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OPTIMAL PORTFOLIO CHOICE WITH PREDICTABILITY IN HOUSE PRICES AND TRANSACTION COSTS

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Optimal Portfolio Choice with Predictability in House Prices and Transaction Costs*

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Abstract

Are housing prices predictable? If so, do households take into account it when making their portfolio choices? We document the existence of housing returns predictability in the US at the aggregate and regional level. We study a model, in which housing prices are predictable and adjustment costs must be paid when there is a housing transaction. We show that two state variables affect the agent's decisions: (i) his wealth-house ratio; and (ii) the time-varying expected growth rate of housing prices. The agent buys (sells) his housing assets only when the wealth-to-housing ratio reaches an optimal upper (lower) bound. These bounds are time-varying and depend on the expected growth rate of housing prices. Finally, we use household level data from the PSID and SIPP surveys to test and support the main implications of the model.

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1 Introduction

Housing plays an important role in the portfolio choice decisions of households because it accounts for an important fraction of their wealth. However, several specific characteristics of housing make portfolio choice decisions nontrivial. First, housing is a durable consumption good as well as an investment asset. Second, moving to a new house involves high transaction costs; therefore, homeowners would find it optimal not to frequently re-balance their position in housing as they would with other investment assets. Third, housing returns present a certain degree of predictability. The main contribution of this paper is to solve a portfolio choice problem that incorporates these three particular characteristics of housing and to test its empirical implications. The paper provides a first step towards understanding the existence of housing returns predictability and its qualitative and quantitative impact on housing consumption and portfolio decisions subject to transaction costs. This study has been articulated in four parts.

Firstly, we motivate and explore predictability in housing returns. We apply the approaches for the analysis of stock returns predictability developed in Campbell and Cochrane (1999) and Menzly, Santos, and Veronesi (2004) to the study of housing predictability. Our results show that the rent-price ratio presents a strong predicting power of future housing returns. At U.S. aggregate level, a 1% variation of rent-price ratio implies a 3.79% variation in a one-year horizon returns over the period 1978 to 2001. For longer horizons, results are even stronger. As we increase the horizon, the coefficient on the rent-price ratios forecasting future housing returns becomes higher and more statistically significant. Similar results appear at the U.S. Census Macro Region level. Furthermore, we find that housing price growth is more predictable than stock returns. Because housing is a major component of wealth, our empirical findings suggest it is important to understand how housing returns predictability affects households' consumption and portfolio decisions.

Secondly, we introduce house returns predictability in a model that studies housing consumption and portfolio choices of an agent in a partial equilibrium framework. We consider a housing market subject to sizeable transaction costs in the sense that the agent incurs a cost when selling the current house to buy a new one, making housing consumption lumpy. In essence, we generalize the model in Grossman and Laroque (1990) (GL henceforth) assuming that the dynamics of housing prices are predictable.[1] The Figure 1 depicts the pronounced cyclicality in US house prices over the period from 1930 to 2007, and two boom periods stand out particularly markedly.[2] First, around the end of World War II, house prices rose by 60% from 1942 to 1947. Second, based on the Case-Shiller US Home Price index, the annual rate of price change increased almost every year from 1998 to 2006, with a cumulative price increase of 85% during that period.[3] A natural candidate to capture regular switches between regimes of different housing price dynamics is a regime-switching model.

Thirdly, we use a long time series of data to estimate the parameters of a two-regime process that assumes that the expected growth of housing prices only takes two values, either low or high. The two-regime model is a reduced form representation of the predictive power of the rent-to-price ratio described above. We find that a model specification that allows the expected growth of housing prices to switch only between two regimes captures sufficiently well the essential dynamics of U.S. housing prices. We estimate a yearly growth rate of housing prices of 0.06% during the low growth regimes and a growth rate of 8.89% during the high regimes. Our analysis also suggests that housing prices are most often in a regime of low growth. Moreover, we estimate the same model at U.S. Census Macro Region level using the repeat sales indexes constructed by the Office of Federal Housing Enterprise Oversight (OFHEO). The estimated parameters are used as inputs for the numerical resolution of our model. We develop relevant theoretical implications. Predictability in housing returns results in a second state variable to the GL framework and implies a time varying inaction region as the bounds shift over time and, as a consequence, a second state variable to the GL framework. In addition to the wealth-to-housing ratio, the time varying expected growth rate of housing prices also determines the optimal timing for re-balancing housing consumption.

Fourthly, we unveil some interesting implications of the model and test them with household level data on consumption, wealth, housing values, and asset holdings available from the Panel

[1] Damgaard, Fuglsbjerg, and Munk (2003) generalize the GL setting allowing for both an perishable and a durable good whose price follows a Geometric Brownian motion. Their general setting allows to study the relation between perishable and durable consumption and the impact of the uncertainty of the durable good price and its correlation with financial asset prices on portfolio behavior. Additionally, we consider predictability in housing returns and test empirical implications of the model.

[2] We define boom in housing market as the time interval that includes the minimum number of periods with at least three consecutive years of positive yearly returns on the Case-Shiller House Price Index (HPI) and at least one year with return higher than 5%.

[3] Since Case and Shiller (1989) showed evidence of predictability in housing returns, the rate of return on the Case-Shiller Home Price Index for U.S. home prices increased almost every year from 1991 to 2005, with a negative rate of -8.04% in 1991 and a yearly return of +12.34% in 2005.

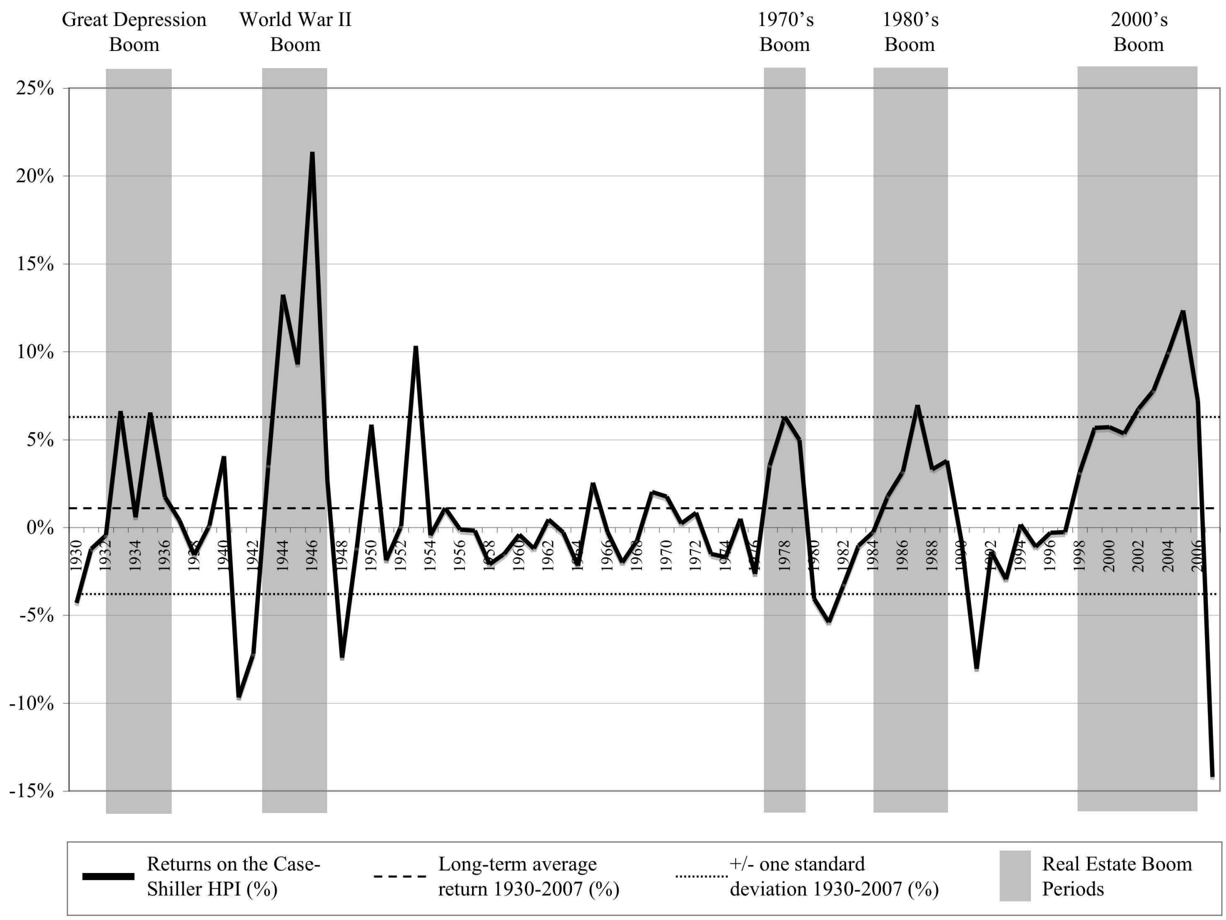

Figure 1: **Case&Shiller US Home Price Index (percentage change per annum) and periods of real estate boom.**

Study of Income Dynamics (PSID) from 1984 to 2007, and from the Survey of Income and Program Participation (SIPP) of the U.S. Census Bureau from 1997 to 2005.[4] We exploit the variation across households at the time they move to a different house. The variable of interest is the wealth-to-housing ratio of households right before a move. It allows us to identify the threshold levels that trigger the re-optimization of the housing wealth. Not surprisingly, we find that the inaction region does exist. Moreover, we find that there exists an upper bound in the wealth-to-housing ratio that triggers the increase of housing holdings (i.e., "moving to a bigger house"). Similarly, there exists a lower bound in the wealth-to-housing ratio that triggers the "moving to a smaller house". More

[4]The SIPP collects income, asset and demographic information from a sample of approximately $20,000 - 30,000$ households. The main advantages of the SIPP relative to PSID are its large sample size and detailed information about covariates as well as its complete housing history. However, PSID covers a larger period for the variables that we are interested. Additionally, the survey includes detailed questions about moving.

interestingly, we also document time variation of the bounds using house price indexes at U.S. State level. Households that moved to a bigger house in a period of expected high housing price appreciation had an ex-ante wealth-house ratio that is significantly lower than those that moved in a period of expected low appreciation. Hence, we provide evidence that we need to consider a second state variable in addition to the variable wealth-to-housing ratio. This second state variable is the time-varying expected growth rate of housing prices. It does not only affects the likelihood of housing adjustment but, conditionally on adjustment taking place, it also affects the size of housing adjustment. With respect to the asset holdings, the model predicts that agents with a higher wealth-to-housing ratio hold a higher share of risky stock than those with a lower ratio. The differences are larger in periods of high expected housing appreciation. However, because of the sparsity of financial data and the dubious quality of the observed variables as proxy for risky stock holdings, we find weak evidence of these facts. Nonetheless, results point in the right direction.

Our paper follows the literature that studies investment decision problems under fixed adjustment costs.[5] The model in Grossman and Laroque (1990) is a milestone in this literature. There are two lines of research that depart from this seminal paper and are related to our paper. First, the empirical part of our analysis is connected to the literature on (S,s) models, which focuses on empirically investigating the inaction region and testing the GL model, such as Eberly (1994), Attanasio (2000), Martin (2003) and Bertola, Guiso, and Pistaferri (2005). We are not aware of previous papers who study of the joint effect of variability and predictability on the price of a durable good, housing in our specific case. Second, our model and its main implications are related to papers that focus on particular implications of portfolio choice in the presence of housing such as Flavin and Yamashita (2002), Cocco (2005), Yao and Zhang (2005), Flavin and Nakagawa (2008), Van Hemert (2008) and Stokey (2009b). This strand of literature assumes that housing prices evolve stochastically following a random walk process.[6] Flavin and Yamashita (2002) use mean variance efficiency framework to examine the household's portfolio problem when owner-occupied housing is included in the set of available assets. The authors focus on the impact of the portfolio constraint imposed by the consumption demand for housing on the household's optimal holding of risky stock, but they do not incorporate the house purchase decision as in Grossman and Laroque

[5] See Stokey (2009a) for a treatment of stochastic control problems in presence of fixed adjustment costs.

[6] Specifically, Damgaard, Fuglsbjerg, and Munk (2003), Cocco (2005), Yao and Zhang (2005), Flavin and Nakagawa (2008) and Van Hemert (2008) make this assumption.

(1990). Cocco (2005) shows that investment in housing plays a crucial role in explaining the patterns of PSID cross-sectional variation in the composition of wealth and level of stock holding. Due to investment and housing price risk, younger and poorer homeowners have limited financial wealth to invest in stocks. Yao and Zhang (2005) investigate household's asset allocation and housing decisions in a life-cycle model. Their model predicts that the housing investment has a negative effect on stock market participation as in Cocco (2005). Chetty and Szeidl (2010) examine how portfolio allocations change when households buy houses. They provide evidence that housing reduces the amount households invest in risky stock substantially.[7]

The outline of the paper is structured as follows. Section 2 motivates and explores predictability in housing returns. Section 3 introduces the model and summarizes the main theoretical implications. In section 4 we describe the data and present the parameters driving the housing prices dynamics. In section 5 we use the results of the estimation exercise to solve the model and show the main results. The inaction regions arise from the transaction costs and the time-varying bounds arise from the predictability of housing returns. In section 6 we use PSID and SIPP data to test the main implications arising from the model solution that were presented in section 3 (i.e., the existence and characteristics of the bounds and the implications of these bounds on the portfolio decisions of the households included in these panels.) Finally, section 7 concludes.

2 Predictability in Housing Markets

Are housing returns predictable? Campbell and Cochrane (1999), Menzly, Santos, and Veronesi (2004), and Cochrane (2008) have explored the predictability of stock returns. Analogously, we explore the forecasting power of the rent-to-price ratio –the equivalent of the dividend price ratio for stocks. To understand why the price-rent ratio could play a role in explaining future returns, we linearize the returns definition as in Campbell and Shiller (1988). Price-rent ratios only move either if they forecast future returns, if they forecast future rent growth, or if there is a bubble.

[7] Our paper is also related to the sizable literature that incorporates stock return's predictability. Lynch and Balduzzi (2000) examine the portfolio choice problem of an agent in the presence of stock returns predictability, analyzing the re-balancing behavior when transaction costs are non zero. Brennan, Schwartz, and Lagnado (1997), Barberis (2000), Kim and Omberg (1996) and Campbell and Viceira (1999) develop models that fall under the first approach. They analyze the impact of myopic versus dynamic decision making when stock returns are predictable but they abstract from considering the impact of transaction costs. Instead, in this paper, we analyze the impact of housing, as a consumption and investment good, on portfolio choices in the presence of transaction costs on housing and housing returns predictability.

There is a bubble when the price-rent ratio grows at a faster rate than the discount rate. From the definition of returns, we can write

$$\frac{P_t}{D_t} = R_{t+1}^{-1}\left(1 + \frac{P_{t+1}}{D_{t+1}}\right)\frac{D_{t+1}}{D_t}, \tag{1}$$

where P_t is the housing price, D_t is the rent flow, and R_t represents returns at any time t. By solving it forward iteratively, taking expectations,[8] and subtracting the current dividend, we find the following expression (lower case letters in logs)

$$p_t - d_t = \alpha + E_t \sum_{j=1}^{\infty} \rho^{j-1}\left(\Delta d_{t+k} - r_{t+j}\right) + E_t \lim_{j\to\infty}\left(p_{t+j} - d_{t+j}\right). \tag{2}$$

where α and ρ are constants.

Our analysis focuses on how future returns and rent growth rates are explained by current rent-price ratios, in absence of bubbles.[9] Equation (2) motivates the following return predictability regression that consists on regressing returns on the lagged price-rent ratio, or the dividend growth predictability, regressing rent growth on lagged price-rent ratio:

$$r_{t+1} - \bar{r} = \kappa_0 + \kappa_r(p_t - d_t) + \varepsilon_{t+1}^{r}\Delta d_{t+1} - \bar{d} = \kappa_0 + \kappa_d(p_t - d_t) + \varepsilon_{t+1}^{d} \tag{3}$$

where $\bar{r}$, κ_0, κ_r, $\bar{d}$ and κ_d are constants, and ε_t^r and ε_t^d are error terms.

The price-rent ratios have been computed as in Campbell et al. (2009) using annualized quarterly data from 1978 to 2001 on housing prices from OFHEO and rents from the Bureau of Labor Statistics (BLS). We use the annualized 3 month Treasury Bill as a risk free rate to obtain excess returns. Housing returns, R_{t+1}^h, are defined as the change in the housing price index, $\frac{P_{t+1}^h}{P_t^h}$, plus the rent-price ratio adjusted by the price growth, $\frac{D_{t+1}^h}{P_t^h}$:

$$R_{t+1}^h = \frac{P_{t+1}^h + D_{t+1}^h}{P_t^h} = \frac{P_{t+1}^h}{P_t^h} + \frac{D_{t+1}^h}{P_{t+1}^h}\frac{P_{t+1}^h}{P_t^h}. \tag{4}$$

Additionally, we compute predictability regressions with an alternative data source: we use

[8]Expression (2) holds exactly, without expectations.

[9]Note that if the price dividend ratio is stationary, or bounded, or it does not explode faster than ρ^{-1}, then the last term disappears and we are back to equation (1). If we impose that there are no bubbles, this third term would be zero.

rent expenditures from the National Income and Product Accounts (NIPA) and market value of residential real estate from the Flow of Funds (item B.100) provided by the Federal Reserve Board. Returns are computed with changes in the market value of residential real estate, subtracting population growth. We deflate returns by the Consumer Price Index excluding shelter. Robustness results with this alternative data set and different sample selections are provided in the appendix A. Favilukis, Ludvigson, and Nieuwerburgh (2010) calibrate a general equilibrium model with housing using Flow of Funds and NIPA data. Their model generates a cyclical behavior of price-rent ratios comparable to the dynamics observed in recent data. According to their model, the ratio also predicts future housing returns and not future rents growth, which is consistent with our finding in the data.

Table 1 presents predictability regressions results. We regress future housing returns, at different horizons, on current rent-price ratios. We observe that the rent-price ratio has a strong predicting power of future housing returns. The predicting power of rent-price ratios is stronger than that of price-dividends ratio in predicting stock returns. At the aggregate level, a 1% variation of rent-price ratio implies a 3.97% variation in a one-year horizon returns. For longer horizons, results are even stronger. As we increase the horizon, the coefficient on the rent-price ratios, $(d_t - p_t)$, forecasting future housing returns becomes higher and more statistically significant.[10] When forecasting 4 and 5 year returns, a 1% increase in rent-price ratios imply an increase of 41% and 46% in housing returns respectively –at the aggregate level. Similar results appear at the U.S. Census Macro Region level. We also find that housing price changes are more predictable than stock prices at all horizons for this particular sample. Table 1 shows that stock returns predictability explained by price-dividend ratios is less than half the predictability that we observe in housing returns. On the right side of the table, it is shown that rents growth rates do not predict future returns. It is the case for either housing or stock returns, reinforcing the idea of housing returns predictability being due to movements in rent-price or dividend-price ratios respectively. The evidence presented in table 1 and in the appendix A motivates the assumption of predictability in housing returns and not in stock returns. We do observe evidence of stock return predictability to a lesser extent.

[10]The explanation for this phenomenon, in absence of the bubble term, is that the $(d_t - p_t)$ ratios are highly persistent. When estimating an $AR(1)$ to rent-price ratios for the sample, we cannot reject non-stationarity, supporting the idea of the bubble-like behavior during the last few years. On the other hand, for the trimmed data set, the autocorrelation coefficient of the rent-price ratios series is 0.93 for annual data. Obviously this results in a larger R^2 as well.

Modeling stock returns with a predictable component results in an additional state variable. For simplicity we abstract from doing so and we focus on the role of housing returns predictability in portfolio choice and housing tenure decisions.

Table 1: Predictability of excess returns and dividends growth with rents-to-price ratios, 1-lags Newey-West corrected standard errors. Data source: price-rent data from Morris Davis web site from 1978 to 2000.

		Excess Returns			Dividend growth		
	Horizon	κ_r	t-stat	R^2	κ_d	t-stat	R^2
USA	k=1	3.97	0.89	0.06	6.54	3.40	0.38
	k=4	41.45	10.35	0.76	10.11	1.49	0.13
	k=5	46.30	10.07	0.82	5.67	0.77	0.03
Midwest	k=1	1.29	0.42	0.01	2.53	1.70	0.22
	k=4	28.92	3.30	0.43	7.64	2.34	0.27
	k=5	38.03	4.40	0.53	7.21	2.10	0.22
Northeast	k=1	0.68	0.25	0.00	-0.97	-0.91	0.06
	k=4	20.30	2.39	0.27	3.18	1.03	0.09
	k=5	30.79	2.88	0.46	5.65	1.68	0.23
South	k=1	3.52	1.20	0.09	1.55	0.85	0.05
	k=4	26.78	5.06	0.61	-2.25	-0.59	0.02
	k=5	34.11	6.64	0.68	-4.30	-0.91	0.06
West	k=1	0.30	0.13	0.00	1.36	0.75	0.04
	k=4	21.92	4.84	0.56	-5.97	-1.52	0.08
	k=5	28.23	6.04	0.70	-10.61	-2.34	0.20
Stocks	k=1	3.92	2.65	0.08	-3.24	-2.07	0.05
	k=4	17.71	3.77	0.27	-0.01	-0.84	0.00
	k=5	20.39	4.31	0.28	0.00	0.04	0.00

Results are very similar at the Metropolitan Statistical Area (MSA) level. Interestingly enough, the predictability results do not hold if we include the last period of house prices increase, or housing bubble for the data set used in table 1. In the appendix, we show results with an alternative data source for which predictability results hold also for the full sample. In the full sample, including the last 7 years, price-rent ratios seem to follow non-stationary behavior. That implies that the last term in equation (1) might not converge to zero fast enough. When growing expectations of future prices is what explains current prices, little power is left for price-dividend ratios or dividend growth to explain future price changes. Campbell, J.Y., S. Giglio, and C. Polk (2010) presents a similar argument justifying the exclusion of the recent years.[11]

3 The Model

The evidence in the previous section indicates that the expected value of housing price growth varies through time and that the degree of housing returns predictability varies across the U.S. Census Macro Regions. In this section, we describe a model with infrequent housing adjustment in the presence of housing returns predictability. Our goal is to develop relevant qualitative implications that we can test on data-set featuring extensive information on housing purchases and measures of housing returns predictability.

We examine the consumption and portfolio choice of an agent in a continuous time economy with a riskless asset, a risky asset and two consumption goods, a perishable and a durable good with uncertain price evolution. Agents in our model have non-separable Cobb-Douglas preferences over housing and non-housing goods. The agent derives utility over a trivial flow of services generated by the house. This specification can be generalized as long as preferences are homothetic. For simplicity, we focus on the Cobb-Douglas implications. The period utility function can be expressed as:

$$u(C_t, H_t) = \frac{1}{1-\gamma}(C_t^{\beta} H_t^{1-\beta})^{1-\gamma}, \tag{5}$$

where H_t is the service flow from the house (square unit size), C_t is other consumption, and $\beta, \gamma \in (0,1)$. The agent has no bequest motive. The period by period budget constraint determines that the agent spends his income in consumption of non-housing goods, changing the house size, and investments for the following period in risky and safe assets. Income is composed by the returns of previous investments and a deterministic endowment.

The stock of housing depreciates at a physical depreciation rate δ. If the agent does not buy or sell any housing assets, the dynamics of the stock of housing follows the process:

$$dH_t = -\delta H_t dt, \tag{6}$$

for a given initial condition $H_0 = \bar{H}$. We assume that the square foot price of the house, P_t, follows

[11] Results for MSA level data and full sample regressions are available in the appendix.

a geometric Brownian motion with time varying drift,

$$dP_t = P_t\mu_t dt + P_t\sigma_P(\rho_{PS}dZ_{1,t} + \sqrt{1-\rho_{PS}^2}dZ_{2,t}), \tag{7}$$

where μ_t is the time-varying drift and ρ_{PS} is the correlation coefficient between the housing price, P_t, and value of the risky financial asset, S_t, defined below.

