Portfolio Choice with House Value Misperception*

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Abstract

We use data on self-reported and market house values at the household level to present stylized facts on house value misperception. We build an optimal portfolio choice model that features misperception, as observed in the data. In the model, households make consumption and portfolio decisions on housing and nonhousing assets with transaction costs in the housing adjustments. Households use subjective housing valuations, which may differ from market values, and decide each period whether to pay for observing the market value or not. Our model delivers several empirical implications that we test using household-level data: more misperception results, on average, in a lower share of risky stock holdings, lower nonhousing consumption, lower household leverage, and higher housing wealth over total wealth.

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1 Introduction

Households' estimates of their house values are often not aligned with market values. This misalignment can have important effects in portfolio choices because households typically make consumption and investment decisions as a function of their wealth, and housing is the most important component of total household wealth. In this paper, we study the portfolio allocation and housing choice implications of such divergence between market and subjective house values. To do so, we setup and solve a portfolio choice model that accounts for house value misperception and we empirically test its main implications using household-level data.

We first present empirical evidence of house value misperception at the household level by comparing data on self-reported (subjective) housing value from the Panel Study of Income Dynamics (PSID) to market housing value constructed using zipcode level data from CoreLogic. Market value is the value at which houses in the same zipcode level are actually transacted and the CoreLogic is a repeated-sales index that measures precisely that. We define house value misperception as the relative difference between the subjective value of the house and its market value. Our measure of misperception displays four stylized facts: (i) there exists considerable dispersion in across households; (ii) it is countercyclical on average; (iii) its sign is persistent (i.e., households who overvalue keep doing so for a few years); (iv) and it reverses back towards zero after a few years of growth.

We develop a partial equilibrium model with an agent making consumption and portfolio choices of housing and nonhousing goods and assets. The model takes into consideration the four stylized facts described above on house value misperception. In our model, the agent does not observe the market value of her house. Instead, she makes portfolio and consumption decisions using her own subjective house value, which may differ from its current unobservable market value. We abstract from modeling the root causes of this divergence. The agent has the option to pay a cost to observe the market value of her home. Therefore, she is not willing to continuously update her information about the market value of her house. Moreover, the agent incurs a transaction cost when selling the house that she currently owns to buy a new one.

In equilibrium, the existence of transaction costs makes housing consumption lumpy. As in the standard S-s literature, the policy function takes the form of two inaction regions in the state variable (e.g., the ratio of total wealth to housing wealth) and, consequently, in two sets of action boundaries. One inaction region determines the states in which the agent does not update her information about the market value of her house. The other inaction region determines the states in which the agent decides not to sell her house and buy a new one that is more adequate to her wealth. Inside the inaction regions, the agents continuously rebalance their portfolio of risky assets and riskless assets, and make consumption decisions according to optimality rules. In our model, state dependent risk aversion is the mechanism driving the dynamics of asset allocation and consumption.

Our model delivers qualitative and quantitative implications for the optimal consumption and portfolio decisions subject to house value misperception and transaction costs. We assess the model implications using household-level data on wealth, self-reported housing values, consumption, and asset holdings available from the Panel Study of Income Dynamics (PSID).

First, we study the implications of house value misperception on the portfolio holdings of risky stocks. We find that if households tend to overvalue their houses, then their share of wealth invested in risky assets is lower than the risky asset share of households who tend to undervalue their houses. In addition, the share of wealth invested in risky assets is lower the higher the uncertainty about the market value of the house. The empirical analysis support this model implication. We find that a 1% increase in misperception leads to a decrease of 2 basis points in the share of risky holdings, from 3.80% to 3.64%

We also reveal the implications of house value misperception for the consumption of nonhousing goods. We find that consumption is lower for those households who tend to overvalue their house than for those who tend to undervalue. Empirically, we find that a 1% increase in misperception decreases the average consumption ratio to 2.36% from 3.60%[1].

Moreover, we study the effects of house value misperception on the portfolio holdings of risk-free assets and leverage. We find that the net debt of households is, on average, 7.2% of their total wealth, i.e., households are levered. The model predicts that leverage decreases with an increase in household leverage. We find that the leverage of households decreases, on average, 3.2% with an increase of 1% in misperception.

Finally, we study the implications of house value misperception on the portfolio holdings of

[1]While this ratio seems to be low, the measure of consumption in the PSID mostly captures food consumption, and it is well know to underestimate total consumption

housing assets and housing adjustments. As in the portfolio choice model with transaction costs in Grossman and Laroque (1990), an agent only moves to a more valuable house when her wealth-to-housing ratio reaches an optimal upper boundary. Similarly, an agent only moves to a less valuable house when her total wealth-to-housing ratio reaches an optimal lower boundary. However, in our analysis, the agent decides whether to acquire information or not and, once she has acquired the information, whether to move to a new home or stay put. When the agent pays the cost and observes the market value of her home, she must decide whether the market-based wealth-to-housing ratio is such that it is worth paying the housing transaction cost and move to a different house. We find that households that overvalue their home present a lower wealth-to-housing ratio (i.e., their share of housing wealth over total wealth is higher) with respect to the benchmark model without house value misperception. Empirically, a 1% increase in misperception leads to a substantial decrease in housing wealth relative to total wealth (a decline ranging from 6% to 30% for different specifications).

