend only on the market price of the house; letting both a_1 and a_2 equal zero and setting two levels of b would make homeowners' housing consumption depend only on the original purchase price of the house. I calibrate the model with each of the above specifications and find that the major results still hold. Assuming housing consumption depends only on the original price of the house induces more moving (upgrading) when housing returns are high, but less moving when housing returns are low. In other words, the asymmetric selling behavior is actually enhanced. Changing the housing parameters has a marginal effect on households' financial portfolio choices. For young and middle aged households, potential homeownership still crowds out stockholdings. The implied fraction of cash-on-hand invested in stocks is always less than 50% for homeowners at age 40–50. Therefore, the key result—frictions associated with homeownership help to resolve the portfolio choice puzzle—continues to hold.

In the base model, the coefficient of relative risk aversion is assumed to be 5. For a lower parameter on risk aversion, homeowners would shift their financial portfolio towards stocks and away from prepayments or bonds. However, compared to the implied stockholdings in the benchmark model without homeownership, the implied ratio of stock-to-cash-on-hand in the base model is still much lower. When the coefficient of relative risk aversion is set to be 3, the benchmark model predicts lifetime renters at age 40–50 put 100% of savings in stocks, whereas the base model with homeownership predicts renters at age 40–50 put 85% savings in stocks, and homeowners at age 40–50 put 52% savings in stocks. Thus, the key result is robust to the degree of risk tolerance.

4. Conclusion

The impact of housing investments on portfolio choices is currently receiving considerable and well-deserved attention. We know from the literature that modeling housing investments without frictions does not help to explain the empirically observed low equity holdings among most households. The purpose of this paper is to study the effect of realistic constraints associated with housing investments on the decision-making process of individuals. It has been shown that risks associated with homeownership do affect a household's optimal choice of consumption, housing, and financial asset investments. I calibrate a model in which a household endogenously transits from renting to mortgage-financed homeownership. The household can later adjust its housing status either voluntarily or because of a forced move, by paying a transaction cost. Households save in financial assets to finance future consumption. The effect of this life-cycle pattern in housing investments on portfolio choices is examined by simulation.

I showed that homeownership partially crowds out stock market participation, even given a rental choice. When households are able to invest in owner-occupied housing, their financial portfolios are very different from those of lifetime renters. Even the self-selected renters tend to be more risk averse in financial asset investments than lifetime renters who are not given a homeownership choice. With the possibility of homeownership, young and middle-aged households have more bond holdings than predicted by traditional models without housing. The owner-occupied house is a risky asset and it substitutes for stocks, while bonds provide liquidity to save for a house and make mortgage payments in case of income shortfalls.

Homeowners' portfolios are also very sensitive to the liquidity of housing assets and the exogenous probability of moving. In response to a high transaction cost, a homeowner may save more in riskless bonds to pay for the fixed housing adjustment cost. However, a higher transaction cost also lowers the probability of housing adjustments, reducing the need for higher precautionary savings. When the probability of exogenous moving is low, a homeowner's risky asset holdings exhibit a U-shape relative to transaction costs, reflecting these two offsetting effects. When the exogenous probability of moving is high, however, the first effect dominates and the risky stockholdings monotonically decrease with transaction costs. This is because homeowners rationally invest in a less risky way to save for the possible mandatory transaction cost payments. As a whole, a high mobility rate and the illiquid and lumpy nature of housing investments help to explain the low equity holdings among most households.

The analysis in this paper also has broader implications for the real estate market. It has been shown that transaction costs discourage selling, especially when house prices are low. Homeowners' selling behavior is asymmetric: homeowners are more likely to upgrade than downgrade with the same level of transaction costs. When a homeowner receives a bad shock on his housing investment, he holds his house for a longer period of time without selling. When he gets a good shock, he realizes the capital gain by paying the transaction cost and adjusts to the optimal balance between housing and the nondurable good consumption. This asymmetry is driven by the assumed positive mean return on housing. Further research using a general equilibrium model is necessary, however, to understand why house prices do not move so as to eliminate this asymmetry.

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