We assume that the housing price growth is predictable in the sense that μ_t follows a Markov chain process. In particular, μ_t can just take two values: a high value μ^h (high) and a low value μ^l (low), with $\mu^h > \mu^l > 0$. Periods with high drift are associated to "hot" housing markets, while periods with low drift are associated to "cold" housing markets. Potentially, μ_t could follow a n-regime Markov chain allowing more rich dynamics of housing prices. Our choice of the simple Markov switching model is based on its ability to capture the prominent features of housing price indexes and to maintain the model tractable. We also explore a three-regime Markov switching model whose results are provided in the appendix. The transition probability of the expected growth follows a Poisson law, such that μ_t is a two-regime Markov chain. Let λ^i denote the rate of leaving regime i; therefore, there is a probability $\lambda^h dt$ that μ_t changes from μ^h to μ^l during an infinitesimal time interval dt. In addition, the expected duration of regime h is $1/\lambda^h$. We assume that the agent knows with certainty the regime of the economy, hence μ_t is observable by the agent at time t. The agent in our model has no uncertainty about the parameters of the model. Pastor and Veronesi (2003) highlight the importance of learning about the mean profitability in stock valuation. Our aim is to first understand how agents make housing and portfolio decisions in the presence of house returns predictability with perfect information and transaction costs. Hence, our agents are endowed with all the information about the current regime.[12]

Let W_t define the agent's wealth in units of non-housing consumption as the investments in the financial assets (riskless and risky financial assets) and the value of current stock of the house:

$$W_t = B_t + \Theta_t + H_t P_t, \tag{8}$$

[12] We abstract from introducing uncertainty about expected house appreciation to keep the model as parsimonious as possible yet still exploiting the implications of predictability and transaction costs in the portfolio choice problem with housing. Nonetheless, we acknowledge that the agents' information set is ambitiously rich. We leave the introduction of learning about the uncertainty of the state variable as useful future line of research.

where B_t is the wealth held in the riskless asset and Θ_t is the amount invested in the risky financial asset, both of them expressed in units of non-housing consumption. The price of the risky asset, S_t, follows a geometric Brownian motion:

$$dS_t = S_t \alpha_S dt + S_t \sigma_S dZ_{1,t}. \tag{9}$$

Given the process for the risky asset prices, the housing stock law of motion, and the housing prices dynamics, wealth evolves according to the following process:

$$\begin{aligned} dW_t = & [r(W_t - H_t P_t) + \Theta_t(\alpha_S - r) + (\mu^i - \delta) H_t P_t - C_t] dt \\ & + (\Theta_t \sigma_S + H_t P_t \rho_{PS} \sigma_P) dZ_{1,t} + H_t P_t \sigma_P \sqrt{1 - \rho_{PS}^2} dZ_{2,t}, \qquad i = h, l. \end{aligned} \tag{10}$$

The homeowner can sell the house at any time τ. The agent incurs in a transaction cost which is proportional to the value of the house he is selling. Since the quantity of housing changes discontinuously at the stopping time τ, the notation $H_{\tau-}$ is used to distinguish the amount of housing immediately prior to the sale from the quantity of housing immediately after the sale, H_τ. At the instant the house is sold, the homeowner's wealth is $W_\tau = W_{\tau-} - \epsilon P_\tau H_{\tau-}$, where $\epsilon P_\tau H_{\tau-}$ is the transaction cost. The homeowner first decides whether it is optimal to instantaneously sell the house by comparing the value function associated to its problem conditional on selling a house (action) to the value function conditional on not selling (inaction). Let τ define the stopping time where the selling action occurs. In practice, homeowners may be required to sell the current house for exogenous reasons. Marital status changes that involve relocating to a new house and changes in family size are two possible interpretations of the exogenous moves. We abstract from introducing exogenous moving shock.[13]

The value function of this problem, $V(W_0, P_0, H_0, i)$, satisfies the following Bellman equation in which the consumer chooses optimal consumption of non-housing and housing, asset allocation and optimal stopping time for buying a new house:

[13] Stokey (2009b) assumes that this shock is Poisson with a constant arrival rate. In her set up, a positive hazard rate for exogenous moves makes housing less attractive and moves more frequent. As result, inaction region widens and the upper and lower bounds increase. In our empirical analysis, we will include changes in demographic characteristics in assessing the qualitative predictions of our model.

$$V(W_0,P_0,H_0,i)=\sup_{C_t,\Theta_t,H_\tau,\tau} E\left[\int_0^\tau e^{-\rho t}u(C_t,H_t)dt+e^{-\rho\tau}V(W_{\tau-}-\epsilon P_\tau H_{\tau-},P_\tau,H_\tau,i)\right],\quad i=h,l. \tag{11}$$

We can use the homogeneity properties of the value function to reduce the problem with four state variables (W_t, P_t, H_t, i) to one with two state variables, $z_t = W_t/(P_t H_t)$, and i, since

$$V(W_t,P_t,H_t,i)=H_t^{1-\gamma}P_t^{\beta(1-\gamma)}V\left(\frac{W_t}{(P_tH_t)},1,1,i\right)=H_t^{1-\gamma}P_t^{\beta(1-\gamma)}v\left(z_t,i\right),\quad i=h,l. \tag{12}$$

Furthermore, let $\hat{c}_t$ and $\hat{\theta}_t$ denote the scaled controls $\hat{c}_t = C_t/(P_t H_t)$ and $\hat{\theta}_t = \Theta_t/(P_t H_t)$.

A solution consists of a value function $v(z_t, i)$ defined on the state space, where bounds $\underline{z}_i$ and $\overline{z}_i$ define an inaction region, z_i^* is the optimal regime dependent return point, and a consumption policy $\hat{c}^*(z_t, i)$ and portfolio policy $\hat{\theta}^*(z_t, i)$ defined on $(\underline{z}_i, \overline{z}_i)$, where $i = h, l$. The function $v(z_t, i)$ satisfies the Hamilton-Jacobi-Bellman equation on the inaction region. Value matching and smooth pasting conditions hold at the two bounds, and an optimality condition holds at the return point. Compared to Grossman and Laroque (1990) and Damgaard, Fuglsbjerg, and Munk (2003), the novel feature exploited here is the persistence in the process that describes the dynamics of housing prices. The model features optimal rules that reflect the possibility for the agent to invest in a different regime of housing price growth in the future. The agent has to determine the optimal rule in each regime, while taking into account the optimal rule in the other one. Thus, the model generates richer rules than the standard one-regime models. The following proposition exposes the optimal housing and portfolio choices properties derived from our model.

Proposition 1 *The solution of the optimal portfolio choice problem defined above presents the following properties:*

1. $v(z_t, i)$ *satisfies*

$$\widetilde{\rho}v(z_t,i)=\sup_{\hat{c}_t,\hat{\theta}_t}\left\{u(\hat{c}_t)+\mathcal{D}v(z_t,i)+\lambda^i(v(z_t,j)-v(z_t,i))\right\},\quad z\in(\underline{z}_i,\overline{z}_i), \tag{13}$$

where

$$\mathcal{D}v(z_t,i) =((z_t-1)(r+\delta-\mu^i+\sigma_P^2(1+\beta(\gamma-1))) \\ +\hat{\theta}_t(\alpha_S-r-(1+\beta(\gamma-1))\rho_{PS}\sigma_S\sigma_P)-\hat{c}_t)v_z(z_t,i) \\ +\frac{1}{2}((z_t-1)^2\sigma_P^2-2(z_t-1)\hat{\theta}_t\rho_{PS}\sigma_P\sigma_S+\hat{\theta}_t^2\sigma_S^2)v_{zz}(z_t,i), \tag{14}$$

$$v(z_t,i)=M(i)\frac{(z_t-\epsilon)^{(1-\gamma)}}{1-\gamma}, \quad z\notin(\underline{z}_i,\overline{z}_i) \tag{15}$$

and $M(i)$ is defined as

$$M(i)=(1-\gamma)\sup_{z\geq\epsilon} z^{\gamma-1}v(z,i), \tag{16}$$

for $i=h,l$ and $j=l,h$.

2. *The return point z_i^* attains the maximum in*

$$v(z^*,i)=M(i)\frac{z_i^{*(1-\gamma)}}{1-\gamma}, \quad \textit{for} \quad i=h,l. \tag{17}$$

3. *Value matching and smooth pasting conditions hold at the two thresholds $(\underline{z}_i,\overline{z}_i)$*

$$v(\hat{z},i)=M(i)\frac{(\hat{z}_i-\epsilon)^{(1-\gamma)}}{1-\gamma}, \tag{18}$$

$$v_z(\hat{z},i)=M(i)(\hat{z}_i-\epsilon)^{-\gamma}, \tag{19}$$

for $\hat{z}_i=\underline{z}_i,\overline{z}_i$ and $i=h,l$.

4. *In a state z_t, where $v(z,i)>M(i)\frac{(z_t-\epsilon)^{1-\gamma}}{1-\gamma}$, the agent chooses a optimal consumption $\hat{c}^*(z_t,i)$ and portfolio $\hat{\theta}^*(z_t,i)$ and $\hat{b}^*(z_t,i)$*

$$\hat{c}^*(z_t,i)=\left(\frac{v_z(z_t,i)}{\beta}\right)^{1/(\beta(1-\gamma)-1)}, \tag{20}$$

$$\hat{\theta}^*(z_t,i)=-\omega\frac{v_z(z_t,i)}{v_{zz}(z_t,i)}+\frac{\rho_{PS}\sigma_P}{\sigma_S}(z_t-1), \tag{21}$$

$$\hat{b}^*(z_t,i)=1-(1+\hat{\theta}^*(z_t,i))/z_t, \tag{22}$$

for $i=h,l$, and the constant ω is defined as $\omega=[\alpha_S-r+(1-\beta(1-\gamma))\rho_{PS}\sigma_P]\frac{1}{\sigma_S^2}$.

The main model implications that will be tested and analyzed in the empirical part of this paper are summarized by the following statements:

1. There exists an inaction region for housing, that is, households do not trade housing continuously. Instead, they wait until their wealth ratio is high (low) enough to increase (decrease) their housing assets. The inaction region is limited by a lower bound $\underline{z}_i$ and an upper bound $\overline{z}_i$ in each regime i, such as $\underline{z}_i < \overline{z}_i$ for $i = h, l$.

2. The upper and lower bounds are not constant, but depend on the regime i. In particular, both the upper and lower bounds in periods of high growth of housing prices are below the respective bounds in periods of low growth, that is, $\overline{z}_h < \overline{z}_l$ and $\underline{z}_h < \underline{z}_l$.

3. The portfolio choices of households $\hat{\theta}^*(z_t, i)$ and $\hat{b}^*(z_t, i)$ depend on their individual value of z_t, which at the same time depend on the regime i. Regarding the risky asset position, the model predicts the following linear relation between asset holdings and the ratio z_t of total wealth to housing wealth when the ratio z_t is very close to the bounds $\underline{z}_i$ and $\overline{z}_i$:

$$\hat{\theta}^*(z_t, i) \approx -\frac{\omega}{\gamma} z_t + \frac{\rho_{PS}\sigma_P}{\sigma_S}(z_t - 1). \tag{23}$$

   The equality holds when $z_t = \underline{z}_i$ or $z_t = \overline{z}_i$. In any of these cases, equation (21) becomes the linear portfolio rule in Merton (1969), which is equivalent to the equality in (23). The first term on the right hand side of (21) becomes "less linear" the further z_t is from $z_t = \underline{z}_i$ and $z_t = \overline{z}_i$, because the coefficient of the relative risk aversion varies with z_t. The lower relative risk aversion when z_t is close to the upper or lower bounds leads to higher fraction of wealth invested in the risky asset than when z_t is in the center of the inaction region. The second term is a hedging term.

Figure 2 illustrates the implications of transaction costs, and predictability in housing returns. Consider that an agent has a ratio of total wealth, W_t, to housing wealth, $P_t H_t$ equal to 2.5 at the initial time $t = 0$. We refer to this ratio as the wealth-to-housing ratio. Assume that $t = 0$ belongs to a time interval in which the growth of housing prices is high (e.g., real estate boom). The agent consumes perishable goods and re-balances his portfolio over time. The agent must pay a transaction cost every time he adjusts his housing consumption; therefore, he does not move to a bigger (smaller) house until he has not cumulated (lost) a sufficient amount of wealth to compensate for this transaction cost. An upper (lower) bound exists. When the wealth-to-housing ratio, $W_t/(P_tH_t)$ in the figure, reaches the upper (lower) bound, the agent immediately sells his house and purchases a bigger (smaller) one in order to reset his wealth-to-housing ratio to its optimal level. In Figure 2, this event corresponds to point 1 at time $t = \tau_1$. As a result, the ratio $W_t/(P_tH_t)$ returns to the optimal level z_h^*, which corresponds to point 1^*. Now assume that the economy moves towards a regime of low growth in housing prices shortly after τ_1. Note that both the upper and lower bounds in this period of low housing prices growth are higher than their respective bounds in the period of high growth. The wealth-to-housing ratio evolves over time until it hits the upper bound again (point 2) at time $t = \tau_2$. Hence, the agent purchases a bigger house (point 2^*). At time $t = \tau_3$ there is a shift to the regime of high expected growth in housing prices (point 3). As a result, the upper bound shifts down and the agent moves to a bigger house (point 3^*), which is bigger than in the regime of low expected growth in housing prices. The example continues with symmetrical situations in which the agent moves to a smaller house when his ratio reaches the lower bound (points 4, 5, and 6). The previous hypothetical example provides intuition about the main contributions of the paper: (i) the portfolio choice implications of three of the main characteristics of housing (e.g., housing being a durable consumption good as well as an investment asset, high transaction costs, and predictability in housing returns); (ii) the testable implications of the wealth-to-housing ratio for households that want to change their housing holdings; and (iii) the testable implications about the overall portfolio allocation of these investors.

Predictability in housing returns implies a time varying inaction region as the bounds shift over time and, as a consequence, a second state variable to the GL framework. In addition to the wealth-to-housing ratio, the time varying expected growth rate of housing prices also determines the optimal timing for re-balancing the housing portfolio.[14] The inaction region is a function of the expectations of the growth rate in housing prices. A change in the housing portfolio happens when the wealth-to-housing ratio reaches the critical level at which point a transaction cost is optimally disbursed. The time variation in housing prices growth causes a change in the housing part of the portfolio. It is the bound that moves towards the agent's wealth-to-housing current ratio up to the point where it is optimal to pay the transaction costs for re-sizing the housing wealth. In the GL

[14] In Grossman and Laroque (1990) the only state variable is the wealth-housing ratio. In our analysis, consumption is a composite of housing services and non-housing goods and services. Using the non-housing good as numeraire allows us to use the housing consumption in terms of non-housing in the state variable.

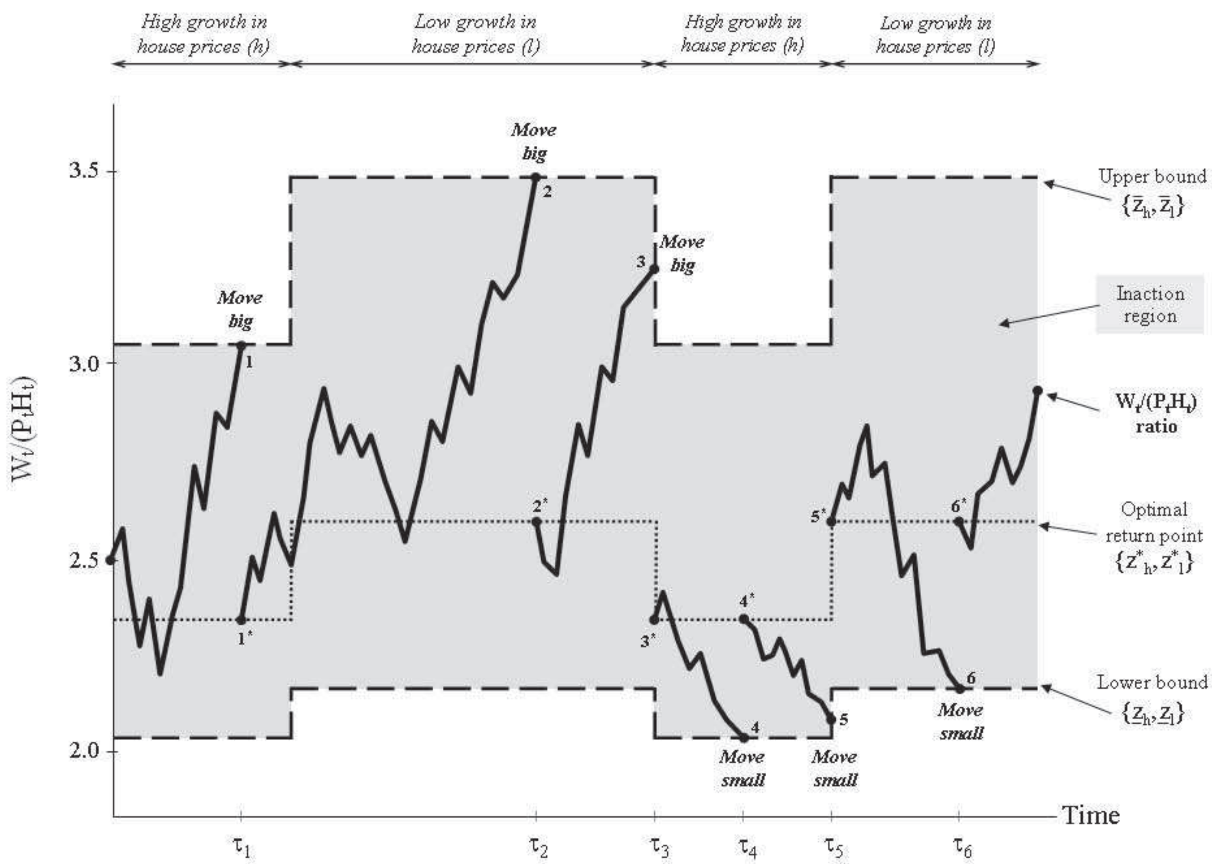

Figure 2: **Illustration.** Hypothetical path of wealth-to-housing ratio and upper and lower bounds associated to the two regimes. Changes in the expected growth of prices cause households to buy or sell the house. When the ratio hits a bound, the benefits of re-sizing the house outweighs the transaction costs.

framework, housing adjustment occurs only when the wealth-housing ratio hits a time-invariant bound. The intuition is as follows. When the expectations of house appreciation are higher, the numerator of the wealth-house ratio increases in the next time period. Because the agent expects to have a lower wealth-house ratio in the next time period due to a regime switch, he upgrades to a bigger house even with a relatively lower wealth. On the other side, in times of lower expectations of appreciation, the agent prefers to wait longer until his own wealth increases in order to upgrade to a bigger house.[15]

[15] Morris, Lehnert, and Martin (2008) document that almost all of the decline in rent-price ratio is attributable to either a steep decline in risk premium or an increase in the expected growth of housing prices, or some combination of these two factors. Fillat (2009) presents evidence of a small predictable component in growth of housing services, which is a proxy for growth in rents. This alone does not explain entirely the mean reversion of rent-price ratios after a shock. Therefore, the absence of a full explanation in the rent growth motivates the presence of predictability in

Our framework generates richer portfolio rules than the GL framework. In particular, the coefficient of risk aversion is also regime dependent, generating a different portfolio allocation rule for each regime. The portfolio allocation rule reflects the possibility of regime switches in the future. Therefore, the agent has to determine the portfolio rule in each regime, while discounting the possibility of a future shift in the expected growth rate in housing prices.

4 Data and Parameter Estimation

4.1 Data and Sample Definition

To estimate the Markov switching model, we use annual data on housing prices from the Case-Shiller Home Price Indexes from 1930 to 2007 for U.S. at aggregate level. The reference index is the Case-Shiller HPI constructed in Shiller (2005). Hence, we obtain quarterly data on average housing prices by U.S. Census Macro Regions (West, Midwest, South and Northeast) and U.S. States from 1978 to 2007 using the repeat sales index constructed by the OFHEO.

To test the theoretical predictions of our model, we use household level survey data from the Panel of Income and Study (PSID) from 1984 to 2007, and from the Survey of Income and Program Participation (SIPP) of the U.S. Census Bureau from 1997 to 2005. Both surveys have data on asset holdings and housing wealth. PSID regularly collects information about home values and mortgage debt; occasionally, it also collects information about behavior on savings and wealth. SIPP has a detailed inventory of annual real and financial assets and liabilities. It also contains more frequent measures of those assets that are relevant for assistance measures since its main purpose is to evaluate effectiveness of government transfer programs. PSID is a nationally representative longitudinal sample of approximately 9,000 households. PSID interviews are conducted annually and emphasize the dynamic aspects of economic and demographic behavior. SIPP at each moment tracks approximately 30,000 households. During the period considered, information was collected from three consecutive groups of households that were interviewed during the years 1996-2000 (four times), 2001-2003 (three times), and 2004-2006 (two times), respectively. During its active period, each panel is interviewed with intervals of several months, while panels of households do not overlap across periods. SIPP over-samples from areas with high poverty concentrations, which should be

housing returns.

taken into account when interpreting the results. Its longitudinal features enable the analysis of dynamic characteristics, such as changes in income and in household and family composition, or housing dynamics. Its cross-sectional features allow us to keep track of the household wealth. Both surveys allow us to study the empirical implications of the model outlined above. In particular, we focus on the identification that arises when households sell their current home to buy a new one. Unfortunately both data sets offer no measure of overall transaction costs paid by households when they change their home.

Using the PSID data we calculate wealth as the summation of an individual's house value, their second house value (net of debt), business value (net of debt), other assets[16] (net of debt), stock holdings (net of debt), checking and savings balances, and IRAs and annuities less the mortgage principal[17] on the primary residence. We delineate these variables into those that are considered risky assets and those that are safe assets. The risky assets are comprised of the stock holdings. The safe asset is comprised of other assets (net of debt), checking and savings balances, and IRA and annuity holdings, less the principal on the primary residence. Generally, the variables we utilized from the SIPP data set are net of debt, the sole exception is property value. Using the SIPP data we calculate risky assets as the summation of equity in stocks and mutual funds. While the safe assets are the summation of interest earning assets in banks and other institutions, equity in IRAs, and equity in 401K and thrifts; less outstanding mortgage balance. The value for wealth is a calculated by adding the risky asset value to safe asset value, business equity, property value of primary residence, housing equity in second residence and other assets. In both data sets, the measure of house value is given by homeowners' estimate of home value. Home value is problematic in that there might be a large amount of measurement error in the figure quoted. However, we would argue that while most home owners only have a general idea of the value of their home, owners which are near to the bound or have recently bought a house have very precise knowledge of the value of their home. Hence, if households do not own risky stock or safe asset such as checking and savings balances, IRA and annuity holdings, we set these these holdings to zero. In addition, we exclude households whose total reported stockholdings are negative. This exclusion does not affect the qualitative results reported below.

[16]Other assets include bonds and insurance.

[17]For comparability across waves of surveys, we focus only on the primary mortgage.

Table 2 shows the descriptive statistics for the main variables that we use in the empirical analysis. We present statistics for the full sample and also for the selection of households that moved to a bigger or a smaller house (second and third pair of columns respectively.) We show mean and standard deviations of the relevant variables. The single most important variable is the wealth-to-housing ratio, z. For the PSID sample we observe that, on average, the value of the house is approximately two-thirds of the total household wealth. This average ratio is lower for movers, not controlling for any other reason to move exogenous to the model. Risky asset holdings are roughly 5.5% of the total wealth, and risk-free asset holdings represents 18.2% of total wealth, much higher for households who buy a more valuable house. We define the dummy Move big (small) to identify households selling the current house to buy a bigger (smaller) one in the same U.S. Census Macro Region. Hence, we report summary statistics for variables that will help us to distinguish between changes in housing that occur because of reasons that are exogenous to the model and changes in housing that occur because individuals have a total wealth-to-housing ratio that is close to the boundary.