Our paper can be framed in a literature that studies how house value misperception affects house prices and households' decisions. Piazzesi and Schneider (2009) and Ehrlich (2013) analyze how house value misperception affect house prices in search and matching models. Davis and Quintin (2016) focus on how the misperception of house prices affects homeowners' decisions on mortgage defaults. There is a more extensive literature that studies the effects of stock value misperception and rational inattention on investor's decisions. For example, Duffie and Sun (1990), Gabaix et al. (2006), Reis (2006), and Abel, Eberly, and Panageas (2007) study models of portfolio choices with rational inattention. Alvarez, Guiso, and Lippi (2012) is the closest study to ours in this literature. They extend these rational inattention models by introducing durable consumption and transaction costs. Our study differs from theirs in many dimensions, the most important being the addition of non-durable consumption. By accounting for non-durable consumption in our model, the optimal rules for consumption and portfolio choices are not constant between two consecutive housing transactions as in Abel, Eberly, and Panageas (2007). These richer optimal rules allow us to analyze the effects of house value misperception on the time-varying consumption and portfolio choices that we observe in the data.

Our paper also builds upon the literature on portfolio choice models with fixed adjustment costs. We use the portfolio choice model in Grossman and Laroque (1990) as a benchmark model for our study. The GL model accounts for transaction costs but it does not account for price misperception. Our paper adds to the literature focusing on particular implications of portfolio choice in the presence of housing (see Flavin and Yamashita (2002), Damgaard, Fuglsbjerg, and Munk (2003), Cocco (2005), Yao and Zhang (2005), Flavin and Nakagawa (2008), Van Hemert (2008), Stokey (2009), Fischer and Stamos (2013), and Corradin, Fillat, and Vergara-Alert (2014).) This literature assumes that households accurately observe house prices and the models studied in these papers do not account for house value misperception. Our paper contributes to fill this gap.

2 Analysis of House Value Misperception

Several studies in the real estate literature have documented the existence of measurement errors in house prices. Kish and Lansing (1954) and Kain and Quigley (1972) compare homeowners reported house values to values from professional appraisals and find that homeowners house values are large. They implicitly assume that appraisals are free of error. Robins and West (1977) drop this assumption and assume that appraisals are an unbiased estimator of house values. They conclude that house values from both homeowners and professional appraisals contain remarkable errors of 7% and 5%, respectively.[2] Although there is a consensus in the existence of measurement errors in house prices, there is no agreement on its sign and magnitude. Kish and Lansing (1954), Robins and West (1977), Ihlanfeldt and Martinez-Vazquez (1986), Goodman Jr and Ittner (1992), Kiel and Zabel (1999), and Agarwal (2007), and Benítez-Silva et al. (2015) document a range in the overestimation of reported house values from 3% to 16%. Contrarily, the empirical analyses in Kain and Quigley (1972) and Follain and Malpezzi (1981) find that reported house values are underestimated by about 2%.

In this paper, we study a measure of house value misperception at the household level and its role in household finance decisions, in particular in portfolio, consumption, and housing. We first broadly define misperception as the difference between the households' subjective valuation of their homes and their actual market value. We construct a proxy for misperception from self-reported home values and home price index at the zipcode level. We use self-reported house values from the Panel Study of Income Dynamics (PSID) as a measure of subjective house value. We use

[2] They find that the root mean square errors of the measures range is $2,900 for the homeowners and $1,900 for the appraisals. The median house value in the U.S. in January 1976 was $41,600.

the CoreLogic Home Price Index (HPI) at the Metropolitan Statistical Area (MSA) and zip code level to construct a proxy for the market valuation. The CoreLogic is a repeated-sales index that matches house price changes on the same properties in the public record files from First American. CoreLogic also computes separate indexes at the zipcode, county, metropolitan statistical area, state, and national level. Since the data are from public records, the HPI is representative of all loans in the market, not simply the conforming loan market of the GSEs like the Federal Housing Finance Agency (FHFA) index. The HPI is a monthly series beginning in 1975. With the appropriate HPI we construct the proxy for the market value of the properties by inflating the purchase price of the house. Consider H_i as the quantity of household i's home and P_t as the house price per square foot. We specifically define house value misperception for each household i at time t, as the relative difference between the subjective house value $(H_i \cdot P_{i,t})^{PSID}$, and the market house value, $(H_i \cdot P_{i,t_0})^{PSID} \cdot \Delta HPI^{CL}_{zip,t_0 \to t}$:

$$m_{i,t} = \frac{(H_i \cdot P_{i,t})^{PSID} - (H_i \cdot P_{i,t_0})^{PSID} \cdot \Delta HPI^{CL}_{zip,t_0 \to t}}{(H_i \cdot P_{i,t_0})^{PSID} \cdot \Delta HPI^{CL}_{zip,t_0 \to t}} \tag{1}$$

where $(H_i \cdot P_{i,t})^{PSID}$ is the value of the house at time t reported in PSID by household i; $(H_i \cdot P_{i,t_0})^{PSID}$ is the value of the house at purchase time (t_0) reported by household i; and $\Delta HPI^{CL}_{zip,t_0 \to t}$ is the price growth rate in zipcode zip from the time of purchase to time t computed with the CoreLogic price indexes. A positive value of $m_{i,t}$ indicates overvaluation, while a negative value indicates undervaluation.

To build this measure, we assume that house value misperception is zero when there is a housing transaction (i.e., $m_{i,t_0} = 0$). We recognize that this assumption reduces the sample size, as we only consider households who moved during the period of study. Nonetheless, it allows us to use a repeated sales index at a very granular level (zipcode) as opposed to a hedonic pricing model.

Figure 1 displays the average house value misperception for the U.S. from 1976 to 2013. We observe two relevant empirical facts. First, the dispersion of the house value misperception is large. Notice that the percentiles 5% and 95% have reached values below -40% and above 75%, respectively. Although the average of the U.S. aggregate house value misperception for the period 1976-2013 is close to zero (1.84%), its standard deviation is high (27.3%). This empirical fact is important for our study because it allows us to exploit the cross-section of house value misper-

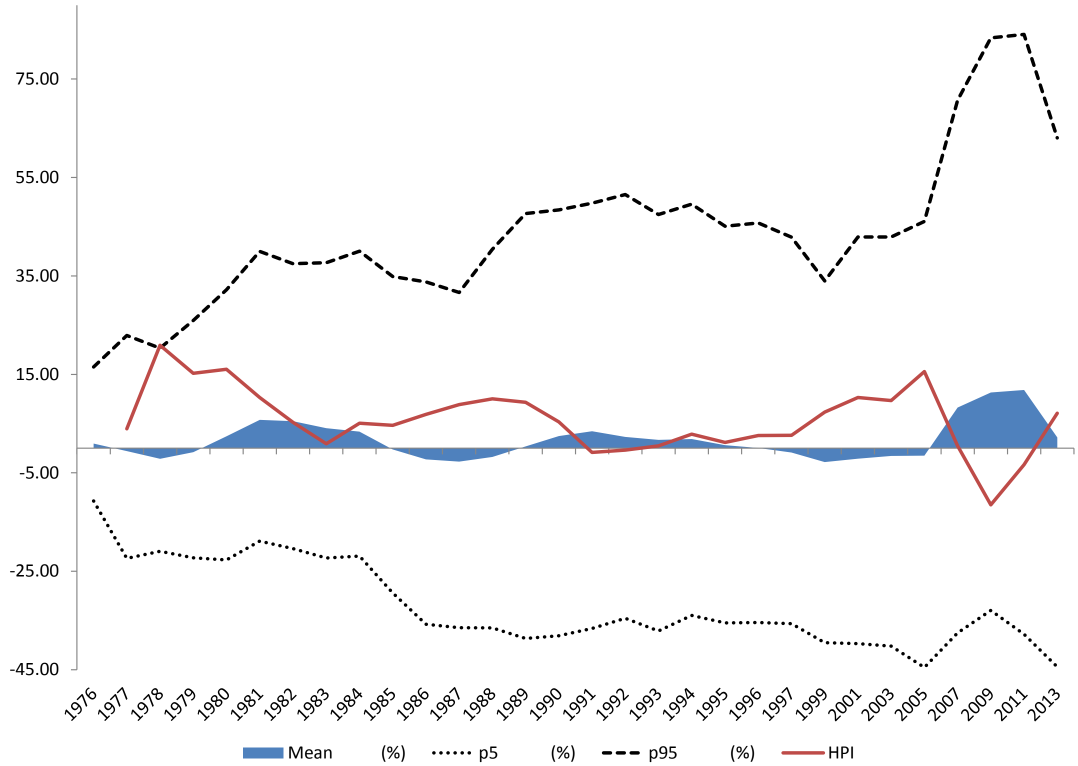

Figure 1: **House value misperception over time.** The figure plots the dynamics of the average house value misperception, the returns on the U.S. aggregate CoreLogic House Price Index (HPI) and the percentiles 5% (p5) and 95% (p95) of the distribution of house value misperception.

ception of the households in our data. Second, the average misperception is countercyclical when compared to the housing markets cycle. Notice that periods of house overvaluation (i.e., positive misperception) usually occur when returns in the U.S. aggregate CoreLogic House Price Index (HPI) are decreasing or negative. We obtain that the correlation between the average house value misperception and the HPI growth is -0.72.

We also observe geographical differences in house value misperception. Table 1 shows that while the mean of house value misperception is positive in some states such as Ohio (7.8%), Mississippi (6.1%), Missouri (5.7%), and Indiana (4.6%), it is negative in other states such as Virginia (-7.2%), Georgia (-6.4%), Florida (-5.6%), and California (-5.2%). Note that the median of this variables is close to zero in most states, which suggests that there are households that present very high and very low values of house value misperception. The observed high values of its standard deviation and the wide range between its minimum and maximum value for all the states confirms the dispersion of the distribution of house value misperception.