In order to capture exogenous shocks, we define variables to examine changes in demographics from the year before to the year after home purchase. Δ Family size shows the statistics of changes in family size. Δ Retired is a dummy variable which takes value of one if the individual enters into retirement in the year of the questionnaire. Δ Married is a dummy variable which takes value of one if the individual gets married. Δ Employment is a dummy variable which takes value of one if the individual changes his employment status. During the sample period analyzed using the PSID data, the size of the household (in number of members) decreased by -0.044, while the retired sample increased in 1.3%. The family size increased for movers to a bigger house, 0.069, while decreased for movers to a smaller house, -0.228, meaning that housing consumption is strictly related to the number of members in the household. Marriages also increase, by almost 1.5%, and again this figure is substantially higher for movers. The age composition of the full sample consists of 9.9% of under 30 years individuals and 48.5% between 30 and 50. The age composition of movers is shifted towards a younger population: the under 30 category represents 24.3% of movers and the between 30 and 50 represent 55% of all movers. The regional composition, in terms of Census regions are 15.5% Northeast, 26.6% Midwest, 41% South, and 16.9% West. The summary statistics using SIPP do not differ substantially. It is worth to mention the differences in age composition,

Table 2: **Descriptive statistics**. Statistics for the main variables used in our analysis from PSID and SIPP data. The variables Move big and Move small correspond to the individuals who moved to a house of higher and lower value, respectively. Full sample refers to all the individuals in the sample, irrespective of their moving situation. The ratio $W/(PH)$ corresponds to the ratio of total wealth over housing wealth, net of debt. Δ Family size shows the statistics of changes in family size. Δ Retired is a dummy variable which takes value of one if the individual enters into retirement in the year of the questionnaire. Δ Married is one if the individual gets married, zero otherwise. Δ Employment is one if the individual changes employment status, zero otherwise. $Age_{y<30}$ and $Age_{30<y<50}$ are dummy variables capturing individuals younger than 30 years old and between 30 and 50 years old respectively. Northeast, Midwest, South and West are U.S. Census Macro Regions dummies.

(a) PSID data

	Full sample (Num. obs.=20343)		Move big (Num. obs.=1290)		Move small (Num. obs.=465)	
Variable	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
$z = W/(PH)$	1.374	1.649	1.300	1.778	1.231	1.635
Risky holdings on wealth ratio θ/z	0.055	0.145	0.064	0.180	0.058	0.154
Risk-free holdings on wealth ratio b/z	0.182	0.333	0.225	0.358	0.175	0.242
Move big	6.3%	24.4%				
Move small	2.3%	14.9%				
Δ Family size	-0.044	0.670	0.069	0.921	-0.228	1.143
Δ Retired	1.3%	24.3%	0.8%	15.7%	1.9%	25.8%
Δ Married	1.6%	12.7%	6.7%	25.0%	3.2%	17.7%
Δ Employment	14.9%	35.6%	10.0%	30.0%	21.5%	41.1%
$Age_{y<30}$	9.9%	29.8%	24.3%	42.9%	18.7%	39.0%
$Age_{30<y<50}$	48.5%	50.0%	55.0%	49.8%	44.9%	49.8%
Northeast	15.5%	36.2%	13.3%	34.0%	9.7%	29.6%
Midwest	26.6%	44.2%	26.9%	44.4%	27.3%	44.6%
South	41.0%	49.2%	39.3%	48.9%	42.8%	49.5%
West	16.9%	37.5%	20.5%	40.4%	20.2%	40.2%

(b) SIPP data

	Full sample (Num. obs.=105447)		Move big (Num. obs.=1784)		Move small (Num. obs.=906)	
Variable	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
$z = W/(PH)$	1.385	1.625	1.384	1.734	1.218	1.444
Risky holdings on wealth ratio θ/z	0.060	0.184	0.080	0.177	0.056	0.145
Risk-free holdings on wealth ratio b/z	0.203	0.383	0.239	0.345	0.170	0.243
Move big	1.7%	12.9%				
Move small	0.9%	9.2%				
Δ Family size	-0.015	0.507	0.078	0.730	-0.086	0.838
Δ Retired	2.0%	13.9%	1.8%	13.3%	3.5%	18.5%
Δ Married	1.1%	10.6%	1.1%	10.5%	4.7%	21.3%
Δ Employment	6.9%	25.3%	9.8%	29.7%	12.6%	33.2%
$Age_{y<30}$	5.9%	23.5%	13.6%	34.3%	10.2%	30.2%
$Age_{30<y<50}$	42.8%	49.5%	59.9%	49.0%	45.1%	49.8%
Northeast	18.0%	38.5%	14.3%	35.0%	13.9%	34.6%
Midwest	27.2%	44.5%	27.9%	44.8%	24.9%	43.3%
South	36.2%	48.1%	32.0%	46.6%	38.5%	48.7%
West	18.5%	38.5%	25.9%	43.8%	22.6%	41.9%

where the youngest group is more represented in PSID. In terms of moving, the group of movers to a bigger and smaller house is lower in SIPP than in PSID in percentage terms, although we have more observations for this group in SIPP. Geographic composition and other relevant variables are comparable both in levels, standard errors, and also conditional on moving household.

Table 3 provides information on the percentage of movers by current ownership status (owner, renter, or occupied) over total households in the PSID and SIPP surveys across all years. The four columns represent percentage of households that moved to a new address, that moved to a new address in the same U.S. Census Macro Region, that moved to a new address in the same U.S. State, and that moved to a new address and were previously not homeowners. While we can easily identify movers in PSID because it reports explicitly whether there has been a move since the previous interview, we have to identify movers in SIPP keeping track of the households' address identifier. That identification mechanism is what generates differences between SIPP and PSID that were not present in Table 2. In the upper panel of Table 3 we observe that the percentage of owners who move is much lower than the percentage of renters, who have much higher mobility than owners. The percentage of movers to a different U.S. Census Macro Region or U.S. State is very low among owners. The total inflow of homeowners is different between PSID and SIPP. While households in SIPP entering in home ownership during the sample is 5.47%, more than half of the movers in PSID are new home-owners.[18] Despite of reporting data for renters, it is necessary to emphasize that we do not model renters' decisions. Our agent does not have the possibility of renting. In order to consume housing services, the only option is to pay a transaction costs and purchase the asset quantity H_t and derive a flow of services from it. Renting is not part of the model and we select the sample of homeowners only. Therefore, the model is mute about the renters who moved during the sample period.

4.2 Parameterization

This subsection presents the estimation procedure of the discrete time counterpart of the Wonham filter.[19] This discrete time version of the filtering problem and estimation is due to Hamilton (1989), and it is implemented with the longer Case-Shiller HPI constructed in Shiller (2005) for U.S. at aggregate level and with OFHEO housing price indexes for the U.S. Census Macro Regions (West, Midwest, South and Northeast). The filter is an iterative procedure which provides estimates of

[18] New in the sense that they did not own at $t-1$ but it could be the case that they were owners in the past.

[19] For a more detailed proof of the derivation and implementation of the filter used in the parametrization see Lipster and Shiryayev (2001).

Table 3: **Movers.** Percentage of households that moved over total households in the PSID and SIPP surveys across all years. The first column captures the percentage of households that changed address. The second column captures the percentage of households that moved to a new address in the same U.S. Census Macro Region. The third column captures the percentage of households that moved to a new address in the same U.S. State. The last column shows the percentage of movers that were not owners in the preceding period.

(a) PSID data

Status	Move	Same U.S. Census Macro Region	Same U.S. State	Not Owner at t-1
Owner	15.43%	14.82%	14.19%	3.79%
Renter	28.70%	27.03%	25.26%	25.31%
Occupied	4.15%	3.87%	3.56%	3.63%

(b) SIPP data

Status	Move	Same U.S. Census Macro Region	Same U.S. State	Not Owner at t-1
Owner	13.55%	12.74%	12.00%	5.47%
Renter	35.16%	33.55%	32.17%	32.67%
Occupied	3.49%	3.31%	3.09%	3.06%

the probability that a given regime is prevailing at each point in time given its previous history.

We assume that the growth of home prices can be expressed as

$$\frac{dP_t}{P_t} = \mu(s_t) + \sigma_P dZ_{P,t}, \tag{24}$$

where s_t is the unobserved regime of the economy, either high or low. Throughout the paper, the 2-regime expected growth rate of housing prices are indexed by h or l, respectively. The Wiener process $Z_{P,t}$ is correlated with the shock to the stock price, and it can be expressed as $dZ_{P,t} = \rho_{PS} dZ_{1,t} + \sqrt{1-\rho_{PS}^2} dZ_{2,t}$. The regime shift follows a Markov two-regime chain with transition probability matrix Φ, with diagonal entries $1-\lambda^h$ and $1-\lambda^l$. The more persistent the Markov chain, the slower mean reversion the process has. The vector of parameters to be estimated is $\Omega_1 = \left\{\lambda^h, \lambda^l, \mu^h, \mu^l, \sigma_P\right\}$.

Figure 3 shows the ex-post estimated probabilities of being in a high expected growth regime. In general, the housing markets are more likely to be the low price growth regime. The probability of being in the high-growth regime is more than 50% (i.e., the probability of growing at 8.89% on average is higher than the probability of growing at 0.06%) only in two periods. These two periods were identified with the World War II and the 2000s real estate booms.

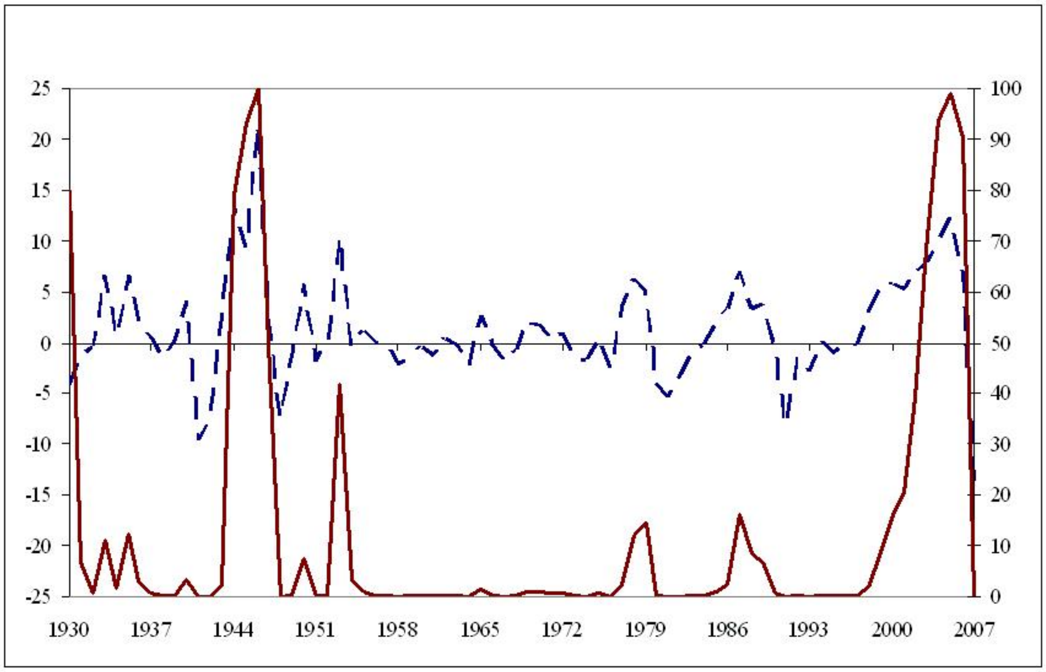

Figure 3: **Probability of being in a high regime.** Contemporaneous estimated probability of being in a regime where housing prices grow at an annual 8.89% (continuous line, right-hand scale) as opposed to the moderate low regime, where the expected growth is 0.06% a year. The figure shows the percentage change per annum of the Case&Shiller US Home Price Index (dotted line, left-hand scale).

Table 4 summarizes the estimates for the housing price dynamics, reporting the parameters tfor the composite S&P Case-Shiller HPI for U.S. at aggregate level and for the OFHEO housing price indexes for the U.S. Census Macro Regions (West, Midwest, South and Northeast). Due to the shorter time series and the most recent boom episode (1998-2006), house prices growth rates are higher in both regimes, high and low, for U.S. Census Macro Regions than U.S. at aggregate level. We provide the charts of the ex-post estimated probabilities of being in a high expected growth regime for the four U.S. Census Macro Regions in the appendix, Figure 6. We have also estimated a three-regime Markov switching model for the U.S. Census Macro Regions. The parameter estimates are reported in Table 17 and Figure 7 shows the ex-post estimated probabilities of being in a high and medium expected growth regime.

Table 5 summarizes calibrated the preference parameters, risk free rate, housing stock dynamics, transaction costs, and the estimated dynamics of prices of risky assets. We assume a curvature of the utility function of 2 and a rate of time preference of 2.5%. The parameter $1 - \beta$ measures how

Table 4: **Parameter values for the housing prices process.** Estimation of the parameters corresponding to the housing price processes using a discrete Markov regime (Wonham filter). The level of the housing price drift in the low and high regimes are represented by μ^l and μ^h, respectively. The unconditional probabilities of moving from the low to the high regime or from the high to the low regime are λ^l and λ^h, respectively. The house price standard deviation is represented by σ_P. The first column shows the parameters obtained using aggregate annual U.S. data from 1930 to 2007. The second to forth columns show the U.S. Census Macro Regions obtained using semiannual data from 1975 to 2007. All parameters are reported in annual basis.

	US aggregate (1930-2007)	West (1975-2007)	Northeast (1975-2007)	South (1975-2007)	Midwest (1975-2007)
μ^h	0.0889	0.1422	0.1186	0.0962	0.1272
μ^l	0.0006	0.0446	0.0186	0.0362	0.0418
σ_P	0.0410	0.0153	0.0183	0.0102	0.0098
λ^h	0.2775	0.1611	0.1152	0.1710	0.2301
λ^l	0.0387	0.0440	0.0991	0.0433	0.0169

much the agent values housing consumption relative to the numeraire consumption. It is set at 0.4 which is consistent with the average proportion of household housing expenditures in the U.S.[20] We assume that the risk free rate is equal to 1.5% annually. Using U.S. data over the period 1889-2005, Kocherlakota (1996) reports an average real return on a market index of 7.7% and a standard deviation of 16.55%. We consider the estimated housing price standard deviation, σ_P, of 4.1% too low, due to inertia in house price indexes. Instead, we assume a housing price standard deviation of 10%. This is close to the one estimated by Campbell and Cocco (2003) and Landvoigt, Piazzesi, and Schneider (2010). Campbell and Cocco (2003) report a housing price standard deviation of 11.5%, using housing price data from the PSID for the years 1970 through 1992. Landvoigt, Piazzesi, and Schneider (2010) report a housing price standard deviation of 10%, using micro data on the San Diego Metro area for the years 1997 through 2008. We set the correlation coefficient ρ_{PS} at 0.25. We assume that the cost of selling a house to be 5% of the value of the unit. This figure includes the agent's commissions, legal fees, time cost of search and the direct cost of moving the consumer's possessions. While the true costs of moving are difficult to measure, they are not negligible and involve significant expenditures of time, effort and money. Following previous literature, we set the housing physical depreciation rate at an annual 2%.

[20]While Cocco (2005) sets $1-\beta$ at 0.1, Yao and Zhang (2005) assume that $1-\beta$ equals 0.2.

Table 5: **Parameter values.**

Variable	Symbol	Value
Curvature of the utility function	γ	2
House flow services	$1-\beta$	0.4
Time preference	ρ	0.025
Risk free rate	r	0.015
House depreciation	δ	0.02
Transaction cost	ϵ	0.05
Risky asset drift	α_S	0.077
Standard deviation risky asset	σ_S	0.1655
Correlation housing price - risky asset	ρ_{PS}	0.25

5 Results

5.1 Numerical Results for the Portfolio Choice Problem

It is not possible to find properties of the portfolio choice problem in closed-form when we take into account transaction costs. Consequently, we implement an iterative procedure to find the numerical solution of the problem. A detailed description of this iterative procedure can be found in the appendix.

Figures 4 and 5 are key to show the three main implications of the model that arose from Proposition 1 and will be tested in the empirical section of this paper. First, let us focus on Figure 4. The upper panel displays the difference between the value function, $v(z_t, i)$, and the value of changing housing consumption, $(z_t - \epsilon)^{1-\gamma} M(i)/(1-\gamma)$, against the value of the wealth-to-housing ratio, z_t, using the parameter values reported on Tables 4 and 5. If this difference is positive, then the agent does not move to a bigger or smaller house (i.e., the agent is in the inaction region.) The agent only moves when this difference is zero, that is when the value function from not moving given by $v(z_t, i)$ is equal to the value from moving given by $(z_t - \epsilon)^{1-\gamma} M(i)/(1-\gamma)$.[21] As Figure 4 shows, agents only move in two situations: (i) when their total wealth is high enough relative to their current house value so that z_t reaches the upper bound $\overline{z}_i$; or (ii) when their house value is too high relative to the total wealth and z_t reaches the lower bound $\underline{z}_i$. The inaction region is

[21] This is equivalent to saying that the values of the upper bounds $\overline{z}_i$ and the lower bounds $\underline{z}_i$ are determined by the value matching conditions (18) for $i = h, l$, by which the agent is indifferent between not moving and moving. Additionally, the smooth pasting conditions in (19) assure that $v(z_t, i)$ is differentiable on the threshold that triggers the agent to move. As Figure 4 shows, this implies that $v(z_t, i)$ is less concave than $(z_t - \epsilon)^{1-\gamma} M(i)/(1-\gamma)$ at these points. However, $v(z_t, i)$ must become more concave than $(z_t - \epsilon)^{1-\gamma} M(i)/(1-\gamma)$ somewhere between $\underline{z}_i$ and $\overline{z}_i$.

limited by a lower bound $\underline{z}_i$ and an upper bound $\overline{z}_i$ in each regime i, such as $\underline{z}_i < \overline{z}_i$ for both the high regime ($i = h$ and top part of Figure 4) and the low regime ($i = l$ and bottom part of Figure 4). In Section 6.1 we will test the existence of the upper and lower bounds hypothesis and we will study its main implications.

Second, the two panels of figure 4 show the differences of the solution across regimes. The upper and lower bound are not constant but depend on the regime i. We obtain that $\underline{z}_l = 1.532$, $\overline{z}_l = 6.539$, and the ratio chosen when a new house is purchased $z_l^* = 3.188$ for the low regime. Equivalently, we find that $\underline{z}_h = 0.258$, $\overline{z}_h = 1.659$, and $z_h^* = 0.729$ for the high regime (see Table 6.) The economic magnitude of the calibrated results is sizeable: during a period of low (high) house appreciation, an average investor will decide to buy a bigger house when the wealth is approximately higher than 6.5 (1.6) times the value of her current house. On the other hand, when her total wealth is approximately less 1.5 (0.2) times the value of the house, the agent will engage in a transaction to buy a smaller house. Note that: (i) the upper and lower bounds in the high regime are below their respective upper and lower bounds in the low regime, that is, $\overline{z}_h < \overline{z}_l$ and $\underline{z}_h < \underline{z}_l$; (ii) the inaction region for the low regime, $[\underline{z}_l, \overline{z}_l]$, is larger than the inaction region for the high regime, $[\underline{z}_h, \overline{z}_h]$; (iii) the inaction regions for the two regimes overlap over a range of z_t values, $[\underline{z}_l, \overline{z}_h]$; and (iv) the optimal housing wealth on total wealth, $1/z_i^*$, for the high (low) regime is 1.370 (0.313) lower than the constant ratio of 2.796 (0.366), α_h^i, chosen by an agent who faces no transaction costs.[22]; (v) the size of upward adjustment and downward adjustment in a high regime is lower in than in a low regime, $\overline{z}_h - z_h^* < \overline{z}_l - z_l^*$ and $z_h^* - \underline{z}_h < z_l^* - \underline{z}_l$. In Section 6.2 we will empirically test these types of findings related to the effects of the predictability in housing returns on the upper and lower bounds.

In addition, in a GL framework, a housing transaction occurs only when the wealth-to-housing ratio, z_t, hits the upper or lower bounds. Figures 4 shows that our framework features a second channel: the regime switching mechanism. A transaction may also occur when the regime switches from high to low and the agent's wealth-to-housing ratio z_t is in the region $[\underline{z}_h = 0.258, \underline{z}_l = 1.532]$. Let us assume that $z_t = 0.500$. In this case, it is not optimal to sell during the high regime because his ratio z_t is not low enough (i.e., $z_t > \underline{z}_h$). However, if there is a switch to the low regime, then

[22]Transaction costs make housing more expensive, so the agent who faced those costs would hold less of his wealth in the form of housing.