Table 1: **House value misperception for US states.** This table shows the summary statistics of the house value misperception measure for the top 20 states by number of observations in our data. All the values are expressed in %, except for the number of observations. The table also includes the mean of the growth in house prices in the period 1999-2007 of the zip code areas of the households in our data.

US State	Mean misperc.	Median misperc.	Std. Dev. misperc.	Max. misperc.	Min. misperc.	House price growth (1999-2007)	Num. Obs.
AR	-3.2	0.0	22.2	115.7	-58.4	44.7	1,053
CA	-5.2	0.0	26.3	144.8	-64.4	129.7	3,407
FL	-5.6	0.0	27.8	110.2	-49.5	119.9	1,026
GA	-6.4	0.0	24.3	96.5	-49.5	36.2	1,341
IL	-0.1	-2.1	30.1	108.5	-55.6	64.0	2,115
IN	4.6	0.0	34.9	430.3	-53.7	16.0	1,962
IA	1.2	-0.7	40.8	339.8	-54.3	32.8	1,044
LA	-4.6	0.0	30.2	121.8	-66.7	56.6	1,251
MD	-5.5	-1.9	33.4	198.0	-57.0	136.2	1,710
MI	2.8	0.0	36.9	297.3	-67.7	11.3	2,784
MS	6.1	0.0	43.2	299.9	-59.8	44.1	1,467
MO	5.7	0.0	32.7	179.9	-44.9	48.5	1,566
NJ	-4.8	-2.3	27.3	128.3	-57.0	102.4	1,143
NY	-3.5	0.0	26.5	101.7	-63.2	98.7	2,432
NC	1.8	0.0	40.3	262.7	-50.4	44.6	1,890
OH	7.8	0.0	27.4	229.5	-51.7	6.4	3,348
PA	0.9	0.0	33.9	187.9	-66.7	74.1	2,250
SC	4.3	0.0	31.2	169.6	-52.2	53.9	2,187
TX	2.8	0.0	35.0	164.5	-58.6	40.5	1,404
VA	-7.2	-6.4	24.8	150.4	-60.2	107.9	1,476

Figure 2 summarizes house value misperception by cohort and tenure for a set of selected years. Each line represents the house value misperception of a group of households that purchased the house in a given year. We observe that households who acquired a new house in 1989, 1990, 1991, 2005, and 2007 overvalued their houses from the year after acquisition. However, households who acquired a new house in 1983, 1985, 1992, 1995, and 1999 undervalued their houses from the year after acquisition. Two relevant stylized facts arise from this figure. First, house value misperception is persistent. Notice that households that overvalued their houses right after its acquisition keep overvaluing their houses over time. The same argument applies to households that undervalue. Second, house value misperception may increase in the first few years but tends to revert to zero over time. This fact suggests that households acquire information on (or pay attention to) the value of their houses, and it is at odds with the evidence in Kuzmenko and Timmins (2011). They show that the bias in self-reported housing prices is positively correlated with tenure. They document that long-standing homeowners do not have the incentive to acquire information on current house prices and, consequently, they report biased housing values. We also find this correlation, conditional on a cohort effect at purchase time. On average, households who bought the house in the periods of house price decline, i.e., a housing bust, tend to over estimate the value of their house over time. Contrarily, those households who bought in periods of substantially positive growth tend to underestimate the value of their house over the years. Here is where the discrepancy between prior and our findings arise: we find this cohort effect tends to dissipate, on average, after 6-7 years of tenure.

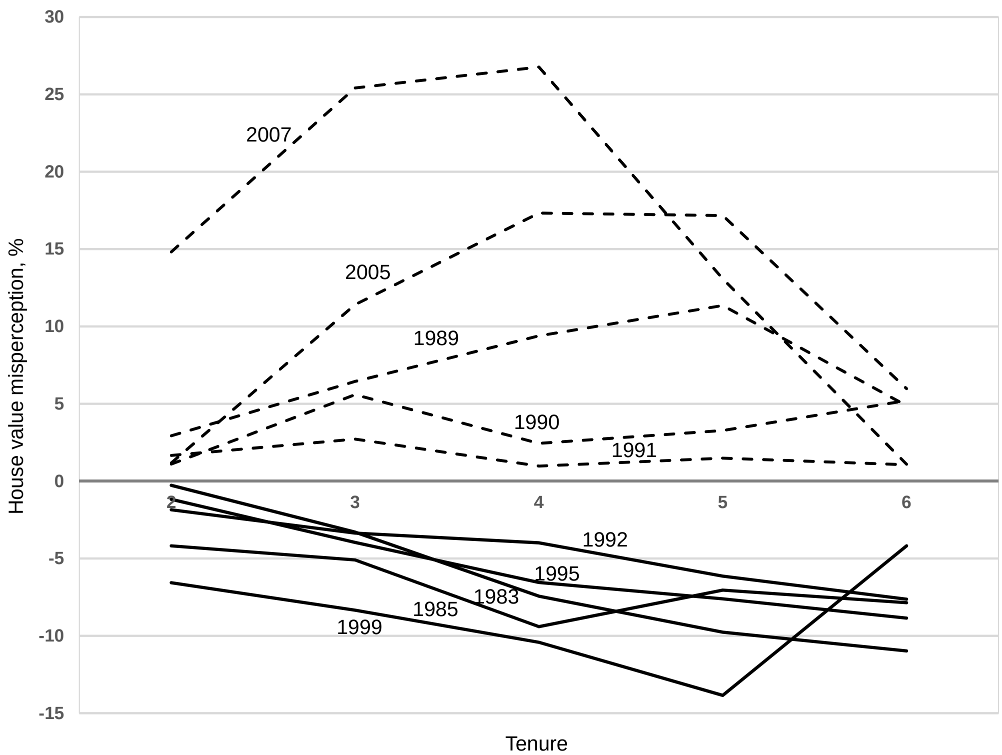

Figure 2: **Persistence of house value misperception.** The figure plots the dynamics of the average house value misperception for cohorts of households who acquire a house in a selected year. Tenure is measured in years since the purchase of the current home, and it is represented in the x-axis. The misperception value is computed as described in the text: the value of purchased is indexed with zip code level HPI and compared with the self-reported value of the house each year. Dashed lines represent the cohorts that overvalued the value of their house from acquisition. Solid lines represent the cohorts that undervalued.

In the remainder of the paper, we analyze theoretically and empirically the household's behavior in the presence of misperception. Households find costly to acquire information about the value of their home (both in pecuniary and non-pecuniary terms) and, as such, the households' estimates of their home values differ from what they ultimately settle for in a market transaction. In the period between house transactions, they make portfolio and consumption decisions based on their subjective estimates, which they know they may not coincide with the market value. During this period, they also have to make the decision of whether to buy information about the value of the house or not.

Information costs do not need to be taken literally as the monetary costs of learning the market value of the house. An appraisal cost is negligible compared to the house value or the household's wealth. Information costs are also affected by the time invested in researching neighboring homes that have been sold recently -even on Zillow takes time to find relevant comparison groups.[3] More importantly, no matter how costly it is for households to figure out the market value of their house, there exists ex-post uncertainty about the final sale price, which can be affected by many factors like liquidity shocks, cyclical components, etc. An analogous interpretation of our paper is based on the fact that market prices are uncertain and every seller faces a random distribution of type and number of buyers. Households still make everyday consumption and portfolio decisions based on what they think they will be able to get from the house, but as they get closer to the transaction boundary, the uncertainty starts playing a role and the households have the incentives to incur in costs to resolve it.

3 The Model

In this section, we develop a model of portfolio choice that is consistent with the stylized facts on house value misperception documented above. In our model, we study consumption and portfolio decisions of an agent in an economy with information costs, housing transaction costs, a risk-free asset, a risky asset, and two types of consumption goods: non-housing and housing goods. Transactions in the housing market are costly. The agent has non-separable Cobb-Douglas preferences over housing and non-housing goods. She derives utility over a trivial flow of services generated by the house.[4] The utility function can be expressed as:

$$u(C,H) = \frac{1}{1-\gamma}(C^{\beta}H^{1-\beta})^{1-\gamma}, \tag{2}$$

[3] One could argue that with the presence of website services like Zillow or Trulia, information costs converge to zero. It is true that it is easy to find out deed data faster on those services. Nonetheless, their own estimates of market valuation are not exempt from uncertainty.

[4] This specification can be generalized as long as preferences are homothetic. Davis and Ortalo-Magne (2011) show that expenditure shares on housing are constant over time.

where H is the service flow from the house (in square footage) and C denotes non-housing consumption. $1-\beta$ measures the preference for housing relative to non-housing consumption goods, and γ is the curvature of the utility function.

We assume that a riskkess bond is the only risk-free asset in this economy. The price of this bond, B, follows the deterministic process:

$$dB = rBdt. \tag{3}$$

where r is constant.

The price of the risky asset, S, follows a geometric Brownian motion:

$$dS = S\ \mu_S dt + S\ \sigma_S dZ_S. \tag{4}$$

with constant drift, μ_S, and standard deviation, σ_S.

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

$$dH = -\delta H dt, \tag{5}$$

for a given initial endowment of housing assets H_0. The agent does not observe the market price of her house, $\widetilde{P}$, and makes decisions using her own subjective value of the house, P. However, the agent has the option to pay an observation cost ϕ_o to observe the market value of the house at any given time. As long as the agent does not pay the cost, she receives no signal about the market value. After observing the market value of the house, the household decides whether to change the size of the house or not. We assume that the subjective value of the house, P, follows a geometric Brownian motion for a given initial price P_0:

$$dP = P\mu_P dt + P\sigma_P dZ_P, \tag{6}$$

where μ_P and σ_P are constant parameters. We assume that dZ_S and dZ_P present a correlation ρ_{PS}.

We assume that the misperception of the household, m^i, takes the form of a constant percentage difference between the market value and the subjective value. For simplicity, misperception can take only two values: m^l and m^h. These two values are constant over time and $m^l < 0 < m^h$. Therefore, let m^l and m^h denote overvaluation and undervaluation in house prices with probability $1 - \pi$ and π, respectively. The agent knows about the existence of house value misperception, as well as the value of the paramaters m^l and m^h, and the probability π.