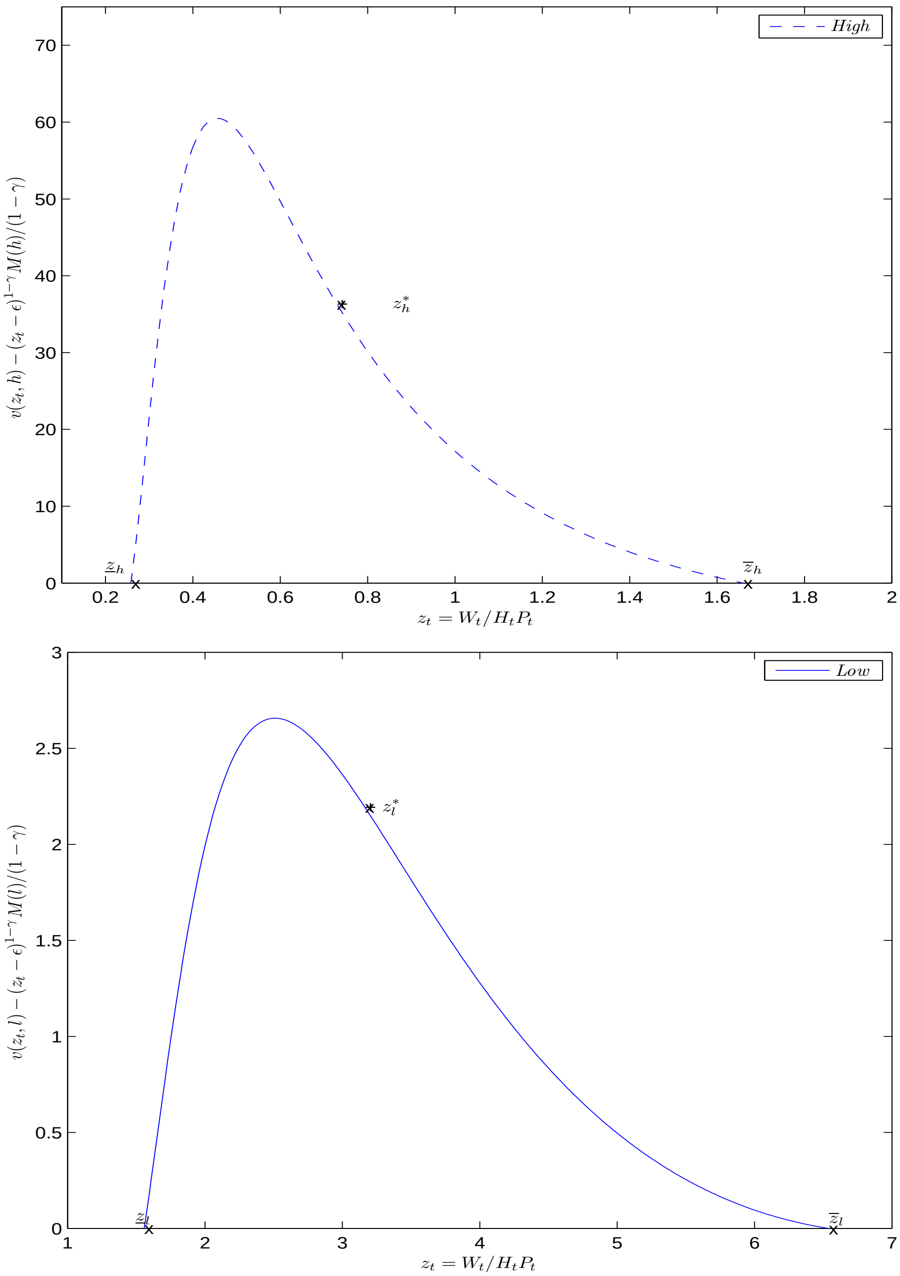

Figure 4: **Value function and value of changing the home.** The difference between the value function, $v(z_t, i)$, and the value of changing housing consumption, $(z_t - \epsilon)^{1-\gamma}M(i)/(1-\gamma)$, is plotted against z_t, where $z_t = W_t/(H_tP_t)$. The dotted line represents the high regime, while the continuous one the low regime (bottom). x (+) indicates the location of z_t at the point when a new purchase becomes optimal in high (low) regime. $\overline{z}_h$ and $\underline{z}_h$ represent the upper and lower bound in high regime. $\overline{z}_l$ and $\underline{z}_l$ represent the upper and lower bound in low regime. z_h^* (z_l^*) indicates the locations of z_t just after the purchase of a new durable in high (low) regime.

the lower bound would increase from $\underline{z}_h$ to $\underline{z}_l$, and, consequently, it would be optimal for the agent to sell reduce his housing holdings because $z_t \leqslant \underline{z}_l$. The other interesting case occurs when there is

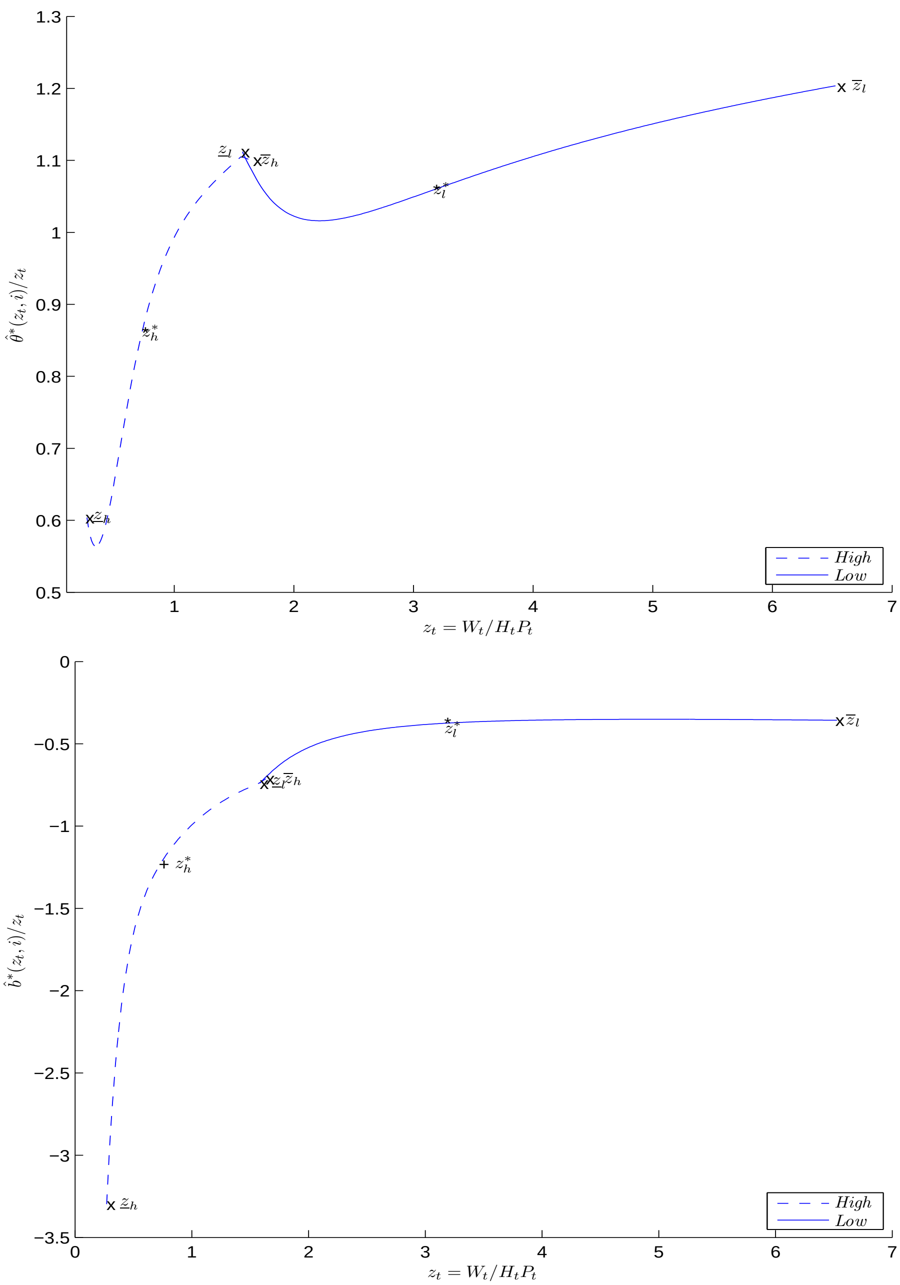

Figure 5: **Risky asset and risk-free asset.** Relative risk aversion and portfolio allocation as a function of z_t, where $W_t/(H_tP_t)$: Share of risky stock $\hat{\theta}(z_t, i)/z_t$ (top) and share of risk-free stock $\hat{b}(z_t, i)/z_t$ (bottom). The dotted line represents the high regime, while the continuous line is the low regime.

a regime switch from low to high and z_t is in the region $[\overline{z}_h = 1.659, \overline{z}_l = 6.539]$.[23]

[23]The location of the bounds depends on the transition probabilities to switch regime at next period given the current regime. Specifically, for the low regime, the estimated transition probability, λ^l, is only about 4%, while λ^h is about 28% for the high regime. As result, the location of the upper bound crucially depends on the probability of a regime switch from high to low.

Third, as one may expect, this regime-switching mechanism generates rich portfolio rules. The upper panel of Figure 5 plots the fraction of wealth invested in risky asset against wealth for the two regimes of expected growth rate of housing prices, $\hat{\theta}^*(z_t, i)/z_t$, for $i = h, l$. Each curve is drawn only for the realizations of z_t within the inaction bounds. We find that it is optimal to increase the holdings of stocks in the low regime and sharply decrease them in the high regime in order to increase the amount of housing stock. Note that the optimal portfolio rules are quite different from the no transaction costs case, where the fraction of wealth invested in each asset is constant. What is the channel that drives the portfolio choices of the agent and makes them different from the ones provided by other models? The key mechanism of the model is the coefficient of relative risk aversion, $-(z_t v_{zz}(z_t, i))/v_z(z_t, i)$, which varies with z_t and with the regime i with $i = h, l$. As in Grossman and Laroque (1990) and Damgaard, Fuglsbjerg, and Munk (2003), the lower relative risk aversion when z_t is close to the upper or lower bounds leads to higher fractions of wealth invested in the risky asset than when z_t is in the center of the inaction region. Hence, the relative risk aversion after a housing trade associated with a high regime, $-(z_h^* v_{zz}(z_h^*, h))/v_z(z_h^*, h)$, is higher than the one associated with a low regime, $-(z_l^* v_{zz}(z_l^*, l))/v_z(z_l^*, l)$. In our benchmark case, we obtain a relative risk aversion of 2.205 for the high and 2.112 for the low regime respectively (Table 6).

In general, transaction costs make housing more expensive, so the agent who faces that cost holds less of her wealth in the form of housing. In our benchmark case, due to transaction costs we observe a reduction of 51% (14%) in housing share in the high (low) regime. In a high regime the optimal housing holding is substantially higher, the inaction region is narrower and housing is quite attractive for investment purposes, but transaction costs have the dramatic effect of lowering the optimal housing wealth to total wealth ratio, $1/z_i^*$, and making the agent more risk averse after a housing trade. Differently from Grossman and Laroque (1990) and Damgaard, Fuglsbjerg, and Munk (2003), the coefficient of risk aversion depends on the current regime. In summary, the model delivers a regime contingent portfolio rule. Additionally, due to the possibility of a regime change, the portfolio rule reflects the agent's investment set in the other regime. Therefore, the agent has to determine the portfolio rule in each regime, while taking into account the portfolio rule in the other regime.

The lower panel plots the fraction of wealth invested in the risk free asset, $\hat{b}^*(z_t, i)/z_t$. We find that: (i) the agent is a net borrower in both regimes; (ii) he borrows a bigger amount in the high regime (to increase his housing holdings, which are more attractive in the high regime) than in the low regime; and (iii) his borrowing increases with his ratio z_t. In Section 6.3 we will empirically test these findings related to the portfolio choices of households.

In section 2, we provide evidence that the degree of predictability varies across the U.S. Census Macro Regions. The theoretical relevance of the housing price dynamics parameters is evident analyzing the results of the calibration. Due to the shorter time series and the most recent boom episode (1998-2006), house prices growth rates are higher in both regimes, high and low, for U.S. Census Macro Regions than U.S. at aggregate level result (Table 4). As result, inaction regions are narrower than the ones calculated in the benchmark case. In order to characterize the implications of predictability, we calculate the long run average of the total wealth-to-housing ratio (right after a housing purchase), $E(z_i^*)/E(\tau_i)$.[24] As expected, the long run average is regime dependent as well. The West region is characterized by smaller values in both regimes. The long rung average is 0.421 in the high regime and 1.531 in the low regime which are higher than the constant ratios of 0.177 and 0.855 respectively, chosen by an agent who faces no transaction costs (Table 6, Column (8)).[25] Furthermore according to the calibration exercise, we should observe cross-sectional variation in the long run average, because the degree of predictability in housing returns varies across the four U.S. Census Macro Regions. In Section 6.1 we will empirically test these implications.

It is important to recognize that while the optimizing behavior characterized above is that of a hypothetical infinitely lived agent, the data we will use later to test model's predictions are drawn from a cross-section of demographically heterogenous consumers. Therefore, to assess the descriptive fit of our model, we will include demographic characteristics and changes in demographic characteristics, for example household head age in two age bands, change in marital status and change in family size, which may absorb determinants other than dynamic variation of the type featured by our representation of a typical agent's problem.

5.2 Sensitivity Analysis

Table 6 presents a sensitivity analysis of the model. It shows the sensitivity of three key variables of the model ($\underline{z}_i$, z_i^*,$\overline{z}_i$) to four scenarios with deviations of four parameters from the benchmark

[24] $E(z_i^*)/E(\tau_i)$ is the function that describes the the long run average of the optimal wealth-to-housing ratio inside the inaction region conditional on the regime where the agent is.

[25] The constant ratio is computed as $1/\alpha_i^h$.

Table 6: **Sensitivity analysis.** Columns (1), (2) and (3) display the lower bound, the optimal return point and the upper bound, respectively. The optimal return point represents the wealth-to-housing ratio immediately after a housing purchase. Column (4) is the the optimal housing-to-wealth ratio without transaction costs and Column (5) is the corresponding ratio with transaction costs immediately after a housing purchase. Column (6) is the relative risk aversion just after housing purchase, and Column (7) is the average holding of the risky asset, estimated just after a housing purchase. Column (8) is the long run average of the optimal wealth-to-housing ratio immediately after a housing purchase. The first row in the table represents the benchmark case, described previously in this section. Four scenarios illustrate alternatives to the benchmark: (A) sensitivity to the correlation between the housing price and the stock market; (B) sensitivity to the transaction costs associated with moving; (C) sensitivity to the curvature of the utility function; and (D) sensitivity to housing price standard deviation. Finally, (E) reports the model results when we use the estimated housing prices parameters for the four U.S. Census Macro Regions that were shown in Table 4.

	Regime	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	i	$\underline{z}_i$	z_i^*	$\overline{z}_i$	α_h^i	$1/z_i^*$	$RRA(z_i^*)$	$\frac{E\left(\frac{\hat{\theta}^*(z^*,i)}{z^*}\right)}{E(\tau_i)}$	$\frac{E(z_i^*)}{E(\tau_i)}$
Benchmark	High	0.258	0.729	1.659	2.796	1.370	2.205	0.882	0.809
(U.S. aggregate: 1930-2007)	Low	1.532	3.188	6.539	0.366	0.313	2.112	1.087	3.679
(A) Correlation P_t - S_t	High	0.212	0.518	1.273	3.762	1.927	2.398	1.222	0.647
$\rho_{PS} = -0.25$	Low	1.043	2.731	4.649	0.553	0.366	2.130	1.102	2.750
(B) Transaction cost	High	0.275	0.707	2.272	2.796	1.413	2.355	0.841	0.900
$\epsilon = 0.075$	Low	1.560	3.379	7.540	0.366	0.295	2.122	1.088	4.036
(C) Curvature	High	0.480	0.868	1.782	2.015	1.151	3.298	0.572	0.937
$\gamma = 3$	Low	1.869	3.159	5.538	0.345	0.316	3.199	0.725	3.599
(D) Housing price st.dev.	High	0.175	0.521	0.880	4.872	1.918	2.325	0.754	0.570
$\sigma_P = 0.075$	Low	1.547	2.906	5.240	0.406	0.344	2.165	1.053	3.205
(E) U.S. Census macro regions (1975-2007)									
West	High	0.186	0.339	0.634	5.623	2.943	3.159	0.333	0.421
	Low	0.698	1.441	2.864	1.128	0.693	2.234	0.970	1.531
Northeast	High	0.198	0.390	0.735	4.432	2.563	2.948	0.512	0.477
	Low	0.966	2.156	4.473	0.694	0.463	2.149	1.041	2.364
South	High	0.292	0.609	1.105	3.202	1.640	2.433	0.777	0.726
	Low	0.876	1.689	3.862	0.824	0.591	2.196	1.015	1.942
Midwest	High	0.195	0.399	0.694	4.778	2.500	2.835	0.485	0.466
	Low	0.784	1.693	3.281	0.937	0.590	2.195	0.998	1.782

model. Moreover, Column (4) is the the optimal housing-to-wealth ratio without transaction costs, α_i^h, and Column (5) is the corresponding ratio with transaction costs immediately after a housing purchase, $1/z_i^*$. Column (6) is the relative risk aversion just after housing purchase, $RRA(z_i^*)$, and Column (7) is the average holding of the risky asset, estimated just after a housing purchase, $E\left(\hat{\theta}^*(z^*,i)/z_i^*\right)/E(\tau_i)$. Column (8) is the long run average of the optimal wealth-to-housing ratio immediately after a housing purchase, $E(z_i^*)/E(\tau_i)$. Scenario A illustrates how a change in the correlation between the housing price and the risky affects the optimal behavior. The optimal level z_i^* decreases in both regimes, meaning that housing consumption increases. In addition, the lower and upper bounds decrease as well. As the correlation decreases, housing becomes more effective as a hedge to diversify away the stock market risk, which leads to increase housing holding. Furthermore, holding risky asset becomes more attractive. In scenario B, we consider the sensitivity of our results to changes in the transaction costs parameter ϵ. We find that a rise in transaction costs tend to widen the inaction region and shift it to the right in both regimes. Increasing ϵ also increases the optimal level z_i^* and raises the the average ratio of optimal wealth-to-housing, $E(z_i^*)/E(\tau_i)$. In scenario C, we vary the curvature coefficient γ from 2 to 3. As expected, the average holding of risky asset falls from 0.882 to 0.572 in the high regime and from 1.087 to 0.725 in the low regime; only in the high regime it is substantially lower than the benchmark case. Scenario D shows that a decrease in house price volatility σ_P leads to a narrower inaction region and a substantial increase in housing consumption. Moreover, housing is quite attractive for investment purposes in the high regime, decreasing the average holding of risky asset from 0.882 to 0.754.

6 Empirical Results

In this section we test the main implications of the theoretical model. We use two different sources of data: (i) PSID individual level data from the surveys of 1984, 1989, 1994, and bi-annual data from 1999 to 2007; and (ii) SIPP individual level data from the surveys of 1997, 1998, 1999, 2002, 2003, and 2005. We use the household level data to test predictions about the agents' wealth-to-housing ratio and their portfolio choices. One of the implications of the model is the existence of a regime dependent inaction region and optimal return levels of the ratio. The model also predicts that asset allocations are also regime dependent. We test the differences in the allocations across the two regimes of housing prices dynamics.[26]

Figure 2 previously illustrated a hypothetical path for wealth-to-housing ratio as well as for the expected growth rate of housing prices. Several hypothesis can be identified in the graphic. Transaction costs generate an inaction zone with upper and lower action bounds. We are able

[26]We acknowledge that data on asset holdings are prone to misreporting and measurement error, hence we should take the results cautiously.

to test whether these bounds are actually different from each other by comparing the wealth-to-housing ratio of individuals who moved to a higher-valued house to the ratio of those who moved to a lower-valued house. The ratio before moving defines the upper and lower action bounds, $\overline{z}$ and $\underline{z}$, respectively. When agents decide to engage in the purchase of a new house after hitting the bound, they choose the value of the new house such that the wealth-to-housing ratio reaches its optimal level. The observed ratio after moving determines the optimal ratio z^*. The model predicts that the bounds and the optimal level of the wealth-to-housing ratio are regime dependent, therefore we can test that these variables are different in hot and cold housing markets.

6.1 Existence of the Upper and Lower Bounds Hypothesis

The first hypothesis to be tested is the existence of the optimal upper and lower bounds provided by the model in the cases in which transaction costs are taken into consideration. We test whether the lower bound is significantly different and, in particular, significantly lower than the upper bound. Although this hypothesis is rather obvious, we use it as the initial step before executing more convoluted tests about the state dependency of the boundaries and optimal levels of wealth-to-housing ratio. Formally,

Hypothesis 1. $\underline{z}(\mu) < \overline{z}(\mu)$. Therefore, $\underline{z}$ is significantly different (and lower) from $\overline{z}$ for a given expected growth in housing prices, μ.

This hypothesis states that ex-ante average value for the ratio of total wealth to housing asset holdings for families who own a house and move to a smaller house $\underline{z}$ is significantly different (and lower) from the ratio of total wealth to housing asset holdings for families who own a house and move to a bigger house $\overline{z}$. We test whether the average value of the ratios z_{it} for families who moved to a bigger house is different from the ratios for families that move to a smaller house. To test this hypothesis, we estimate the following reduced form model, which exploits the variation across households and years.

$$z_{it} = \gamma_0 + \gamma_1 \cdot m_{BIG_{it}} + \gamma_2 \cdot m_{SMALL_{it}} + \Gamma \cdot X_{it} + u_{it}, \tag{25}$$

where z_{it} is the total wealth-to-housing of household i at time t; $m_{BIG_{it}}$ is a binary variable equal to one if the family is increasing its housing holdings (e.g., moving to a bigger house); $m_{SMALL_{it}}$

is a binary variable equal to one if the family is decreasing its housing holdings (e.g., moving to a small house); X_{it} contains a set of control variables that intend to capture changes in housing due to exogenous causes, unrelated to wealth-to-housing ratio, and u_{it} is an error term. The set of controls in X_{it} includes changes in employment status, changes in family size, retirement, changes in marital status, and age controls. All variables control ex-ante changes to examine changes from the year before to the year after home purchase. The regression omits the families who do not move, treating them as a benchmark. Therefore, we check whether γ_1 is significantly positive and different than zero, which means that the wealth-to-housing ratio of the households who move to a bigger house is significantly higher than the ratio of those who do not move. We run the pooled regression in equation (25) with year fixed effects and also separate regressions for each year.

The results of testing the first hypothesis are shown in Table 7. The first column shows the results for the pooled regression wiht year fixed effects. It shows that the average value of z_{it} for families that do not move, γ_0, is 1.983 for PSID data and 1.961 for SIPP data. The ex-ante (e.g., prior to moving) average value of z_{it} for families that moved to a bigger house is 0.214 and 0.243 above the non-movers average with a 99% of significance for PSID and SIPP, respectively. Similar results are obtained when running yearly regressions. Note that γ_2 is not significantly different from γ_0 in general. Thus, the average ratio z_{it} for the non movers is not significantly different from the average ratio of the movers to smaller houses. It can be inferred that the distribution of wealth-to-housing ratio is skewed to the left and on average, agents are closer to move down according to our model. We also run a test on the coefficients γ_1 and γ_2 being equal, which is strongly rejected for most of the years. This result supports the obvious hypothesis of the existence of the inaction zone in the presence of transaction costs since the test shows that the upper and lower bounds are significantly different from each other. The results of the test also show evidence that the ratio z_{it} is time-varying, on average. This is a clear effect for non-movers and for agents who move to a bigger place in SIPP. For non-movers γ_0 is 1.886 in 1997, it goes up to 1.928 in 1999, and it decreases to 1.671 in 2005. For families that move to a bigger place $\gamma_0 + \gamma_1$ is 2.193 in 1997, and it decreases to 1.956 in 2005. Similar results hold for the PSID data.

The effect of the regional dummies is statistically significant and economically sizable. The ex-ante (e.g., prior to moving) average value of z_{it} for families living in West and South is lower than for the ones living in Northeast (the benchmark) and Midwest. The result holds for PSID and

SIPP. The estimated effects lend support to the model predictions. According to our estimates of a three-regime Markov switching model for the U.S. Census Macro Regions, we observe the following pattern for West, South and Northeast. According to the ex-post estimated probability of being in a certain regime we identify two periods: 1998 (2) - 2004 (1) is characterized by medium housing price growth, while the successive period 2004 (2) - 2006 (2) is characterized by high housing price growth (Figure 7). Instead, Midwest housing markets are characterized by a low housing price growth over the same period. Our model predicts that long run averages of z for West, South and Northeast should be lower than the one for Midwest and decreasing over the same period (Table 18). The prediction is consistent to what we observe in the coefficient estimates for the considered years. Although, if we compare the ranking suggested by the model according to the long run average with the one derived by the coefficient estimates, West occupies the right position while South and Northeast should swap it.

Our estimates of the effect of the lower boundary, γ_2, are not correctly signed and insignificant. One possible explanation is the absence of labor income in the classic GL framework we are considering. In the data, our measure of wealth includes all financial assets of the household. These include traditional savings and stocks as well as small business capital, and other owned real estate. The measure also includes liabilities outstanding to the household. Outstanding liabilities are subtracted from the total assets to give the agents net wealth position, W_t. One could consider a broader definition of wealth, accounting for current and future labor income.[27] In addition, the model should be also extended to consider the optimal behavior of a hypothetical finitely lived agent. In this set up, we expect to observe optimal downward adjustments in housing when the agent is older and his human capital is decreasing but his financial wealth is still substantial and unchanged. Our set of explanatory variables, X, can only partially control for crucial features of human capital accumulation.[28] We acknowledge that uncertain human capital accumulation definitely plays an important role in housing decisions. However, this set up would be more complicated

[27] Martin (2003) incorporates the present value of the agent's lifetime labor income assuming that human capital is a linear function of years remaining in work force, education, race and current income. However, he is implicitly assuming that individual is not facing labor income uncertainty. Bertola, Guiso, and Pistaferri (2005) analyze infrequent durable goods stock adjustment in the presence of idiosyncratic income uncertainty finding that the latter affects the likelihood but not the size of stock adjustment. They consider three categories of durable goods: vehicles, furniture and jewelry.

[28] Limiting our attention to households who sell the current house to buy new one, we observe that the average age of the household head is 49.66 years for moving small and 43.92 years for moving big in SIPP, while it is 45.74 and 40.29 respectively in PSID.

because in practice the absence of the ability to borrow against human capital leads to the main difference between the classic GL framework and the empirical results.[29] We do not aim at offering a full characterization of all realistic features of optimal housing decisions and we prefer focusing on qualitative insights into house returns predictability.

6.2 Effects of the Predictability Hypothesis and the Probability of Moving

The second set of hypotheses to be tested is related to the effects of predictability of housing returns in the action bounds and the probabilities of moving derived in the portfolio choice problem. Let us state hypotheses 2a and 2b to test whether the optimal bounds and the probabilities of moving change under the different regimes in the growth in housing prices.