Let W denote the value of the agent's subjective wealth in units of non-housing consumption. Wealth is composed of investments in financial assets and the subjective value of the current housing stock:

$$W = B + \Theta + HP, \tag{7}$$

where B is the wealth held in the riskless asset and Θ is the amount invested in the risky asset.

The agent decides how long to remain without acquiring information, τ. Once the agent pays the cost to acquire the information, $\phi_o PH$, the true market value is revealed and she has to change the size of the house or to stay in the same house for another period τ until the next acquisition of information. If the household moves to a new house, she incurs a transaction cost that is proportional to the value of the house that she is selling, $\phi_a PH$. The agent also makes her consumption and portfolio decisions using her subjective valuation while she has no other information on the market value of the house. The evolution of wealth is

$$\begin{aligned} dW &= [r(W - HP) + \Theta(\mu_S - r) + (\mu_P - \delta)HP - C]dt \\ &\quad + (\Theta\sigma_S + HP\rho_{PS}\sigma_P)dZ_S + HP\sigma_P\sqrt{1 - \rho_{PS}^2}dZ_P. \end{aligned} \tag{8}$$

The value function of the problem for acquiring information is:

$$\begin{aligned} V(W, H, P) = \max_{C,\Theta,H',\tau} E \Bigg[&\int_0^\tau u(C, He^{-\delta t})dt \\ &+ \mathbb{I}_{H'>H} e^{-\rho\tau} \left[\pi V\left(W(\tau), He^{-\delta\tau}, P(\tau)\right) + (1-\pi)\widetilde{V}\left(W(\tau), H(\tau), P(\tau)\right)\right] \\ &+ \mathbb{I}_{H'<H} e^{-\rho\tau} \left[(1-\pi) V\left(W(\tau), He^{-\delta\tau}, P(\tau)\right) + \pi\widetilde{V}\left(W(\tau), H(\tau), P(\tau)\right)\right]\Bigg], \end{aligned} \tag{9}$$

where the wealth at the information acquisition time is $W(\tau) = W(\tau^-) - \phi_o P(\tau^-)H(\tau^-) + m^i P(\tau^-)H(\tau^-)$, the price at the information acquisition time is $P(\tau) = P(\tau^-)(1+m^i)$, the housing stock at the information acquisition time is $H(\tau) = H'$, and the housing stock right before the information acquisition time is $H(\tau^-) = He^{-\delta\tau}$.

Moreover, if the agent adjusts housing to a new housing stock H', then the new wealth at the housing transaction time is $W(\tau) = W(\tau^-) - \phi_a P(\tau^-)H(\tau^-) - \phi_o P(\tau^-)H(\tau^-) + m^i P(\tau^-)H(\tau^-)$ and $\widetilde{V}$ is the indirect utility of adjusting housing.

4 Equilibrium of the Model

Equilibrium is defined as a set of allocations $H(t), B(t), \Theta(t)$, and $C(t)$, a policy function that describes the optimal timing of acquisition of information τ, such that the household maximizes her lifetime utility and the period-by-period budget constraint is satisfied.

The value function of this problem, $V(W(t), H(t), P(t))$, satisfies the following Hamilton-Jacobi-Bellman (HJB) partial differential equation

$$\sup_{C,\Theta,H',\tau} E\left(dV\left(W,H,P\right) + u\left(C,H\right)dt\right) = 0. \tag{10}$$

We can use the homogeneity properties of the value function to formulate the problem in terms of the financial wealth-to-housing ratio, $z = \widetilde{W}/(PH) = (\Theta + B)/(PH)$, as follows:

$$V(W,H,P) = \bar{V}(\widetilde{W},H,P) = H^{1-\gamma}P^{\beta(1-\gamma)}\ \bar{V}\left(\frac{\widetilde{W}}{PH},1,1\right) = H^{1-\gamma}P^{\beta(1-\gamma)}v\left(z\right). \tag{11}$$

This formulation simplifies the problem to just solving for $v(z)$. The homogeneity properties are shared by V, which allows us to use 11 in the solution of the problem at the boundary, where the agent decides to acquire information and potentially to adjust housing. Furthermore, let c denote the scaled control $c = C/(PH)$ and θ the scaled control $\theta = \Theta/(PH)$.

The financial wealth-to-housing ratio, z, is the only state variable of this problem. The optimal timing for re-balancing wealth composition and the size of housing and non-housing adjustments are determined by the state variable z. A solution for the equilibrium of the model consists of a value function $v(z)$ defined on the state space, where boundaries $\underline{z}_o$ and $\overline{z}_o$ define an inaction region for the information acquisition problem, while $\underline{z}_a$ and $\overline{z}_a$ are the boundaries for adjusting housing and z_H^* is the optimal return point. Finally, the consumption and portfolio policy c^* and θ^* are defined on $(\underline{z}_o,\ \overline{z}_o)$. The function $v(z)$ satisfies the Hamilton-Jacobi-Bellman equation on the inaction region. Value matching and smooth pasting conditions hold at the two sets of upper and lower boundaries, and an optimality condition holds at the return point.

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

1. *$v(z)$ satisfies*

$$\widetilde{\rho} v(z) = \sup_{c,\theta} \left\{ u(c) + \mathcal{D}v(z) \right\}, \quad z \in (\underline{z}_o, \overline{z}_o), \tag{12}$$

where

$$\begin{aligned}\mathcal{D}v(z) =& (z(r + \delta - \mu_P + \sigma_P^2(1 + \beta(\gamma - 1))) \\ &+ \theta(\mu_S - r - (1 + \beta(\gamma - 1))\rho_{PS}\ \sigma_S\sigma_P) - c)v_z(z) \\ &+ \frac{1}{2}(z^2\sigma_P^2 - 2z\hat{\theta}\ \rho_{PS}\ \sigma_P\sigma_S + \theta^2\sigma_S^2)v_{zz}(z),\end{aligned} \tag{13}$$

$$v(z) = M\frac{(z + 1 - \phi_a - \phi_0)^{(1-\gamma)}}{1-\gamma}, \quad z \notin (\underline{z}_a, \overline{z}_a) \tag{14}$$

and M is defined as

$$M = (1-\gamma)\sup_{z \geq \epsilon}(z+1)^{\gamma-1}v(z), \tag{15}$$

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

$$v(z^*) = M\frac{(z_a^* + 1)^{(1-\gamma)}}{1-\gamma}. \tag{16}$$

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

$$v(z) = \pi v\left(\frac{\overline{z}_o}{1+m^h} + 1 - \phi_o\right) + (1-\pi)M\frac{(\overline{z}_a + 1 - \phi_a - \phi_o)^{(1-\gamma)}}{1-\gamma}, \tag{17}$$

$$v(z) = (1-\pi)v\left(\frac{\underline{z}_o}{1+m^l} + 1 - \phi_o\right) + \pi M\frac{(\underline{z}_a + 1 - \phi_a - \phi_o)^{(1-\gamma)}}{1-\gamma} \quad if \quad z > 0,$$

$$v(z) = \pi v\left(\frac{\underline{z}_o}{1+m^h} + 1 - \phi_o\right) + (1-\pi)M\frac{(\underline{z}_a + 1 - \phi_a - \phi_o)^{(1-\gamma)}}{1-\gamma} \quad if \quad z \leq 0, \tag{18}$$

where $\overline{z}_a = \overline{z}_o/(1+m^l)$*,* $\underline{z}_a = \underline{z}_o/(1+m^h)$ *if* $z > 0$ *and* $\underline{z}_a = \underline{z}_o/(1+m^l)$ *if* $z \leq 0$*.*

4. Given a financial wealth-to-housing ratio z *in the area* $(\underline{z}_o, \overline{z}_o)$*, the agent chooses a optimal consumption* $c^*(z)$ *and portfolio* $\theta^*(z)$ *and* $b^*(z)$

$$c^*(z) = \left(\frac{v_z(z)}{\beta}\right)^{1/(\beta(1-\gamma)-1)}, \tag{19}$$

$$\theta^*(z) = -\omega\frac{v_z(z)}{v_{zz}(z)} + \frac{\rho_{PS}\sigma_P}{\sigma_S}z, \tag{20}$$

$$b^*(z) = z - \theta^*(z), \tag{21}$$

for the constant ω *defined as* $\omega = [\mu_S - r + (1-\beta(1-\gamma))\rho_{PS}\sigma_P]/\sigma_S^2$*.*

Figure 3 uses a simple setup to provide intuition on the equilibrium of the model. Consider an agent who has a total wealth-to-housing ratio determined by the price of her house $P(0)$, the size of her house $H(0)$, and her non-housing wealth at the initial time (i.e., initial point $P(0)$ in Figure 3). The agent must pay a transaction cost every time she moves to a bigger or smaller house and also an observation cost every time she decides to learn the market value of her house. Therefore, she does not continuously update the house and she does not pay for an appraisal until she has accumulated a sufficient amount of wealth to compensate for the observation costs and, in case she decides to move, for the transaction cost. When her subjective wealth-to-housing ratio, that is, the solid line in the figure, reaches the upper boundary of the inaction region for information acquisition (point $P(\tau)$), the agent pays the observation cost, observes the market house price and decides whether to sell the house and purchase another house. If the agent overvalues her house, she learns that the price of her house is not $P(\tau)$ but $P(\tau) + m^l$, where $m^l < 0$. Therefore, her wealth-to-housing ratio increases and hits the upper boundary for adjusting housing. As a result,