Hypothesis 2a. $\overline{z}^h < \overline{z}^l$. Therefore, the value of the ratio of wealth to housing holdings that defines the upper bound in periods in which μ_t is high, $\overline{z}^h$, is significantly lower than the value of the ratio that defines the upper bound in periods in which μ_t is low, $\overline{z}^l$. Equivalently, $\underline{z}^h < \underline{z}^l$ for the lower bound.[30]

Hypothesis 2b. The probability of increasing the agent's housing holdings is higher in periods of high growth of housing prices (i.e., hot markets) than in periods of low growth and agents move to an even bigger house during periods of high growth.

To test these hypotheses, we follow two different approaches. Firstly, we develop a difference-in-differences analysis to test Hypothesis 2a. The goal is to capture the interactions between the type of moving (e.g., moving big or small) and the type of year (e.g., year cold or hot). Without loss of generality, we focus on the test for the upper bound. Secondly, we estimate a Heckman two-stage selection model to test Hypothesis 2b, where the first stage concerns the selection of homeowners who sell the current house to move to a bigger one, and the second stage the size of adjustment. We use PSID data for the difference-in-differences analysis because it covers more than 20 years from 1984 to 2005. Conversely, we use SIPP data for the second test because it includes a higher number of households who sell the current house to move to a bigger one.

[29] In the data, some agents hold negative values of financial wealth. These agents are borrowing against a positive present value of lifetime non-financial wealth.

[30] Therefore, the value of the ratio of wealth to housing asset holdings that defines the lower bound in periods in which μ_t is high, $\underline{z}^h$, is significantly different (and lower) from the value of the ratio that defines the lower bound in periods in which μ_t is low, $\underline{z}^l$.

6.2.1 Does predictability affect the action bounds? Difference-in-differences analysis

Let us consider the following reduced form model:

$$\begin{aligned} z_{it} =& \gamma_0 + \gamma_1 \cdot year_{HOT_t} + \gamma_2 \cdot m_{BIG_{it}} + \gamma_3 \cdot m_{SMALL_{it}} \\ &+ \gamma_4 \cdot m_{BIG_{it}} \times year_{HOT_t} + \gamma_5 \cdot m_{SMALL_{it}} \times year_{HOT_t} + \Gamma \cdot X_{it} + u_{it}, \end{aligned} \tag{26}$$

where z_{it} is each family's ex-ante value for the wealth-to-housing ratio. In order to capture periods of persistent high appreciation in housing prices we introduce the variable $year_{HOT_t}$. We define $year_{HOT}$ as a binary variable that is equal to one when we observe three consecutive years of positive yearly real returns on the OFHEO house price index of the U.S. state where the household lives and at least one year with a real return higher than 5%.[31] Thus, we aim to exploit the different degree of predictability across the U.S. States. $m_{BIG_{it}}$ is a binary variable equal to 1 if the household is moving to a house of a higher value than the one currently owned. Conversely $m_{SMALL_{it}}$ equals one if the household moves to a house of lower value than the currently owned. Hence, we interact $year_{HOT}$ with $m_{BIG_{it}}$ and $m_{SMALL_{it}}$. In this regression, we include the same control variables listed above.

The hypotheses testing consist on a difference-in-differences analysis. Table 8 reports its results. We choose households that did not move in cold years as the control group. The negative sign in the coefficient γ_1 confirms that the upper and lower bounds are, on average, 0.159 lower in hot markets than in cold markets. The positive sign in γ_2 shows that households that moved big (increased his housing holdings) had a 0.253 higher z_{it} than households that did not move in a cold year. The main results of this specific analysis arise from the terms in which we interact $move_{BIG}$ with $year_{HOT}$ and $move_{SMALL}$ with $year_{HOT}$. The term $move_{BIG} \times year_{HOT}$ captures the difference between the following two terms: (i) the difference between the average z_{it} for the upper boundary in cold years and in hot years; and (ii) the difference between the average z_{it} for non-movers in cold and hot years. The negative sign in $move_{BIG} \times year_{HOT}$ indicates that the decrease in z_{it} in the upper boundary in the transition from cold to hot markets is lower than the decrease in z_{it} for non-movers in the transition from cold to hot markets. The opposite result holds for $move_{SMALL} \times year_{HOT}$,

[31] We have also constructed the same variable using OFHEO house price indexes at MSA level, however there is no clear match between the MSAs defined by the OFHEO and the ones defined in PSID and SIPP.

whose coefficient's positive sign indicates that the decrease in z_{it} in the lower boundary during a transition from cold to hot markets is higher than the decrease for non-movers in cold and hot years. These empirical results confirm the implications of the model in the sense that when the upper and lower bounds move from cold to hot and from hot to cold markets do not move in parallel and the *size* of the inaction region changes over time. The empirical results are significant and the coefficients of the control variables are consistent to the other empirical analysis in this paper. Moreover, the regional analysis shows that, compared to the Northeast (benchmark region), households in the Midwest present higher wealth-to-housing ratios and households in the South and the West present lower ratios.

6.2.2 Does predictability affect the probability of moving and the size of adjustment? A Heckman two-stage selection model

To answer this question, we follow Bertola, Guiso, and Pistaferri (2005) and we implement a Heckman two-stage selection model. We will focus our empirical approach on effects of housing returns predictability on the frequency and the width of upward adjustment (i.e., increasing their amount of housing holdings). We let the upward adjustment of the current housing stock occur when a latent variable $D_i^* = X_{it}^{'}\varphi + u_{it}$, is driven to be larger than zero. The assumption that the error term u_{it} is normally distributed yields the probit model:

$$Pr(D_i^* > 0) = \phi(X_{it}^{'}\varphi), \tag{27}$$

where X_{it} is a vector of variables and $\phi(X_{it}^{'}\varphi)$ is the standard normal cumulative density function evaluated at $X_{it}^{'}\varphi$. In our framework, such a latent variable is interpreted as the distance between the wealth-to-housing ratio, z, and the optimal return point, z^*. The model predicts that adjustment is more likely to be observed, for a given z, when house prices experience high appreciation. We re-introduce the dummy variable $year_{HOT}$ to capture periods of persistent high growth in housing prices of the U.S. State where the households live. In practice, households can sell the current house located in a U.S. State and buy a bigger (smaller) house in another U.S. State. Hence, it would be also important to control for the level of house prices of the U.S. State to which the household is moving. This latter variable should affect the likelihood and the size of housing adjustment. However, this exclusion does not affect the qualitative results reported below because we are considering households selling the current house to buy a bigger one in the same U.S. Census Macro Region and the percentage of movers to a different U.S. State is substantially low among owners (Table 3).[32] Column 1 of Table 9 reports marginal effect estimates from the probit regressions for increasing the amount of housing holdings. After controlling for observable characteristics, the probability of upgrading increases with the value of the ratio of wealth to house value, z, and with our second state variable $year_{HOT}$, as predicted by our theoretical model. Both coefficients are highly statistically significant and economically important. In addition, households living in the West are more likely to upgrade and the economic effect is also substantial.

The probit regression is the first step to test Hypothesis 2b. Our model also delivers sign predictions for the size of the adjustment conditional on adjusting. It predicts that persistent higher growth in housing prices decreases the size of the adjustment. However, the disturbance of the regression equation for the size of the adjustment depends upon unobserved heterogeneity. We treat the problem adopting Heckman selectivity corrections in the regression. We use the value of z prior to adjustment as selection variable because theory predicts that it affects the likelihood of adjusting but not the size of adjustment if it occurs. Following Bertola, Guiso, and Pistaferri (2005), we use as independent variable the log of the adjustment, $\ln(\bar{z} - z^{*})$.[33] The results of the second stage of the Heckman selectivity regressions are reported in Column 2.[34] The most important effect is captured by the variable $year_{HOT}$. The effect is statistically significant and economically sizable. It implies that the distance between the upper bound $\overline{z}_i$ and the optimal adjustment point z^{*} is lower in periods of persistent high growth in house prices.

[32] In our set up, we abstract from introducing the option of selling the house at the price P_t in the household's current market and buying a bigger or smaller one at the price P_t' in the region to which the household relocates in the next move. In this set up, the indirect utility of the household depends on six state variables, $V(W_t, P_t, H_t, P_t', j, k)$, where j is the regime, high or low, characterizing house price P_t, while k is the regime, high or low, characterizing house price P_t'. A similar model without house returns predictability is analyzed by Flavin and Nakagawa (2008).

[33] In the second stage, we do not include households who sell the current house to buy a bigger one but whose wealth-to-housing ratio increases between the two purchases. We have two possible explanations. The first one is that total wealth is not following the continuous diffusion process assumed by our model but positive jumps might occur in the wealth process. The second one is that total wealth might be affected by measurement error.

[34] We implement a standard GLS procedure to calculate appropriate standard errors for the estimated coefficients (see Greene (2008)).

6.3 Portfolio Choice Hypothesis

Do consumers hold more risky stock before moving to a bigger house? Do they hold more risk-free assets before moving to a bigger house? To answer these questions, we develop the following two tests, in which we study the risky stock and risk-free securities holdings relative to wealth and their link to the decision of buying a bigger or smaller house.

We study the portfolio holdings of the agents that are on the upper bound in hypothesis 3a.

Hypothesis 3a. $\theta_{m_{BIG}}/z_{it} > \theta_{it}/z_{it}$. Therefore, the risky stock holding relative to wealth before moving to a bigger house, $\theta_{m_{BIG}}/z_{it}$, is significantly different (and higher) from the average risky stock holding relative to wealth of households who do not move, θ_{it}/z_{it}.

To test hypothesis 3a, we estimate the following reduced form model:

$$\frac{\theta_{it}}{z_{it}} = \gamma_0 + \gamma_1 \cdot m_{BIG} + \gamma_2 \cdot m_{SMALL} + \Gamma \cdot X_{it} + u_{it}. \tag{28}$$

With this reduced form model, we test empirically one of the implications of the theoretical model that was shown in Figure 5: the risky stock holding relative to wealth increases in the empirically relevant region.

The results of the test of hypothesis 3a are shown in Table 10. As before, we run the pooled regression with year fixed effects and also year by year. The first column shows the results for the pooled data. It shows that the average holdings of risky stock on wealth for non-movers is 5.9% for PSID data and 9.5% for SIPP data. The average holdings of risky stock relative to wealth for households that moved to a bigger house is 1.9% higher, that is 7.8%. For SIPP movers to a bigger house the risky holdings account for 11.7% of their total wealth. Looking at the coefficients year by year in the subsequent columns, we observe that the average holdings of risky stock for non-movers is in the range $[5.3\%, 12.9\%]$ for PSID and $[2.8\%, 9.2\%]$ for SIPP. Households that move to bigger houses have higher risky asset holdings. Uncertainty around the estimates for the lower bound does not allow us to make a statement around how the share of risky assets in the portfolio of an investor who just moved to a smaller house should be. In Table 11, we report results for the same regressions for households who have a positive risky stock holding. Approximately, two-thirds of the households are excluded from the PSID and SIPP sample. The coefficient associated with moving to a bigger house, γ_1, is still significant in PSID, but not in SIPP. However, estimating the regression only on the subsample of stock market participants yields biased estimates because changes in home equity or mortgage affect stock market participation rates, generating selection effects.

Using the subsample of homeowners who sell the current house to buy another one, we observe a dispersed distribution of changes in risky stock holding relative to wealth from the year before to year after home purchase. According to the model, we would expect a decrease in the risky stock holding because a household primarily sells stocks to finance house purchase. Then households who buy more expensive house in a period of high house appreciation should reduce more risky stock holding. Instead, we observe an increase in the risky stock holding approximately for half of the households in our subsample. Recently, Chetty and Szeidl (2010) use SIPP data to study how portfolio allocations change when households buy houses. They provide evidence that housing reduces the amount households invest in risky stocks substantially. However, their sample is different from the one considered in this paper, because they include households who were previously renting before home purchase.[35] According to Table 3, including the renters increases more than one third the sample of homeowners who move to a new house.

We can study the risk-free holdings of households following the same empirical strategy used for hypothesis 3a.

Hypothesis 3b. $b_{m_{BIG}}/z_{it} > b_{it}/z_{it}$. Therefore, the optimal holding of risk-free securities before moving to a bigger house $b_{m_{BIG}}/z_{it}$ is significantly different (and higher) from the average holding of risk-free securities of the consumers who do not move b_{it}/z_{it}.

To test hypothesis 3b, we estimate the following reduced form model:

$$\frac{b_{it}}{z_{it}} = \gamma_0 + \gamma_1 \cdot m_{BIG} + \gamma_2 \cdot m_{SMALL} + \Gamma \cdot X_{it} + u_{it}. \tag{29}$$

Table 12 shows the results of the test of hypothesis 3b. The first column shows the results for the pooled data for all the years. It shows that households who move to a bigger house hold an the average of 3.9% more of risk-free securities relative to wealth than non-movers for PSID

[35] Specifically, they set the house value to zero in the year before home purchase for those who were previously renting.

data. For the case of SIPP data, the average holding is 14.6%, while the mover to a bigger house holds 3.4% more. Looking at the coefficients over time, we observe that the average holdings of risk-free securities relative to wealth for PSID non-movers is in the range $[15.8\%, 23.8\%]$. For SIPP households, the average holdings of risk-free securities relative to wealth is in the range $[15.5\%, 21.5\%]$. The risk-free holdings for the sub-sample who moved to a bigger house range from being not significantly different from zero from 1984 to 2001 to as much as 9.2% above the average holdings of the non-movers in 2005. On the other hand, for those who moved to a smaller house, the coefficient γ_2 is slightly significant in SIPP, but not in PSID. Therefore, households that move to bigger houses have higher risk-free asset holdings right before moving up. In Table 13, we report results for the same regressions accounting for the mortgage balance on the primary residence.

7 Conclusions

A literature that analyzes the optimal portfolio choice decisions of agents in an economy with durable consumption goods and transaction costs has been developed following the model in Grossman and Laroque (1990) (GL model). Our paper provides a study of an extension of this model to make it more realistic. Specifically, we incorporate predictability in housing prices (i.e., prices of the durable consumption good are constant in the GL model) and we investigate the effects of housing returns predictability in the portfolio choice decisions.

We show that economic agents consider two state variables to make their decisions under predictability in housing returns and transaction costs. These two variables are the wealth-to-housing holdings ratio and the time-varying mean rate of housing price growth. As in the GL model, agents increase (decrease) their housing asset holdings only when their wealth-house ratio reach an optimal upper (lower) bound; consequently, they do not trade housing when their wealth-to-housing ratio is between the upper and lower bounds. One of the main contributions of our model is to show that these bounds are time-varying and decrease when housing prices are expected to rise, that is, the bounds are low in "hot" housing markets and high in "cold" markets. We also show that relative risk aversion is different in states of "hot" and "cold" housing markets, which explains the differences in optimal portfolio choices between both states.

Additionally, we use PSID and SIPP data to test the implications of our model empirically. In particular, we examine implications for portfolio rules and housing consumption in the presence of predictability in housing returns and transaction costs. The model and its empirical implications are relevant for policy makers, lenders, and asset managers because they provide explanations for the behavior of households in the presence of two important features of housing assets: predictability in housing returns and costs associated to housing transactions.

References

Attanasio, O. 2000. "Consumer Durables and Inertial Behaviour: Estimation and Aggregation (S,s) Rules for Automobile Purchases." *Review of Economic Studies* 67 (4): 667–696 (October).

Barberis, N. 2000. "Investing for the Long Run When Returns are Predictable." *Journal of Finance* 55:225–264.

Bertola, G., L. Guiso, and L. Pistaferri. 2005. "Uncertainty and Consumer Durables Adjustment." *Review of Economic Studies* 72 (4): 973–1007 (October).

Brennan, M., E. Schwartz, and R. Lagnado. 1997. "Strategic Asset Allocation." *Journal of Economic Dynamics and Control* 21:1377–1403.

Campbell, J. Y., and J. F. Cocco. 2003. "Household Risk Management and Optimal Mortgage Choice." *Quarterly Journal of Economics* 118 (4): 1449–1494 (November).

Campbell, J. Y., and L. M. Viceira. 1999. "Consumption and Portfolio Decisions When Expected Returns are Time Varying." *The Quarterly Journal of Economics* 114:433–495.

Campbell, J.Y., and J.H. Cochrane. 1999. "By Force of Habit: A Consumption-based Explanation of Aggregate Stock Market Behavior." *Journal of Political Economy* 107 (2): 205–251.

Campbell, J.Y., and R.J. Shiller. 1988. "The dividend-price ratio and expectations of future dividends and discount factors." *Review of Financial Studies*, pp. 195–228.

Campbell, S.D., M.A. Davis, J. Gallin, and R.F. Martin. 2009. "What Moves Housing Markets: A Variance Decomposition of the Rent-price Ratio." *Journal of Urban Economics* 66 (2): 90–102.

Campbell, J.Y., S. Giglio, and C. Polk. 2010. "Hard Times." *Working Paper*.

Case, K., and R. Shiller. 1989. "The Efficiency of the Market for Single Family Homes." *American Economic Review*, no. 79:125–137.

Chetty, R., and A. Szeidl. 2010. "The Effect of Housing on Portfolio Choice." Working paper, University of California, Berkeley.

Cocco, J. F. 2005. "Portfolio Choice in the Presence of Housing." *The Review of Financial Studies* 18 (2): 535–567.

Cochrane, J.H. 2008. "The Dog that Did not Bark: A Defense of Return Predictability." *Review of Financial Studies* 21 (4): 1533.

Cuoco, D., and H. Liu. 2000. "Optimal Consumption of a Divisible Durable Good." *Journal of Economic Dynamics and Control* 24 (4): 561–613.

Damgaard, A., B. Fuglsbjerg, and C. Munk. 2003. "Optimal Consumption and Investment Strategies with a Perishable and an Indivisible Durable Consumption Good." *Journal of Economic Dynamics and Control* 28 (2): 209–253.

Eberly, J. 1994. "Adjustment of Consumers' Durable Stocks: Evidence from Automobile Purchases." *Journal of Political Economy* 102 (3): 403–436 (June).

Favilukis, J., S. Ludvigson, and S. Van Nieuwerburgh. 2010. "Macroeconomic Implications of Housing Wealth, Housing Finance, and Limited Risk-Sharing in General Equilibrium." Working paper, NYU.

Fillat, J. L. 2009. "Housing as a Measure for Long-run Risk in Asset Pricing." *University of Chicago Manuscript*.

Flavin, M., and S. Nakagawa. 2008. "A Model of Housing in the Presence of Adjustment Costs: A Structural Interpretation of Habit Persistence." *American Economic Review* 98:474–495.

Flavin, M., and T. Yamashita. 2002. "Owner-Occupied Housing and the Composition of the Household Portfolio." *American Economic Review*, no. 92:345–362.

Greene, W. H. 2008. *Econometric Analysis*. 6th. Prentice Hall.

Grossman, S. J., and G. Laroque. 1990. "Asset Pricing and Optimal Portfolio Choice in the Presence of Illiquid Durable Consumption Goods." *Econometrica* 58 (1): 22–51 (January).

Hamilton, J. D. 1989. "A New Approach to the Economic Analysis of Nonstationary Time Series and the Business Cycle." *Econometrica* 57:357–384.

Kim, T. S., and E. Omberg. 1996. "Dynamic Nonmyopic Portfolio Behavior." *Review of Financial Studies* 9:141–161.

Kocherlakota, N. R. 1996. "The Equity Premium: It's Still a Puzzle." *Journal of Economic Literature* 34:42–71.

Landvoigt, T., M. Piazzesi, and M. Schneider. 2010. "Housing Market(s) in San Diego." Working paper, University of Stanford.

Lipster, R. S., and A. N. Shiryayev. 2001. *Statistics of Random Processes.* Springer-Verlag, New York.

Lynch, A. W., and P. Balduzzi. 2000. "Predictability and Transaction Costs: The Impact on Rebalancing Rules and Behavior." *The Journal of Finance* 55 (5): 2285–2309.

Martin, R. F. 2003. "Consumption, Durable Goods, and Transaction Costs." Working paper, Board of Governors of the Federal Reserve System.

Menzly, L., T. Santos, and P. Veronesi. 2004. "Understanding Predictability." *Journal of Political Economy* 112, no. 1.

Merton, R.C. 1969. "Lifetime Portfolio Selection Under Uncertainty: The Continuous-time Case." *The Review of Economics and Statistics*, pp. 247–257.

Morris, A. D., A. Lehnert, and R. F. Martin. 2008. "The Rent-Price Ratio for the Aggregate Stock of Owner-Occupied Housing." *Review of Income and Wealth* 39 (3): 350–359.

Pastor, L., and P. Veronesi. 2003. "Stock Valuation and Learning about Profitability." *Journal of Finance* 58:1749–1789.

Shiller, R. J. 2005, February. *Irrational Exuberance.* 2nd. Princeton University Press.

Stokey, N. L. 2009a. *The Economics of Inaction, Stochastic Control Models with Fixed Costs.* Princeton University Press.

———. 2009b. "Moving Costs, Nondurable Consumption and Portfolio Choice." *Journal of Economic Theory* 144:2419–2439.

Van Hemert, O. 2008. "Life-cycle Housing and Portfolio Choice with Bond Markets." Working paper, New York University, Stern Business School.

Yao, R., and H. H. Zhang. 2005. "Optimal Consumption and Portfolio Choices with Risky Housing and Borrowing Constraints." *The Review of Financial Studies* 18 (1): 197–239.

Appendices

A Predictability Results

In this section we present some robustness results for the predictability in house prices. In particular we will focus on the two data sets used in the main body of the paper. The first one is from Campbell et al. (2009) and uses annualized quarterly data from 1978 to 2001 on housing prices from Office of Federal Housing Enterprise Oversight (OFHEO) and rents from the Bureau of Labor Statistics (BLS). The data are available at http://morris.marginalq.com/whatmoves.html. The second source for price-rent series is constructed with residential investment values in the Flow of Funds and rents from National Income and Product accounts. Both sets produce similar results for the sample used in the paper. We present in this appendix results for the entire sample, which includes the last 6 years, and we also present detailed results at the MSA level (only for the first data set, for which we have MSA level data available). Results are robust to the data set used, to the regional level considered, but not to the sample size. Including the last results in a sign change. As we explain in section 2, that is due to the non-stationarity of rents-price ratio during the recent episode of housing prices bubble. When current price growth is explained by future price growth, predictability power of rent-price ratio disappears.

Table A shows the results of the same predictability regressions in table 1 with Flow of Funds and NIPA data.

In table A we use the entire sample available for both data sets. As mentioned above, there is a substantial change in the results when considering the last years of the housing bubble.

We also provide results at the MSA level (see table table 16). In general each region shows results that are consistent with the aggregate results, except some exceptions like Denver or Miami.

B Derivation of the Model

B.1 Model Without Transaction Costs ($\epsilon = 0$)

The value function is defined by

$$\bar{V}(W_0, P_0, i) = \sup_{C_t, \Theta_t, H_t} E\left[\int_0^\infty e^{-\rho t} u(C_t, H_t) dt\right], \quad i = h, l. \tag{30}$$

The associated system Hamilton-Jacobi-Bellman equations is the following:

$$\rho \bar{V}(\cdot, l) = \sup_{C_t, \Theta_t, H_t} \left\{ U(C_t, H_t) + \mathcal{D}\bar{V}(\cdot, l) + \lambda^l (\bar{V}(\cdot, h) - \bar{V}(\cdot, l)) \right\}, \tag{31}$$

$$\rho \bar{V}(\cdot, h) = \sup_{C_t, \Theta_t, H_t} \left\{ U(C_t, H_t) + \mathcal{D}\bar{V}(\cdot, h) + \lambda^h (\bar{V}(\cdot, l) - \bar{V}(\cdot, h)) \right\}, \tag{32}$$

where

$$\begin{aligned}
\mathcal{D}\bar{V}(\cdot, i) &= [r(W_t - H_t P_t) + \Theta_t(\alpha_S - r) + (\mu^i - \delta) H_t P_t - C_t] \bar{V}_W(\cdot, i) \\
&\quad + \mu_i P_t \bar{V}_P(\cdot, i) + \frac{1}{2}(\Theta_t^2 \sigma_S^2 + 2 H_t P_t \Theta_t \rho_{PS} \sigma_S \sigma_P + H_t^2 P_t^2 \sigma_P^2) \bar{V}_{WW}(\cdot, i) \\
&\quad + \frac{1}{2} P_t^2 \sigma_P^2 \bar{V}_{PP}(\cdot, i) + (\Theta_t P_t \rho_{PS} \sigma_S \sigma_P + H_t P_t^2 \sigma_P^2) \bar{V}_{WP}(\cdot, i), \quad i = h, l.
\end{aligned} \tag{33}$$

We can use the homogeneity properties of the value function to reduce the problem with four state variables $(W_t, P_t n, H_t n, i)$ to one with two state variables, $z_t = W_t/(P_t H_t)$ and i, since

$$\bar{V}(W_t, P_t, i) = P_t^{\beta(1-\gamma)} \bar{V}_i\left(\frac{W_t}{P_t}, 1, i\right) = P_t^{\beta(1-\gamma)} \bar{v}(x_t, i), \quad i = h, l. \tag{34}$$

Let introduce the scaled controls $\bar{c}_t = C_t/P_t$ and $\bar{\theta}_{i,t} = \Theta_t/P_t$. Substituting and simplifying we obtain

$$\bar{\rho}\bar{v}(x_t, l) = \sup_{\bar{c}_t, \bar{\theta}_t, H_t} \left\{ U(\bar{c}_t, H_t) + \mathcal{D}\bar{v}(x_t, l) + \lambda^l (\bar{v}(x_t, h) - \bar{v}(x_t, l)) \right\}, \tag{35}$$

$$\bar{\rho}\bar{v}(x_t, h) = \sup_{\bar{c}_t, \bar{\theta}_t, H_t} \left\{ U(\bar{c}_t, H_t) + \mathcal{D}\bar{v}(x_t, h) + \lambda^h (\bar{v}(x_t, l) - \bar{v}(x_t, h)) \right\}, \tag{36}$$

where

$$\mathcal{D}\bar{v}(x_t,i) =((x_t-H_t)(r-\mu_i+\sigma_P^2(1+\beta(\gamma-1)))+\bar{\theta}_t(\alpha_S-r-(1+\beta(\gamma-1))\rho_{PS}\sigma_S\sigma_P)-\bar{c}_t)\bar{v}_x(x_t,i)$$
$$+\frac{1}{2}((x_t-H_t)^2\sigma_P^2-2(x_t-H_t)\bar{\theta}_t\rho_{PS}\sigma_P\sigma_S+\bar{\theta}_t^2\sigma_S^2)\bar{v}_{xx}(x_t,i), \quad i=h,l. \tag{37}$$

Let

$$\bar{\rho}=0.5(-2\rho+\beta(-1+\gamma)(-2\mu_i+(1+\beta(\gamma-1))\sigma_P^2), \tag{38}$$

We derive explicit expressions for both the value function and the optimal policies. We first guess that the optimal controls are given by

$$\bar{c}^*(x_t,i)=\alpha_c^i x_t, \quad H^*(x_t,i)=\alpha_h^i x_t/P_t, \quad \bar{\theta}^*(x_t,i)=\alpha_\theta^i x_t \tag{39}$$

and the value function for the no transaction costs problem is given by

$$\bar{v}(x_t,i)=\alpha_v^i\frac{x_t^{1-\gamma}}{1-\gamma}, \tag{40}$$

where $i=h,l$. Then, we verify that the value function and the candidate control policies are the optimal policies for the no transaction costs case.

B.2 Model With Transaction Costs ($\epsilon>0$)

The value function is defined by

$$V(W_0,P_0,H_0,i)=\sup_{C_t,\Theta_t,H_\tau,\tau} E\left[\int_0^\tau e^{-\rho t}u(C_t,H_t)dt+e^{-\rho\tau}V(W_\tau,P_\tau,H_\tau,i)\right], \quad i=h,l. \tag{41}$$

We first solve the problem in the inaction region and then we try to characterize the upper and lower bounds of the inaction region and the optimal return point between them. The associated system Hamilton-Jacobi-Bellman equations is the following:[36]

$$\rho V(\cdot, l) = \sup_{C_t, \Theta_t} \left\{ U(C_t, H_t) + \mathcal{D}V(\cdot, l) + \lambda^l (V(\cdot, h) - V(\cdot, l)) \right\}, \tag{42}$$

$$\rho V(\cdot, h) = \sup_{C_t, \Theta_t} \left\{ U(C_t, H_t) + \mathcal{D}V(\cdot, h) + \lambda^h (V(\cdot, l) - V(\cdot, h)) \right\}, \tag{43}$$

where

$$\begin{aligned} \mathcal{D}V(\cdot, i) &= [r(W_t - H_t P_t) + \Theta_t(\alpha_S - r) + (\mu^i - \delta) H_t P_t - C_t] V_W(\cdot, i) \\ &\quad + \mu_i P_t V_P(\cdot, i) - \delta H_t V_H(\cdot, i) + \frac{1}{2}(\Theta_t^2 \sigma_S^2 + 2 H_t P_t \Theta_t \rho_{PS} \sigma_S \sigma_P + H_t^2 P_t^2 \sigma_P^2) V_{WW}(\cdot, i) \\ &\quad + \frac{1}{2} P_t^2 \sigma_P^2 V_{PP}(\cdot, i) + (\Theta_t P_t \rho_{PS} \sigma_S \sigma_P + H_t P_t^2 \sigma_P^2) V_{WP}(\cdot, i), \quad i = h, l. \end{aligned} \tag{44}$$

The component $\lambda^i (V(\cdot, j) - V(\cdot, i))$ reflects the impact of the housing price drift switch on the value functions. This term is the product of the instantaneous probability of a regime shift and the change in value function occurring after a regime switch. We can use the homogeneity properties of the value function to reduce the problem with four state variables (W_t, P_t, H_t, i) to one with two state variables, $z_t = W_t/(P_t H_t)$ and i since

$$V(W_t, P_t, H_t, i) = H_t^{1-\gamma} P_t^{\beta(1-\gamma)} V\left(\frac{W_t}{(P_t H_t)}, 1, 1, i \right) = H_t^{1-\gamma} P_t^{\beta(1-\gamma)} v(z_t, i), \quad i = h, l. \tag{45}$$

Let introduce the scaled controls $\hat{c}_t = C_t/(P_t H_t)$ and $\hat{\theta}_t = \Theta_t/(P_t H_t)$. Substituting and simplifying, we obtain

$$\widetilde{\rho} v(z_t, l) = \sup_{\hat{c}_t, \hat{\theta}_t} \left\{ u(\hat{c}_t) + \mathcal{D}v(z_t, l) + \lambda^l (v(z_t, h) - v(z_t, l)) \right\}, \tag{46}$$

$$\widetilde{\rho} v(z_t, h) = \sup_{\hat{c}_t, \hat{\theta}_t} \left\{ u(\hat{c}_t) + \mathcal{D}v(z_t, h) + \lambda^h (v(z_t, l) - v(z_t, h)) \right\}, \tag{47}$$

where

$$u(\hat{c}_t) = \frac{\hat{c}_t^{\beta(1-\gamma)}}{1-\gamma}, \tag{48}$$

[36]Thereafter, the notation $V(\cdot, i)$ refers to $V(W_t, P_t, H_t, i)$.

$$
\begin{aligned}
\mathcal{D}v(z_t,i) =&((z_t-1)(r+\delta-\mu^i+\sigma_P^2(1+\beta(\gamma-1))) \\
&+\hat{\theta}_t(\alpha_S-r-(1+\beta(\gamma-1))\rho_{PS}\sigma_S\sigma_P)-\hat{c}_t)v_z(z_t,i) \\
&+\frac{1}{2}((z_t-1)^2\sigma_P^2-2(z_t-1)\hat{\theta}_t\rho_{PS}\sigma_P\sigma_S+\hat{\theta}_t^2\sigma_S^2)v_{zz}(z_t,i), \quad i=h,l. \qquad (49)
\end{aligned}
$$

Let

$$
\widetilde{\rho} = 0.5(-2\rho-2(\gamma-1)(\mu^i-\delta+\beta(\gamma-1)(1+\beta(\gamma-1))\sigma_P^2). \qquad (50)
$$

The first order conditions are

$$
\hat{c}^*(z_t,i) = \left(\frac{v_z(z_t,i)}{\beta}\right)^{1/(\beta(1-\gamma)-1)}, \qquad (51)
$$

$$
\hat{\theta}^*(z_t,i) = -(\alpha_S-r)\frac{v_z(z_t,i)}{\sigma_S^2 v_{zz}(z_t,i)}-(1-\beta(1-\gamma))\rho_{PS}\sigma_P\frac{v_z(z_t,i)}{\sigma_S^2 v_{zz}(z_t,i)}+(z_t-1)\frac{\rho_{PS}\sigma_P}{\sigma_S}, \qquad (52)
$$

for $i=h,l$.

We need to identify the properties of the inaction region. It follows from (41) that

$$
\begin{aligned}
&V(W_0,P_0,H_0,i) = \\
&\sup_{C_t,\Theta_t,H_\tau,\tau} E\left[\int_0^\tau e^{-\rho\tau}u(C_t,H_0e^{-\delta t})dt+e^{-\rho\tau}V(W_{\tau-}-\epsilon P_\tau H_{\tau-},P_\tau,H_\tau,i)\right], \quad i=h,l. \qquad (53)
\end{aligned}
$$

We get

$$
\begin{aligned}
&P_0^{\beta(1-\gamma)}H_0^{1-\gamma}v(z_0,i) = \\
&\sup_{\hat{c}_t,\hat{\theta}_t,H_\tau,\tau} E\left[\int_0^\tau e^{-\rho\tau}\frac{P_\tau^{\beta(1-\gamma)}(\hat{c}_tH_0e^{-\delta t})^{1-\gamma}}{1-\gamma}dt+e^{-\rho\tau}P_\tau^{\beta(1-\gamma)}H_\tau^{1-\gamma}v(z_\tau,i)\right], \quad i=h,l. \qquad (54)
\end{aligned}
$$

Following Damgaard, Fuglsbjerg, and Munk (2003), let

$$
\begin{aligned}
e^{-\rho\tau}P_\tau^{\beta(1-\gamma)}H_\tau^{1-\gamma}v(z_\tau,i) &= e^{-\rho\tau}P_\tau^{\beta(1-\gamma)}H_{\tau-}^{1-\gamma}\left(\frac{H_{\tau-}}{H_\tau}\right)^{\gamma-1}v\left(\frac{W_{\tau-}-\epsilon P_\tau H_{\tau-}}{P_\tau H_\tau},i\right) \\
&= e^{-\rho\tau}P_\tau^{\beta(1-\gamma)}H_{\tau-}^{1-\gamma}\left(\frac{H_{\tau-}}{H_\tau}\right)^{\gamma-1}v\left(\frac{H_{\tau-}}{H_\tau}\left(\frac{W_{\tau-}}{P_\tau H_{\tau-}}-\epsilon\right),i\right)
\end{aligned}
$$

and we can derive

$$e^{-\rho\tau}P_\tau^{\beta(1-\gamma)}(H_0e^{-\delta\tau})^{1-\gamma}\left(z_{\tau-}-\epsilon\right)^{1-\gamma}\left(\frac{H_{\tau-}}{H_\tau}\left(z_{\tau-}-\epsilon\right)\right)^{\gamma-1}v\left(\frac{H_{\tau-}}{H_\tau}\left(z_{\tau-}-\epsilon\right),i\right),\quad i=h,l.$$

Let re-express our Bellman equation

$$P^{\beta(1-\gamma)}v(z_0,i)=\sup_{\bar{c}_t,\bar{\theta}_t,\tau}E\left[\int_0^\tau e^{-\hat{\rho}\tau}\frac{P_\tau^{\beta(1-\gamma)}\bar{c}_t^{1-\gamma}}{1-\gamma}dt+e^{-\hat{\rho}\tau}P_\tau^{\beta(1-\gamma)}M_i\frac{\left(z_{\tau-}-\epsilon\right)^{1-\gamma}}{1-\gamma}\right],\tag{55}$$

where

$$\begin{aligned}M(i)&=\sup_{H_\tau\leq He^{-\delta\tau}(z_{\tau-}-\epsilon)/\epsilon}(1-\gamma)\left(\frac{H_{\tau-}}{H_\tau}\left(z_{\tau-}-\epsilon\right)\right)^{\gamma-1}v\left(\frac{H_{\tau-}}{H_\tau}\left(z_{\tau-}-\epsilon\right),i\right)\\&=(1-\gamma)\sup_{z\geq\epsilon}z^{\gamma-1}v(z,i),\quad i=h,l,\end{aligned}\tag{56}$$

and $\hat{\rho}=\rho+\delta(1-\gamma)$.

B.3 Algorithm for the Numerical Resolution

We modify the Grossman Laroque algorithm to solve our problem. The algorithm is a stepwise numerical procedure to find the optimal values $(M(h),\underline{z}_h,\overline{z}_h,z_h^*)$ and $(M(l),\underline{z}_l,\overline{z}_l,z_l^*)$:

1. Guess $M(h)=M(h)_0$ and $M(l)=M(l)_0$.

2. Solve the free bound problem with $M(h)=M(h)_0$ and $M(l)=M(l)_0$ as follows:

   (i) Guess $\underline{z}_h=\underline{z}_{h,0}$ and $\underline{z}_l=\underline{z}_{l,0}$;

   (ii) Solve the ODEs Eq.(13) using as initial conditions the four of equations defined by Eq.(18) until the value matching conditions are satisfied. We adopt a finite difference scheme to solve the system of ODEs;

   (iii) If the smooth pasting conditions specified by Eq.(19) are satisfied, then the candidate value functions $v_{M(h)_0}(z,h)$ and $v_{M(l)_0}(z,l)$ are found, otherwise repat steps (i) and (ii).

3. Compute the implied $M^*(h)_0=(1-\gamma)\sup_z z^{\gamma-1}v(z,h)=(1-\gamma)z_h^{*(\gamma-1)}v(z_h^*,h)$ and $M^*(l)_0=$

$(1-\gamma)\sup_z z^{\gamma-1}v(z,l) = (1-\gamma)z_l^{*(\gamma-1)}v(z_l^*,l)$ using Eq.(16). If $M^*(h)_0 = M(h)_0$ and $M^*(l)_0 = M(l)_0$, the problem is solved, otherwise go to step 1.

As a starting point, we use the solution to the problem of no transaction costs, $\epsilon = 0$. That solution consists of the optimal ratio of housing to wealth α_h^i, the optimal ratio of risky assets α_θ^i and the optimal ratio of numeraire consumption α_c^i, for the two possible realizations of the regime, $i = h, l$. The first set of iterations uses a fixed portfolio policy. For initial values of $M(i)$ and z_i^*, we use $M(i) = \alpha_v^i$ and $z_i^* = 1/\alpha_h^i$, where $i = h, l$. However, there is little to guide the initial estimations (i.e., guesses) about $\underline{z}_i$ and $\overline{z}_i$, except to require $\underline{z}_i < z_i^*$ and $\overline{z}_i > z_i^*$. After the iterative procedure has converged, the solution is used to construct an approximation to the policy function $\hat{\theta}^*(z_t, i)$. Then, we adopt a value iteration and a policy iteration procedure to obtain $(\underline{z}_i, \overline{z}_i, M(i), z_i^*)$.

C Robustness Checks

In this appendix we make different robustness checks of the results that we obtain in our study. We focus on analyze how robust our results are with respect to two important issues. First, we check the choice of two regimes (i.e., high versus low housing prices growth) instead of three regimes (i.e., high versus medium versus low housing prices growth). Second, we develop a regional analysis to study how robust our results are for the different main regions.

Two main conclusions arise from this robustness study. First, the contributions of the paper can be exposed using a parsimonious two-regime model. Hence, the use of a model with three (or a higher number) of regimes, would have not conceptually improved the results. Second, the regional analysis not only confirms the regional robustness of our results, but also provides some interesting empirical facts. We use the results reported on tables 17 and 18, and figures 6 and 7 to reach these conclusions.

Table 17 shows the parameter values that we obtain if we extend the 2-regime switching model developed in the paper to a 3-regime switching model (i.e., high, medium, and low housing price growth regimes). This table is equivalent to Table 4 for a 2-regime model shown in the paper. We observe that the growth in housing prices parameters (μ^h, μ^m, and μ^l) that we obtain for a 3-regime model only expand the spectrum of values that we obtained in Table 4 for μ^h and μ^l. We find that the conditional probability of switching straight from a high to a low regime, $\lambda^{h\to l}$, is high (e.g., 19.17% in the West and 30.17% for the Northeast) while the conditional probability of switching from a high to a medium regime, $\lambda^{h\rightarrow m}$, is zero in all regions, except for South. Oppositely, the conditional probability of switching straight from a low to a high regime, $\lambda^{l\rightarrow h}$, is zero or very low for all regions while the conditional probability of switching from a low to a medium regime, $\lambda^{l\rightarrow m}$, is between 6% and 10% for all the regions. Additionally, the conditional probability of switching from the medium regime to either a high or a low regime is quite high for all regions (i.e., it is between 6.42% and 10.56% for all cases except for moving to the high regime in the Midwest and moving to the low regime in the Northeast in which these calibrated probabilities are close to zero).

Figure 6 shows the contemporaneous estimated probability of being in a high regime for the four U.S. Census Macro Regions over the period 1975-2007. This figure is equivalent to Figure 3, which showed U.S. aggregate housing markets for the period 1930-2007. Three main issues arise from this graphs: (i) the real estate boom in the late 1970s is captured in all regions; (ii) only the Northeast region showed high probabilities of being in a boom (i.e., a high regime) in the mid-1980s; and (iii) all regions but the Midwest present high probabilities of being in a boom in the 2000s.

Figure 7 extends Figure 6 for a 3-regime model. It shows the contemporaneous estimated probability of being in a high regime or in a medium regime for the four U.S. Macro Census Macro Regions over the period 1975-2007. We see real estate booms are captured by high probabilities of being in high or in medium regimes. We observe similar patterns for the West and Northeast regions. The South is similar too, except for the fact that it was not affected by any real estate boom in the 1980s. Finally, the Midwest presents a different pattern than the other three regions: except for the 1970s real estate boom, it seems to always be between low and medium regimes of housing price growth.

Table 18 reports the numerical results of the model for the regional analysis under a 3-regime model. This tables extends to a 3-regime setting the results shown in Part (E) of Table 6. We observe that the parameters that define the lower and upper bounds ($\underline{z}_i$, and $\overline{z}_i$) as well as the optimal return point (z_i^*) that we obtain for a 3-regime model expand the spectrum of values that we obtained in Table 6 the 2-regime model (high versus low). We also find that the West and the Northeast present the low values for the upper and lower bounds as well as the optimal return points. Oppositely, the Midwest and the South present high values for these parameters.

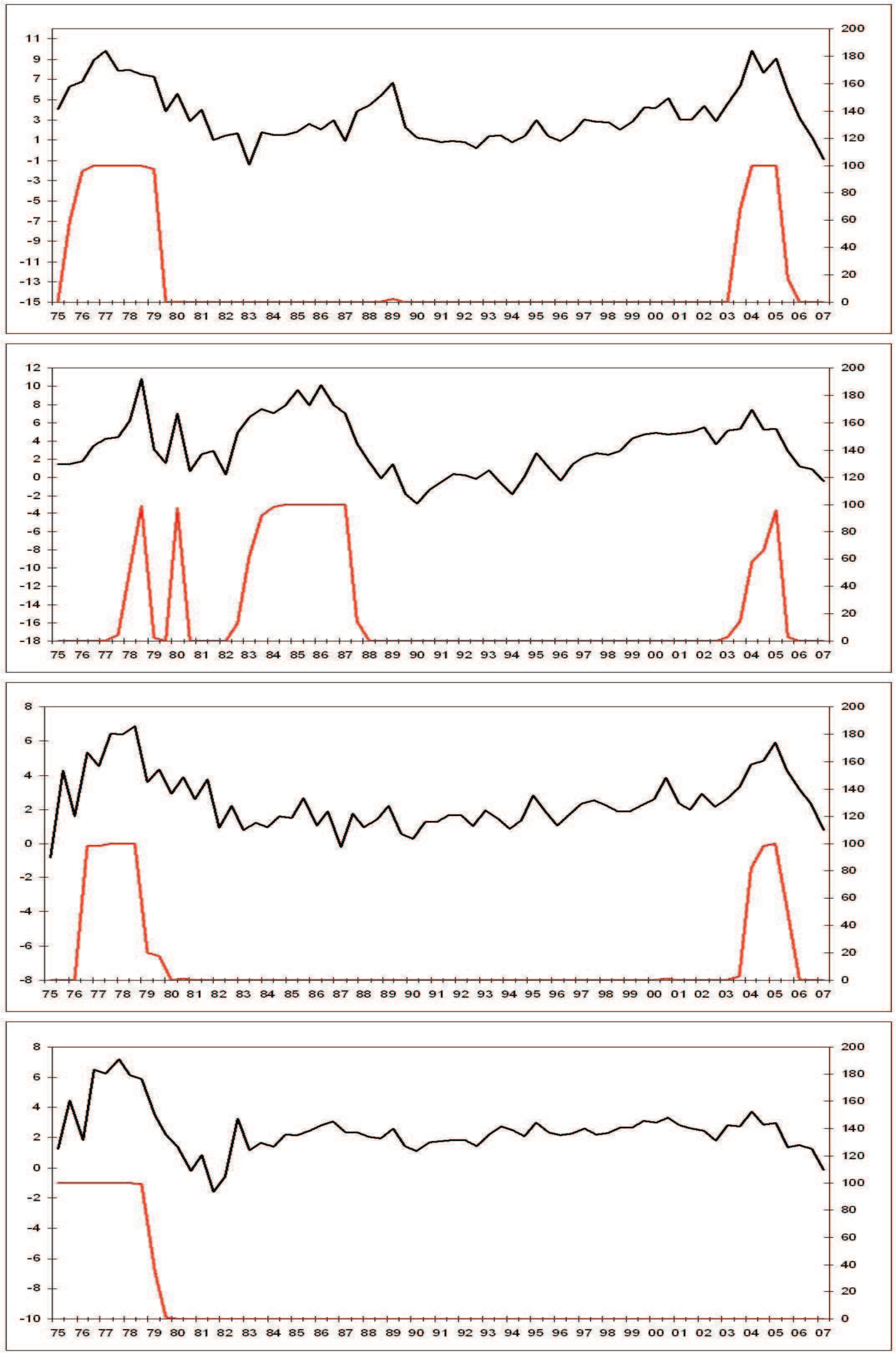

Figure 6: **Probability of being in a high regime and house price returns. Regional analysis.** Probabilities of being in a high regime in red lines and values according to the right hand side vertical axis. Housing returns in black lines and values according to the left hand side vertical axis. Graphs shown in the following order: West (Top), Northeast, South and Midwest (Bottom).

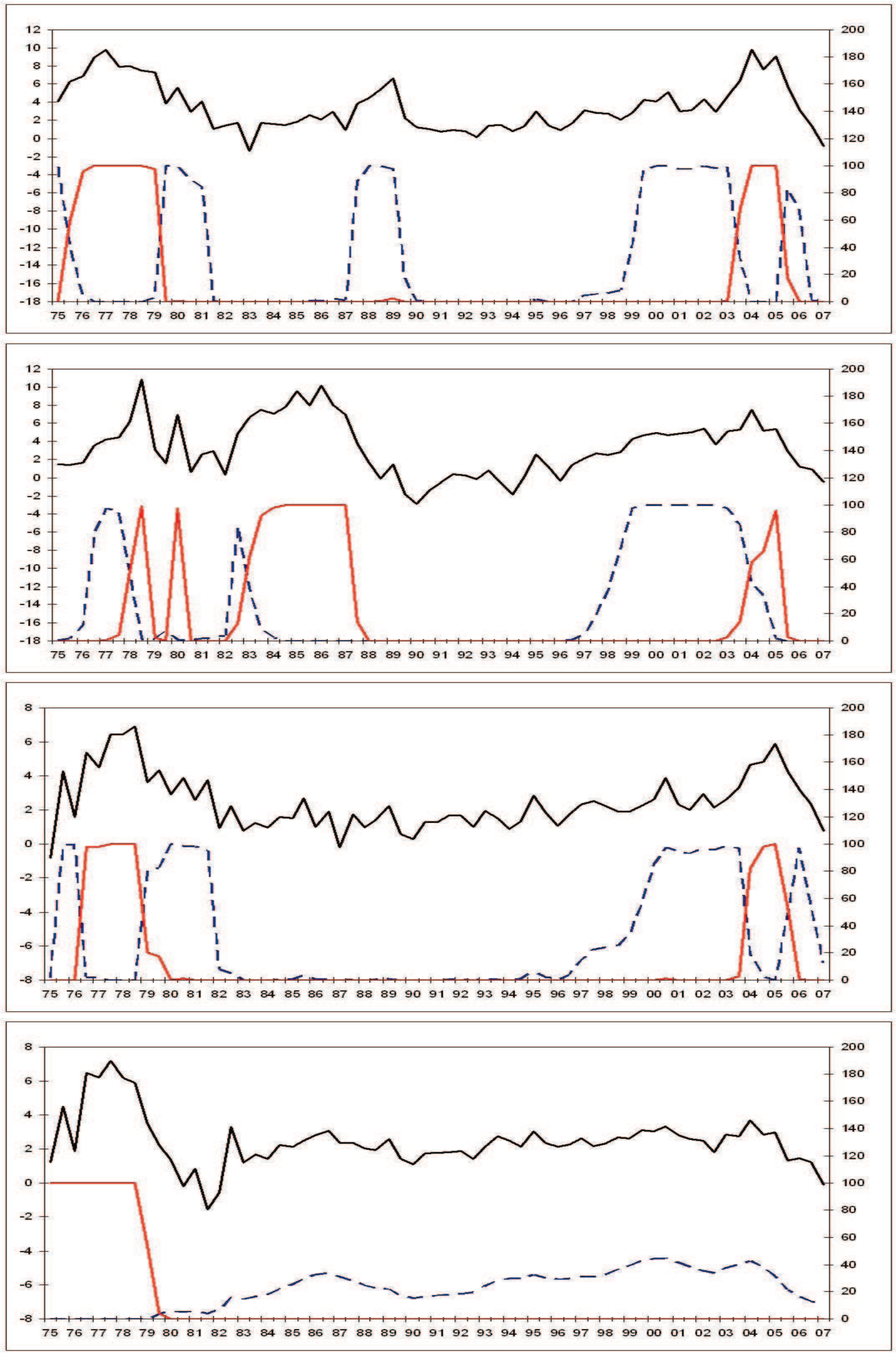

Figure 7: **Probability of being in a high and medium regimes and house price returns. Regional analysis.** Probabilities of being in a high regime in red lines. Probabilities of being in a medium regime in blue dotted lines. Values of probabilities according to the right hand side vertical axis. Housing returns in black lines and values according to the left hand side vertical axis. Graphs shown in the following order: West (Top), NorthEast, South and Midwest (Bottom).

Table 7: **Test of Hypothesis 1**. Coefficients are estimated by using a standard OLS model and ex-ante (e.g., before moving) values of z_{it} as endogenous variable. Standard errors are reported in parentheses. *** denotes significance at the 1% level, ** at the 5% level, and * at the 10% level. $m_{BIG_{it}}$ ($m_{SMALL_{it}}$) is a dummy variable equal to one if the family is increasing (decreasing) its housing holdings, i.e., moving to a bigger (smaller) house. The pooled regressions include year dummies.

(a) PSID data

	All	1984	1989	1994	1999	2001	2003	2005
constant (γ_0)	1.983***	1.959***	2.059***	1.985***	2.017***	1.955***	1.816***	1.763***
	(0.043)	(0.091)	(0.089)	(0.096)	(0.085)	(0.080)	(0.074)	(0.073)
Move big (γ_1)	0.214***	0.334*	0.398*	0.395*	0.317*	0.118	0.159	0.082
	(0.046)	(0.151)	(0.160)	(0.180)	(0.127)	(0.111)	(0.094)	(0.096)
Move small (γ_2)	0.004	-0.162	0.186	-0.038	-0.010	-0.148	0.172	0.034
	(0.074)	(0.273)	(0.295)	(0.297)	(0.195)	(0.155)	(0.169)	(0.148)
Δ Family	0.017	-0.010	0.023	0.076	-0.006	0.022	0.013	0.034
	(0.017)	(0.053)	(0.057)	(0.071)	(0.042)	(0.038)	(0.037)	(0.037)
Δ Retired	-0.074	-0.104	-0.085	-0.227	-0.091	0.007	-0.006	-0.095
	(0.046)	(0.134)	(0.134)	(0.160)	(0.119)	(0.106)	(0.116)	(0.107)
Δ Married	0.054	0.048	-0.395	-0.322	0.466*	-0.293	0.408*	-0.036
	(0.089)	(0.288)	(0.333)	(0.346)	(0.215)	(0.209)	(0.189)	(0.192)
Δ Employment	-0.179***	-0.148	-0.268**	-0.071	-0.227*	-0.171*	-0.250**	-0.078
	(0.032)	(0.084)	(0.085)	(0.092)	(0.095)	(0.081)	(0.082)	(0.081)
$Age_{y<30}$	-1.351***	-1.142***	-1.412***	-1.420***	-1.549***	-1.396***	-1.358***	-1.246***
	(0.040)	(0.100)	(0.111)	(0.130)	(0.118)	(0.107)	(0.099)	(0.093)
$Age_{30<y<50}$	-0.924***	-0.713***	-0.972***	-0.982***	-1.041***	-0.974***	-0.873***	-0.888***
	(0.024)	(0.071)	(0.068)	(0.074)	(0.064)	(0.059)	(0.055)	(0.056)
Midwest	0.166***	-0.031	0.261**	0.243*	0.266**	0.171	0.095	0.150
	(0.035)	(0.099)	(0.099)	(0.105)	(0.095)	(0.089)	(0.084)	(0.085)
South	-0.024	-0.157	-0.006	0.180	-0.046	-0.025	-0.040	-0.057
	(0.033)	(0.092)	(0.090)	(0.099)	(0.089)	(0.084)	(0.079)	(0.079)
West	0.041	0.036	0.174	0.197	-0.023	-0.007	-0.020	0.010
	(0.039)	(0.111)	(0.110)	(0.120)	(0.104)	(0.098)	(0.091)	(0.091)
R^2	0.466	0.468	0.505	0.478	0.454	0.458	0.459	0.455
Num. Obs.	20362	2507	2587	2458	3130	3234	3228	3218

(b) SIPP data

	All years	1997	1998	1999	2002	2003	2005
constant (γ_0)	1.961***	1.886***	1.843***	1.928***	1.848***	1.737***	1.671***
	(0.130)	(0.031)	(0.032)	(0.031)	(0.032)	(0.031)	(0.025)
Move big (γ_1)	0.243***	0.307**	0.280**	0.297**	-0.026	0.261**	0.285***
	(0.037)	(0.101)	(0.097)	(0.097)	(0.101)	(0.091)	(0.071)
Move small (γ_2)	-0.073	-0.039	0.022	-0.134	-0.062	0.022	-0.219*
	(0.052)	(0.131)	(0.138)	(0.137)	(0.129)	(0.137)	(0.104)
Δ Family	0.002	0.005	0.013	-0.021	0.007	-0.025	0.008
	(0.010)	(0.024)	(0.025)	(0.030)	(0.025)	(0.029)	(0.017)
Δ Retired	0.078*	0.015	0.127	0.042	0.019	0.123	0.144*
	(0.035)	(0.080)	(0.089)	(0.102)	(0.085)	(0.101)	(0.071)
Δ Married	-0.039	-0.115	-0.010	-0.231	0.088	-0.160	0.011
	(0.047)	(0.115)	(0.123)	(0.153)	(0.111)	(0.144)	(0.084)
Δ Employment	-0.129***	-0.200***	-0.175**	-0.161**	-0.143***	-0.123**	-0.073*
	(0.019)	(0.061)	(0.062)	(0.061)	(0.043)	(0.045)	(0.032)
$Age_{y<30}$	-1.257***	-1.342***	-1.305***	-1.367***	-1.292***	-1.236***	-1.069***
	(0.021)	(0.053)	(0.057)	(0.057)	(0.054)	(0.053)	(0.040)
$Age_{30<y<50}$	-0.766***	-0.845***	-0.853***	-0.842***	-0.770***	-0.715***	-0.613***
	(0.010)	(0.025)	(0.027)	(0.026)	(0.026)	(0.025)	(0.020)
Midwest	0.133***	0.167***	0.130***	0.109**	0.114**	0.117**	0.153***
	(0.015)	(0.036)	(0.038)	(0.037)	(0.039)	(0.037)	(0.029)
South	-0.093***	-0.088*	-0.112**	-0.163***	-0.059	-0.093**	-0.054
	(0.014)	(0.035)	(0.036)	(0.036)	(0.036)	(0.035)	(0.028)
West	-0.131***	-0.091*	-0.115**	-0.187***	-0.164***	-0.133***	-0.107***
	(0.016)	(0.040)	(0.042)	(0.041)	(0.042)	(0.040)	(0.032)
R^2	0.463	0.453	0.431	0.469	0.464	0.461	0.504
Num. Obs.	105587	18394	17117	16457	15646	15401	22572

Table 8: **Test of Hypothesis 2a.** Difference-in-differences regressions. Coefficients estimated using a standard OLS model with ex-ante (e.g., before moving) values of z_{it}. Standard errors are reported in parentheses. *** denotes significance at the 1% level, ** at the 5% level, and * at the 10% level. The regression includes year dummies. Survey: PSID.

	All b/se
constant (γ_0)	2.043***
	(0.044)
Year hot (γ_1)	-0.159***
	(0.033)
Move big (γ_2)	0.253***
	(0.054)
Move small (γ_3)	-0.096
	(0.085)
Move big x Year hot (γ_4)	-0.207
	(0.106)
Move small x Year hot (γ_5)	0.446*
	(0.179)
Δ Family	0.010
	(0.017)
Δ Retired	-0.070
	(0.047)
Δ Married	0.074
	(0.090)
Δ Employment	-0.179***
	(0.032)
$Age_{y<30}$	-1.358***
	(0.041)
$Age_{30<y<50}$	-0.935***
	(0.024)
Midwest	0.111**
	(0.037)
South	-0.087*
	(0.035)
West	0.044
	(0.039)
R^2	0.469
Num. Obs.	19707

Table 9: **Test of Hypothesis 2b**. Probit for the upgrading of housing and Heckman selectivity model. The table reports marginal effects. Standard errors are reported in parantheses. All the regressions include a constant and year dummies. *** denotes significance at the 1% level, ** at the 5% level, and * at the 10% level. The Heckman selectivity model includes fixed effects for years. Source: SIPP. Period: 1997-2005.

	Probit model Probability of adjustment $Pr(D^* > 0)$	Heckman selectivity model Size of the adjustment $\ln(\bar{z} - z^*)$
z	0.002***	
	(0.000)	
Year hot	0.004***	-0.797***
	(0.001)	(0.233)
Δ Family	0.005***	-0.648***
	(0.001)	(0.157)
Δ Retired	0.006	-1.077**
	(0.003)	(0.657)
Δ Married	0.008	-1.284**
	(0.005)	(0.753)
Δ Employment	0.005**	-0.765**
	(0.002)	(0.308)
$Age_{y<30}$	0.045***	-4.759***
	(0.004)	(0.559)
$Age_{30<y<50}$	0.018***	-2.453***
	(0.001)	(0.318)
Midwest	0.004***	-0.662**
	(0.001)	(0.293)
West	0.010***	-1.786***
	(0.002)	(0.342)
South	0.003*	-0.534**
	(0.001)	(0.286)
R^2		0.286
Num. Obs.	105068	1122

Table 10: **Results of Test 3a.** Coefficients estimated using a standard OLS model and ex-ante (e.g., before moving) values of the ratio of total risky stock holdings relative to wealth, θ_{it}/z_{it}. Standard errors are reported in parentheses. *** denotes significance at the 1% level, ** at the 5% level, and * at the 10% level. $m_{BIG_{it}}$ ($m_{SMALL_{it}}$) is a dummy variable equal to one if the family is increasing (decreasing) its housing holdings, i.e., moving to a bigger (smaller) house. The pooled regressions include year dummies.

(a) PSID data

	All	1984	1989	1994	1999	2001	2003	2005
constant (γ_0)	0.059***	0.053***	0.062***	0.129***	0.093***	0.081***	0.068***	0.067***
	(0.004)	(0.006)	(0.007)	(0.011)	(0.008)	(0.007)	(0.008)	(0.006)
Move big (γ_1)	0.019***	-0.007	0.036**	0.087***	0.007	0.022*	0.015	0.010
	(0.004)	(0.009)	(0.012)	(0.021)	(0.012)	(0.010)	(0.010)	(0.008)
Move small (γ_2)	0.010	-0.007	0.015	0.001	-0.000	0.017	0.034*	0.003
	(0.007)	(0.017)	(0.023)	(0.035)	(0.018)	(0.014)	(0.017)	(0.013)
Δ Family	0.003*	0.001	0.009*	0.007	0.007	0.003	-0.002	0.001
	(0.002)	(0.003)	(0.004)	(0.008)	(0.004)	(0.004)	(0.004)	(0.003)
Δ Retired	0.005	0.009	0.017	0.009	0.010	-0.023*	0.009	0.016
	(0.004)	(0.008)	(0.010)	(0.019)	(0.011)	(0.010)	(0.012)	(0.009)
Δ Married	-0.002	-0.010	-0.043	-0.055	-0.002	-0.029	0.032	0.031
	(0.008)	(0.018)	(0.025)	(0.040)	(0.020)	(0.019)	(0.019)	(0.016)
Δ Employment	-0.016***	-0.007	-0.013*	-0.025*	-0.023**	-0.017*	-0.019*	-0.012
	(0.003)	(0.005)	(0.006)	(0.011)	(0.009)	(0.007)	(0.008)	(0.007)
$Age_{y<30}$	-0.040***	-0.022***	-0.025**	-0.062***	-0.043***	-0.042***	-0.036***	-0.047***
	(0.004)	(0.006)	(0.008)	(0.015)	(0.011)	(0.010)	(0.010)	(0.008)
$Age_{30<y<50}$	-0.018***	-0.008	-0.013*	-0.011	-0.016**	-0.018***	-0.027***	-0.024***
	(0.002)	(0.004)	(0.005)	(0.009)	(0.006)	(0.005)	(0.006)	(0.005)
Midwest	-0.004	-0.003	0.016*	-0.009	-0.015	-0.003	-0.007	-0.007
	(0.003)	(0.006)	(0.008)	(0.012)	(0.009)	(0.008)	(0.009)	(0.007)
South	-0.021***	-0.025***	-0.014*	-0.039***	-0.031***	-0.022**	-0.008	-0.013
	(0.003)	(0.006)	(0.007)	(0.012)	(0.008)	(0.008)	(0.008)	(0.007)
West	-0.001	-0.001	0.008	-0.007	-0.008	-0.002	0.003	-0.000
	(0.004)	(0.007)	(0.008)	(0.014)	(0.009)	(0.009)	(0.009)	(0.008)
R^2	0.150	0.121	0.170	0.214	0.152	0.145	0.099	0.132
Num. Obs.	20345	2491	2584	2460	3130	3234	3228	3218

(b) SIPP data

	All	1997	1998	1999	2002	2003	2005
constant (γ_0)	0.095***	0.081***	0.092***	0.077***	0.071***	0.062***	0.028***
	(0.015)	(0.004)	(0.005)	(0.003)	(0.004)	(0.003)	(0.002)
Move big (γ_1)	0.022***	0.030*	0.035*	0.032**	0.013	0.005	0.019***
	(0.004)	(0.014)	(0.014)	(0.011)	(0.012)	(0.009)	(0.005)
Move small (γ_2)	-0.002	-0.001	-0.006	-0.012	0.011	-0.005	-0.003
	(0.006)	(0.018)	(0.020)	(0.015)	(0.015)	(0.014)	(0.007)
Δ Family	0.002	0.004	0.008*	-0.004	-0.004	0.004	0.000
	(0.001)	(0.003)	(0.004)	(0.003)	(0.003)	(0.003)	(0.001)
Δ Retired	0.006	0.007	0.022	0.012	-0.007	0.005	-0.002
	(0.004)	(0.011)	(0.013)	(0.011)	(0.010)	(0.010)	(0.005)
Δ Married	-0.006	-0.017	-0.021	-0.007	-0.005	-0.003	0.010
	(0.006)	(0.015)	(0.018)	(0.017)	(0.013)	(0.014)	(0.005)
Δ Employment	-0.006**	-0.012	-0.011	-0.002	-0.006	-0.007	-0.002
	(0.002)	(0.008)	(0.009)	(0.007)	(0.005)	(0.004)	(0.002)
$Age_{y<30}$	-0.023***	-0.019**	-0.034***	-0.027***	-0.024***	-0.023***	-0.016***
	(0.002)	(0.007)	(0.008)	(0.006)	(0.006)	(0.005)	(0.003)
$Age_{30<y<50}$	-0.006***	-0.006	0.006	-0.009**	-0.012***	-0.010***	-0.007***
	(0.001)	(0.003)	(0.004)	(0.003)	(0.003)	(0.003)	(0.001)
Midwest	0.003	-0.000	0.001	0.003	0.006	0.006	0.003
	(0.002)	(0.005)	(0.006)	(0.004)	(0.004)	(0.004)	(0.002)
South	-0.008***	-0.012*	-0.012*	-0.008*	-0.007	-0.005	-0.004*
	(0.002)	(0.005)	(0.005)	(0.004)	(0.004)	(0.003)	(0.002)
West	-0.000	0.003	-0.001	0.004	-0.002	-0.007	0.000
	(0.002)	(0.005)	(0.006)	(0.005)	(0.005)	(0.004)	(0.002)
R^2	0.112	0.099	0.120	0.143	0.105	0.117	0.068
Num. Obs.	105531	18376	17108	16446	15638	15396	22567

Table 11: **Results of Test 3a - Stock Market Participants.** Coefficients estimated using a standard OLS model and ex-ante (e.g., before moving) values of the ratio of total risky stock holdings relative to wealth, θ_{it}/z_{it}. Standard errors are reported in parentheses. *** denotes significance at the 1% level, ** at the 5% level, and * at the 10% level. $m_{BIG_{it}}$ ($m_{SMALL_{it}}$) is a dummy variable equal to one if the family is increasing (decreasing) its housing holdings, i.e., moving to a bigger (smaller) house. The pooled regressions include year dummies.

(a) PSID data

	All	1984	1989	1994	1999	2001	2003	2005
constant (γ_0)	0.146***	0.158***	0.147***	0.136***	0.240***	0.215***	0.176***	0.179***
	(0.010)	(0.016)	(0.015)	(0.012)	(0.020)	(0.019)	(0.024)	(0.017)
Move big (γ_1)	0.033**	-0.046	0.066*	0.087***	-0.028	0.030	0.037	0.038
	(0.011)	(0.029)	(0.028)	(0.022)	(0.031)	(0.028)	(0.033)	(0.028)
Move small (γ_2)	0.017	-0.003	0.007	-0.002	0.005	0.042	0.100	-0.012
	(0.018)	(0.062)	(0.051)	(0.035)	(0.055)	(0.042)	(0.059)	(0.041)
Δ Family	0.005	0.001	0.025	0.008	0.014	-0.001	-0.009	0.001
	(0.005)	(0.011)	(0.013)	(0.009)	(0.015)	(0.012)	(0.015)	(0.013)
Δ Retired	0.001	0.002	0.010	0.007	-0.025	-0.002	0.012	-0.036
	(0.011)	(0.031)	(0.028)	(0.019)	(0.035)	(0.031)	(0.045)	(0.039)
Δ Married	-0.010	-0.043	-0.099	-0.059	-0.027	-0.031	0.056	0.102
	(0.021)	(0.059)	(0.076)	(0.041)	(0.056)	(0.067)	(0.061)	(0.052)
Δ Employment	-0.010	-0.021	-0.007	-0.026*	-0.005	0.015	0.011	0.067*
	(0.008)	(0.019)	(0.018)	(0.011)	(0.031)	(0.026)	(0.035)	(0.031)
$Age_{y<30}$	-0.064***	-0.039	-0.042	-0.064***	-0.069	-0.062	-0.064	-0.105**
	(0.010)	(0.025)	(0.023)	(0.016)	(0.037)	(0.035)	(0.038)	(0.032)
$Age_{30<y<50}$	-0.028***	-0.048**	-0.047***	-0.013	-0.015	-0.040*	-0.034	-0.030
	(0.005)	(0.015)	(0.013)	(0.009)	(0.017)	(0.016)	(0.020)	(0.015)
Midwest	0.025***	0.040*	0.052**	-0.011	0.014	0.044*	0.041	0.043*
	(0.007)	(0.018)	(0.016)	(0.013)	(0.022)	(0.022)	(0.028)	(0.022)
South	0.014*	0.012	0.061***	-0.041***	0.025	0.026	0.060*	0.060**
	(0.007)	(0.019)	(0.017)	(0.012)	(0.022)	(0.022)	(0.026)	(0.021)
West	0.012	0.014	0.029	-0.008	0.020	0.022	0.013	0.016
	(0.008)	(0.020)	(0.018)	(0.014)	(0.024)	(0.024)	(0.029)	(0.022)
R^2	0.418	0.456	0.497	0.222	0.551	0.519	0.383	0.535
Num. Obs.	6906	588	829	2370	794	829	773	723

(b) SIPP data

	All	1997	1998	1999	2002	2003	2005
constant (γ_0)	0.231***	0.232***	0.262***	0.226***	0.190***	0.176***	0.146***
	(0.040)	(0.011)	(0.012)	(0.009)	(0.009)	(0.008)	(0.007)
Move big (γ_1)	0.001	0.001	-0.010	0.021	-0.013	-0.025	0.037
	(0.011)	(0.032)	(0.032)	(0.024)	(0.028)	(0.022)	(0.019)
Move small (γ_2)	-0.034	-0.051	-0.060	-0.032	0.005	-0.032	-0.022
	(0.017)	(0.044)	(0.050)	(0.040)	(0.038)	(0.037)	(0.033)
Δ Family	0.005	0.004	0.022	-0.004	-0.013	0.014	0.003
	(0.004)	(0.010)	(0.012)	(0.010)	(0.009)	(0.009)	(0.007)
Δ Retired	0.008	0.005	0.030	0.019	-0.009	-0.002	-0.002
	(0.012)	(0.029)	(0.033)	(0.028)	(0.027)	(0.026)	(0.023)
Δ Married	0.010	-0.026	-0.035	0.067	-0.012	0.029	0.061*
	(0.018)	(0.048)	(0.055)	(0.051)	(0.035)	(0.044)	(0.028)
Δ Employment	-0.012	-0.020	-0.004	-0.001	-0.012	-0.016	-0.010
	(0.007)	(0.024)	(0.026)	(0.017)	(0.013)	(0.012)	(0.010)
$Age_{y<30}$	-0.015	0.013	-0.020	-0.021	-0.026	-0.008	-0.033*
	(0.009)	(0.023)	(0.027)	(0.019)	(0.019)	(0.017)	(0.017)
$Age_{30<y<50}$	-0.027***	-0.023*	0.006	-0.034***	-0.040***	-0.032***	-0.045***
	(0.003)	(0.009)	(0.010)	(0.007)	(0.008)	(0.007)	(0.006)
Midwest	0.017***	0.005	0.016	0.014	0.022*	0.022*	0.026**
	(0.005)	(0.013)	(0.014)	(0.010)	(0.011)	(0.010)	(0.009)
South	0.033***	0.022	0.042**	0.037***	0.041***	0.033***	0.020*
	(0.005)	(0.013)	(0.014)	(0.010)	(0.011)	(0.009)	(0.009)
West	0.006	0.019	0.008	0.012	-0.001	-0.015	0.012
	(0.005)	(0.014)	(0.016)	(0.011)	(0.012)	(0.010)	(0.009)
R^2	0.361	0.313	0.374	0.455	0.316	0.371	0.396
Num. Obs.	30089	5774	5406	5129	5210	4807	3763

Table 12: **Results of Test 3b.** Coefficients estimated using a standard OLS model and ex-ante (e.g., before moving) values of the risk-free securities holding relative to wealth, b_{it}/z_{it}. Standard errors are reported in parentheses. *** denotes significance at the 1% level, ** at the 5% level, and * at the 10% level. $m_{BIG_{it}}$ ($m_{SMALL_{it}}$) is a dummy variable equal to one if the family is increasing (decreasing) its housing holdings, i.e., moving to a bigger (smaller) house. The pooled regressions include year dummies.

(a) PSID data

	All	1984	1989	1994	1999	2001	2003	2005
constant (γ_0)	0.163***	0.210***	0.161***	0.158***	0.230***	0.238***	0.202***	0.214***
	(0.009)	(0.016)	(0.021)	(0.014)	(0.015)	(0.015)	(0.022)	(0.017)
Move big (γ_1)	0.039***	0.007	-0.008	0.030	0.009	0.021	0.060*	0.092***
	(0.010)	(0.027)	(0.038)	(0.026)	(0.022)	(0.021)	(0.028)	(0.022)
Move small (γ_2)	-0.006	-0.052	0.013	-0.004	-0.012	-0.002	-0.008	0.008
	(0.016)	(0.049)	(0.070)	(0.044)	(0.034)	(0.029)	(0.050)	(0.034)
Δ Family	0.001	0.008	-0.000	0.012	0.003	0.009	-0.005	-0.010
	(0.004)	(0.010)	(0.014)	(0.010)	(0.007)	(0.007)	(0.011)	(0.008)
Δ Retired	-0.005	0.028	-0.065*	-0.025	0.004	0.012	0.003	-0.020
	(0.010)	(0.024)	(0.032)	(0.023)	(0.021)	(0.020)	(0.034)	(0.024)
Δ Married	-0.001	0.008	0.033	-0.030	0.018	-0.016	0.041	-0.036
	(0.019)	(0.052)	(0.079)	(0.051)	(0.037)	(0.040)	(0.056)	(0.044)
Δ Employment	-0.036***	-0.028	-0.025	-0.027*	-0.024	-0.025	-0.086***	-0.032
	(0.007)	(0.015)	(0.020)	(0.014)	(0.017)	(0.015)	(0.024)	(0.018)
$Age_{y<30}$	0.015	0.018	0.038	0.038*	-0.016	0.009	0.021	0.004
	(0.009)	(0.018)	(0.026)	(0.019)	(0.021)	(0.020)	(0.029)	(0.021)
$Age_{30<y<50}$	-0.015**	-0.036**	0.008	0.012	-0.009	-0.040***	-0.008	-0.022
	(0.005)	(0.013)	(0.016)	(0.011)	(0.011)	(0.011)	(0.016)	(0.013)
Midwest	0.010	-0.050**	0.058*	0.015	0.016	-0.015	0.041	0.005
	(0.007)	(0.018)	(0.024)	(0.015)	(0.017)	(0.017)	(0.025)	(0.019)
South	-0.035***	-0.080***	-0.020	-0.008	-0.051**	-0.045**	-0.001	-0.042*
	(0.007)	(0.017)	(0.022)	(0.014)	(0.015)	(0.016)	(0.023)	(0.018)
West	-0.016*	-0.039	0.036	0.021	-0.049**	-0.012	0.000	-0.051*
	(0.008)	(0.020)	(0.026)	(0.018)	(0.018)	(0.019)	(0.027)	(0.021)
R^2	0.238	0.209	0.188	0.327	0.324	0.293	0.190	0.239
Num. Obs.	20345	2491	2584	2460	3130	3234	3228	3218

(b) SIPP data

	All	1997	1998	1999	2002	2003	2005
constant (γ_0)	0.146***	0.177***	0.155***	0.209***	0.209***	0.204***	0.215***
	(0.032)	(0.006)	(0.007)	(0.008)	(0.008)	(0.008)	(0.007)
Move big (γ_1)	0.034***	0.012	0.049*	0.049*	0.030	0.038	0.027
	(0.009)	(0.021)	(0.021)	(0.025)	(0.025)	(0.024)	(0.020)
Move small (γ_2)	-0.030*	0.000	-0.023	-0.059	-0.037	-0.050	-0.022
	(0.013)	(0.027)	(0.029)	(0.035)	(0.032)	(0.036)	(0.029)
Δ Family	0.002	0.005	0.027***	0.005	-0.006	-0.010	-0.006
	(0.002)	(0.005)	(0.005)	(0.008)	(0.006)	(0.008)	(0.005)
Δ Retired	0.025**	0.003	0.014	0.130***	-0.016	-0.017	0.053**
	(0.009)	(0.016)	(0.019)	(0.026)	(0.021)	(0.027)	(0.020)
Δ Married	-0.004	-0.005	0.026	-0.024	-0.018	-0.015	-0.004
	(0.012)	(0.023)	(0.026)	(0.039)	(0.028)	(0.038)	(0.024)
Δ Employment	-0.017***	-0.015	0.001	-0.023	-0.023*	-0.019	-0.017
	(0.005)	(0.012)	(0.013)	(0.015)	(0.011)	(0.012)	(0.009)
$Age_{y<30}$	-0.014**	-0.031**	-0.054***	-0.012	-0.014	0.041**	-0.008
	(0.005)	(0.011)	(0.012)	(0.014)	(0.014)	(0.014)	(0.011)
$Age_{30<y<50}$	0.021***	0.015**	-0.033***	0.013*	0.038***	0.033***	0.054***
	(0.002)	(0.005)	(0.006)	(0.007)	(0.007)	(0.007)	(0.005)
Midwest	0.023***	0.014	0.007	0.007	0.033***	0.030**	0.046***
	(0.004)	(0.007)	(0.008)	(0.010)	(0.010)	(0.010)	(0.008)
South	-0.013***	-0.006	-0.003	-0.032***	-0.018*	-0.012	-0.006
	(0.003)	(0.007)	(0.008)	(0.009)	(0.009)	(0.009)	(0.008)
West	-0.010*	-0.004	0.008	-0.006	-0.025*	-0.029**	-0.006
	(0.004)	(0.008)	(0.009)	(0.010)	(0.010)	(0.010)	(0.009)
R^2	0.228	0.227	0.141	0.205	0.236	0.232	0.289
Num. Obs.	105531	18376	17108	16446	15638	15396	22567

Table 13: **Results of Test 3b with Mortgage.** Coefficients estimated using a standard OLS model and ex-ante (e.g., before moving) values of the ratio of total risk-free securities holdings relative to wealth, b_{it}/z_{it}. Standard errors are reported in parentheses. *** denotes significance at the 1% level, ** at the 5% level, and * at the 10% level. $m_{BIG_{it}}$ ($m_{SMALL_{it}}$) is a dummy variable equal to one if the family is increasing (decreasing) its housing holdings, i.e., moving to a bigger (smaller) house. The pooled regressions include year dummies.

(a) PSID data

	All	1984	1989	1994	1999	2001	2003	2005
constant (γ_0)	0.390***	0.121	0.247*	0.025	0.065	-0.284*	0.007	-0.064
	(0.061)	(0.088)	(0.100)	(0.108)	(0.129)	(0.124)	(0.125)	(0.124)
Move big (γ_1)	-0.099	0.341*	0.076	0.134	0.351	-0.088	-0.426**	-0.327*
	(0.066)	(0.146)	(0.179)	(0.201)	(0.191)	(0.172)	(0.159)	(0.160)
Move small (γ_2)	-0.293**	0.154	-0.376	-0.514	-0.203	-0.342	-0.467	-0.183
	(0.105)	(0.265)	(0.331)	(0.333)	(0.294)	(0.240)	(0.285)	(0.248)
Δ Family	-0.075**	0.019	-0.116	-0.078	-0.171**	-0.096	-0.059	0.054
	(0.024)	(0.052)	(0.064)	(0.079)	(0.063)	(0.059)	(0.062)	(0.061)
Δ Retired	-0.008	0.099	0.101	-0.114	-0.014	-0.032	0.118	-0.173
	(0.065)	(0.130)	(0.150)	(0.178)	(0.180)	(0.164)	(0.196)	(0.180)
Δ Married	-0.138	-0.388	0.072	-0.062	-0.195	-0.623	0.307	-0.012
	(0.126)	(0.279)	(0.373)	(0.388)	(0.324)	(0.324)	(0.319)	(0.322)
Δ Employment	0.031	0.040	-0.097	-0.005	-0.100	0.155	0.154	0.189
	(0.046)	(0.082)	(0.095)	(0.103)	(0.144)	(0.126)	(0.138)	(0.136)
$Age_{y<30}$	-2.183***	-1.467***	-1.750***	-2.319***	-2.341***	-2.324***	-2.602***	-2.490***
	(0.057)	(0.097)	(0.125)	(0.145)	(0.178)	(0.165)	(0.167)	(0.155)
$Age_{30<y<50}$	-0.973***	-0.656***	-0.932***	-1.059***	-1.208***	-0.917***	-1.023***	-0.980***
	(0.034)	(0.069)	(0.076)	(0.082)	(0.096)	(0.092)	(0.093)	(0.093)
Midwest	-0.210***	-0.257**	-0.176	-0.006	-0.162	-0.009	-0.443**	-0.335*
	(0.050)	(0.097)	(0.110)	(0.117)	(0.143)	(0.139)	(0.142)	(0.142)
South	-0.264***	-0.289**	-0.337***	-0.148	-0.269*	-0.057	-0.349**	-0.371**
	(0.047)	(0.089)	(0.101)	(0.111)	(0.134)	(0.130)	(0.132)	(0.133)
West	-0.357***	-0.190	-0.264*	-0.092	-0.617***	-0.274	-0.543***	-0.358*
	(0.055)	(0.108)	(0.124)	(0.134)	(0.157)	(0.152)	(0.153)	(0.152)
R^2	0.215	0.204	0.196	0.251	0.206	0.204	0.237	0.232
Num. Obs.	20345	2491	2584	2460	3130	3234	3228	3218

(b) SIPP data

	All	1997	1998	1999	2002	2003	2005
constant (γ_0)	-0.165	0.055	0.009	0.003	0.048	0.059	0.077*
	(0.172)	(0.038)	(0.044)	(0.042)	(0.042)	(0.043)	(0.033)
Move big (γ_1)	0.123*	0.233	0.116	0.497***	-0.015	-0.275*	0.169
	(0.050)	(0.126)	(0.132)	(0.128)	(0.132)	(0.126)	(0.094)
Move small (γ_2)	-0.031	0.065	-0.040	-0.021	-0.266	-0.016	0.048
	(0.069)	(0.163)	(0.187)	(0.182)	(0.168)	(0.188)	(0.138)
Δ Family	-0.032*	-0.053	-0.092**	-0.021	0.005	-0.017	-0.013
	(0.013)	(0.030)	(0.034)	(0.039)	(0.033)	(0.040)	(0.023)
Δ Retired	-0.003	-0.087	0.145	-0.121	-0.121	0.151	0.035
	(0.046)	(0.100)	(0.121)	(0.135)	(0.111)	(0.139)	(0.094)
Δ Married	-0.125*	-0.121	-0.199	-0.374	-0.121	-0.053	-0.013
	(0.063)	(0.143)	(0.168)	(0.204)	(0.145)	(0.199)	(0.112)
Δ Employment	-0.147***	-0.301***	-0.318***	-0.164*	0.005	-0.112	-0.158***
	(0.026)	(0.076)	(0.084)	(0.081)	(0.056)	(0.062)	(0.043)
$Age_{y<30}$	-2.370***	-2.447***	-2.572***	-2.647***	-2.120***	-2.387***	-2.145***
	(0.028)	(0.066)	(0.078)	(0.075)	(0.070)	(0.073)	(0.054)
$Age_{30<y<50}$	-0.915***	-1.000***	-1.130***	-0.924***	-0.805***	-0.877***	-0.777***
	(0.013)	(0.032)	(0.036)	(0.034)	(0.035)	(0.035)	(0.026)
Midwest	-0.092***	-0.006	-0.011	-0.000	-0.117*	-0.176***	-0.224***
	(0.019)	(0.045)	(0.052)	(0.050)	(0.050)	(0.051)	(0.039)
South	-0.224***	-0.221***	-0.257***	-0.249***	-0.196***	-0.202***	-0.228***
	(0.018)	(0.043)	(0.049)	(0.047)	(0.047)	(0.048)	(0.037)
West	-0.365***	-0.395***	-0.376***	-0.317***	-0.401***	-0.337***	-0.375***
	(0.021)	(0.050)	(0.057)	(0.054)	(0.054)	(0.055)	(0.042)
R^2	0.172	0.187	0.190	0.175	0.145	0.164	0.170
Num. Obs.	105531	18376	17108	16446	15638	15396	22567

Table 14: Predictability of excess returns and dividends growth with rents-to-price ratios, 1-lags Newey-West corrected standard errors. Data source: rents data correspond to housing services expenditures (NIPA from BLS) and housing values from the Flow of Funds. Sample from 1960 to 1998.

		Excess Returns			Dividend growth		
	Horizon	β	t-stat	R^2	β	t-stat	R^2
Housing	k=1	1.48	4.85	0.40	0.08	0.41	0.01
	k=4	10.82	5.99	0.54	-0.61	-1.22	0.04
	k=5	16.01	5.28	0.50	-1.06	-1.54	0.08
Stocks	k=1	2.83	1.20	0.03	-3.33	-1.96	0.05
	k=4	7.75	1.15	0.04	-2.38	-1.42	0.02
	k=5	11.37	1.41	0.05	-4.41	-2.36	0.04

Table 15: Panel A. Predictability of excess returns and dividends growth with rents-to-price ratios, 1-lags Newey-West corrected standard errors. Data source: price-rent data from Morris Davis website from 1978 to 2007. Panel B. Same regressions with rents data from NIPA and values data from Flow of Funds from 1960 to 2007.

Panel A							
		Excess Returns			Dividend growth		
	Horizon	β	t-stat	R^2	β	t-stat	R^2
USA	k=1	-3.37	-1.82	0.16	0.40	0.53	0.01
	k=4	-19.59	-1.54	0.14	2.49	0.80	0.02
	k=5	-21.94	-0.98	0.08	1.29	0.34	0.00
Midwest	k=1	-1.76	-1.38	0.06	0.89	1.41	0.07
	k=4	-3.97	-0.46	0.01	3.49	1.50	0.12
	k=5	-2.54	-0.20	0.00	3.28	1.25	0.08
Northeast	k=1	-1.36	-0.83	0.03	-0.84	-1.19	0.08
	k=4	8.04	0.77	0.04	1.82	0.66	0.04
	k=5	18.85	1.45	0.14	4.21	1.30	0.14
South	k=1	-3.61	-2.29	0.16	-0.36	-0.42	0.01
	k=4	-3.99	-0.22	0.01	-1.86	-0.65	0.02
	k=5	6.80	0.30	0.01	-3.32	-0.89	0.04
West	k=1	-4.54	-2.18	0.29	0.13	0.18	0.00
	k=4	-22.27	-1.43	0.17	-3.81	-1.14	0.05
	k=5	-21.63	-0.98	0.09	-8.23	-2.18	0.16
Stocks	k=1	3.92	2.65	0.08	-3.24	-2.07	0.05
	k=4	17.71	3.77	0.27	-0.01	-0.84	0.00
	k=5	20.39	4.31	0.28	0.00	0.04	0.00

Panel A							
		Excess Returns			Dividend growth		
	Horizon	β	t-stat	R^2	β	t-stat	R^2
Housing	k=1	1.40	3.68	0.36	0.08	0.72	0.01
	k=4	11.91	8.24	0.62	-0.63	-1.60	0.06
	k=5	19.17	9.01	0.68	-0.92	-1.98	0.09
Stocks	k=1	2.58	1.50	0.03	-3.04	-2.35	0.05
	k=4	7.17	1.54	0.05	-3.85	-2.07	0.07
	k=5	11.64	2.37	0.08	-5.33	-2.81	0.08

Table 16: Predictability of excess returns and dividends growth with rents-to-price ratios, 1-lags Newey-West corrected standard errors. Data source: price-rent data from Morris Davis website from 1978 to 2000.

		Excess Returns			Dividend growth		
	Horizon	β	t-stat	R^2	β	t-stat	R^2
Chicago	k=1	1.21	0.53	0.01	3.22	2.94	0.29
	k=5	32.02	3.83	0.44	10.42	3.65	0.48
Cincinnati	k=1	0.42	0.15	0.00	2.14	1.93	0.20
	k=5	36.42	5.44	0.58	6.79	2.72	0.24
Cleveland	k=1	1.13	0.58	0.01	1.80	1.33	0.11
	k=5	24.61	2.33	0.32	3.25	0.81	0.07
Detroit	k=1	-1.31	-0.79	0.04	0.46	0.59	0.04
	k=5	14.77	1.62	0.19	3.88	1.71	0.18
Kansas City	k=1	3.28	1.83	0.19	0.89	0.67	0.03
	k=5	23.19	7.64	0.63	-5.99	-1.56	0.14
Milwaukee	k=1	2.70	1.24	0.09	2.60	2.72	0.36
	k=5	29.84	5.08	0.62	1.68	0.61	0.03
Minneapolis	k=1	-1.33	-0.49	0.02	-0.89	-0.72	0.04
	k=5	15.14	2.24	0.25	-9.28	-2.74	0.35
St. Louis	k=1	0.15	0.06	0.00	1.62	1.40	0.08
	k=5	29.80	6.39	0.58	2.28	0.37	0.01
Boston	k=1	1.79	0.81	0.03	-1.12	-1.06	0.08
	k=5	36.92	3.22	0.56	6.98	2.13	0.29
New York	k=1	1.57	0.71	0.03	-1.59	-2.19	0.28
	k=5	25.92	2.21	0.37	0.32	0.11	0.00
Philadelphia	k=1	0.82	0.45	0.01	1.37	0.88	0.06
	k=5	29.03	2.83	0.43	12.01	3.24	0.48
Pittsburgh	k=1	1.10	0.66	0.01	2.07	1.61	0.15
	k=5	19.96	2.56	0.34	1.08	0.31	0.01
Atlanta	k=1	0.47	0.14	0.00	1.41	0.45	0.01
	k=5	25.52	2.11	0.21	-22.48	-1.78	0.15
Dallas	k=1	1.60	1.21	0.05	0.36	0.39	0.01
	k=5	18.10	3.05	0.39	3.05	0.60	0.03
Houston	k=1	2.86	2.02	0.17	1.43	1.18	0.08
	k=5	25.03	6.83	0.68	8.09	3.85	0.37
Miami	k=1	-5.51	-2.32	0.17	-2.92	-1.90	0.17
	k=5	-0.74	-0.06	0.00	-8.17	-3.10	0.34
Denver	k=1	-5.55	-2.84	0.27	-4.85	-3.60	0.51
	k=5	3.12	0.24	0.00	-17.41	-3.30	0.38
Honolulu	k=1	-0.09	-0.04	0.00	0.32	0.36	0.01
	k=5	17.45	1.17	0.13	6.26	2.15	0.24
Los Angeles	k=1	1.84	0.59	0.01	3.43	3.29	0.35
	k=5	55.12	5.88	0.78	15.10	3.90	0.38
Portland	k=1	-0.84	-0.74	0.02	-0.19	-0.37	0.01
	k=5	12.83	1.25	0.09	3.11	1.11	0.11
San Diego	k=1	2.15	1.08	0.03	4.00	2.68	0.31
	k=5	43.18	10.98	0.86	5.30	0.78	0.04
San Francisco	k=1	1.11	0.38	0.01	2.21	1.97	0.16
	k=5	42.02	5.63	0.67	9.06	2.52	0.25
Seattle	k=1	-2.25	-2.18	0.08	-1.22	-1.79	0.13
	k=5	6.27	0.81	0.04	-0.97	-0.66	0.02

Table 17: **Parameter values for the housing prices process in a 3-regime model.** Estimation of the parameters corresponding to the housing price processes using a discrete Markov regime (Wonham filter) with 3-regimes. Data is semiannual from 1975 to 2007. All parameters are reported in annual basis.

	West (1975-2007)	Northeast (1975-2007)	South (1975-2007)	Midwest (1975-2007)
μ^h	0.1605	0.1518	0.1094	0.0967
μ^m	0.0863	0.0928	0.0590	0.0476
μ^l	0.0306	0.0180	0.0286	0.0388
σ_P	0.0108	0.0157	0.0082	0.0116
$\lambda^{h\to m}$	0.0000	0.0000	0.2402	0.0000
$\lambda^{h\to l}$	0.1917	0.3017	0.0000	0.1045
$\lambda^{m\to h}$	0.0995	0.1749	0.1066	0.0000
$\lambda^{m\to l}$	0.1557	0.0000	0.1201	0.3261
$\lambda^{l\to m}$	0.0682	0.0844	0.0642	0.1056
$\lambda^{l\to h}$	0.0000	0.0307	0.0000	0.0000

Table 18: **Model results for the four U.S. Census Macro Regions. 3-regime model.** Columns (1), (2) and (3) display the lower bound, the optimal return point and the upper bound, respectively. The optimal return point represents the wealth-to-housing ratio immediately after a housing purchase. Column (4) is the the optimal housing-to-wealth ratio without transaction costs and Column (5) is the corresponding ratio with transaction costs immediately after a housing purchase. Column (6) is the relative risk aversion just after housing purchase, and Column (7) is the average holding of the risky asset, estimated just after a housing purchase. Column (8) is the long run average of the optimal wealth-to-housing ratio immediately after a housing purchase.

	Regime i	(1) $\underline{z}_i$	(2) z_i^*	(3) $\overline{z}_i$	(4) α_h^i	(5) $1/z_i^*$	(6) $RRA(z_i^*)$	(7) $\frac{E(\hat{\theta}^*(z_t,i)/z_t)}{E(\tau_i)}$	(8) $\frac{E(z_i^*)}{E(\tau_i)}$
West	High	0.125	0.239	0.519	6.615	4.173	3.683	0.175	0.334
	Medium	0.228	0.488	1.137	2.888	2.133	2.553	0.677	0.599
	Low	0.807	2.022	3.447	0.933	0.497	2.150	1.009	2.024
Northeast	High	0.155	0.269	0.538	6.186	3.716	3.549	0.276	0.350
	Medium	0.228	0.478	1.017	3.311	2.087	2.536	0.702	0.540
	Low	0.949	2.450	4.439	0.861	0.408	2.103	1.052	2.529
South	High	0.180	0.375	0.757	3.926	2.663	2.792	0.592	0.592
	Medium	0.416	0.702	1.948	1.620	1.422	2.391	0.803	0.903
	Low	0.889	2.016	3.776	0.777	0.495	2.089	1.021	2.058
Midwest	High	0.220	0.414	0.888	3.233	2.413	2.958	0.615	0.521
	Medium	0.676	1.634	2.439	1.077	0.611	2.313	0.957	1.736
	Low	0.877	1.933	3.686	0.844	0.517	2.137	0.994	1.888