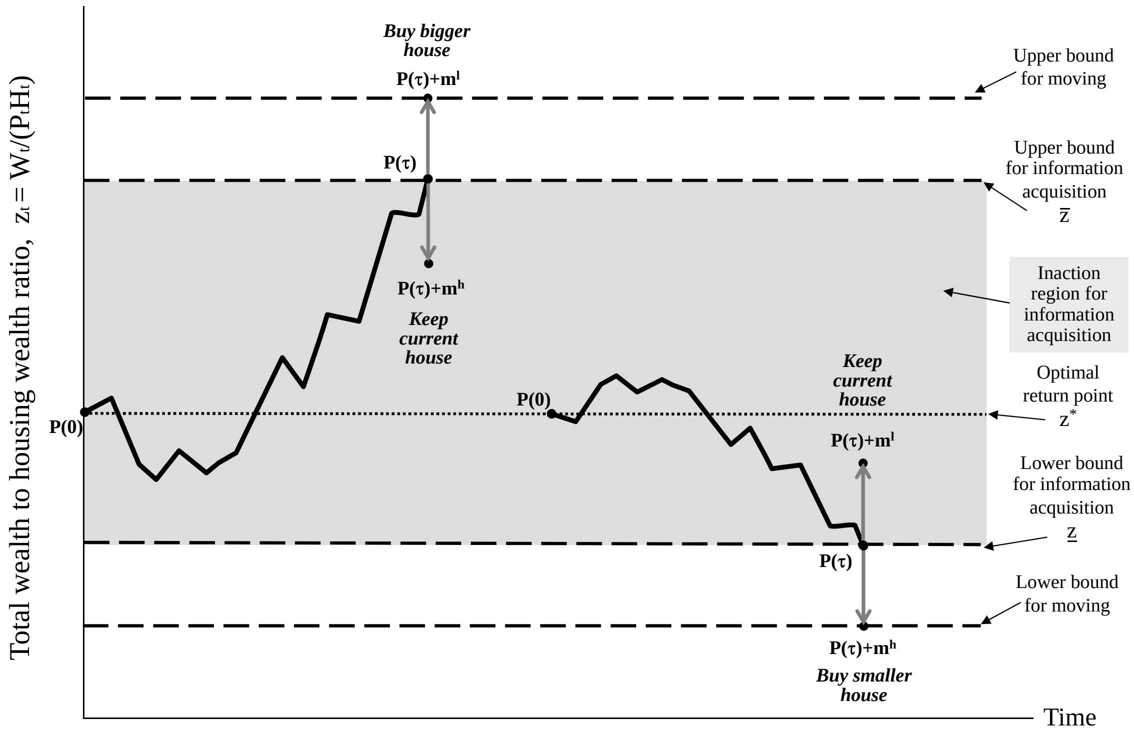

Figure 3: **Mechanism of the model.** The figure plots two hypothetical paths of the agent's subjective wealth-to-housing ratio. The agent will not acquire information about her house price if this ratio lays within the inaction region for information acquisition. When her wealth-to-housing ratio reaches the upper or lower boundary of this inaction region, then the agent pays the information acquisition cost and learns about her market house price, which can be lower by an amount m^l (with $m^l < 0$) or higher by an amount m^h (with $m^l > 0$). If her wealth-to-housing ratio is on the upper bound for information acquisition and she learns that the market price is lower than her subjective price, then she would buy a bigger house. However, if she learns that the market price is lower than her subjective price, then she would keep the current house. These results are symmetric for the lower bound for information acquisition.

she moves to a bigger house to increase her housing holdings. Oppositely, if the agent undervalues her house, then she learns that the price of her house is not $P(\tau)$ but $P(\tau)+m^h$, where $m^h > 0$. In this case, her wealth-to-housing ratio decreases, she remains in the inaction region for information acquisition, and she keeps her current house.

The effects are symmetric for the lower boundary of information acquisition. Consider the second wealth-to-housing process in Figure 3 that starts with the price of her house $P(0)$ after the agent moved to a new house. This process evolves over time until it reaches the lower boundary for information acquisition (point $P(\tau)$) and the agent pays the observation cost. She observes the market house price and decides whether to sell the house and purchase another one. If the agent overvalues her house and she learns that the price of her house is $P(\tau) + m^l$, then her wealth-to-housing ratio increases and she remains in the inaction region for information acquisition. As a result, she keeps her current house because it is small enough relative to her level of wealth. Oppositely, if the agent undervalues her house, then she learns that the price of her house is $P(\tau) + m^h$. Therefore, her wealth-to-housing ratio decreases and hits the lower boundary for adjusting housing, which causes her to move to a smaller house.

5 Numerical Results and Testable Implications of the Model

The problem described and analyzed in Sections 3 and 4 cannot be solved in closed-form. Therefore, we implement a numerical approach to derive the solution of this optimal control problem. We use the numerical results of the model to provide the main testable implications of the model.

Table 2 reports the parameters that we use for the benchmark calibration of the model. Regarding the parameters of the utility function, we assume a curvature of the utility function γ of 2, a rate of time preference ρ equal to 2.5%, and a degree of house flow services $1 - \beta$ equal to 40%. We set the annual risk-free rate to 1.5% and the drift and standard deviation of the risky asset to 7.7% and 16.55%, respectively. These figures are consistent with the long-term return and standard deviation of U.S. aggregate stock indices. We assume that the transaction cost of adjusting housing ϕ_a is 6% of the total value of the house, while the information cost ϕ_o is 1%. We set the physical depreciation rate of the house at 2%.

We also assume that the standard deviation of the house price growth is equal to 12.5%. We also parameterize the housing value misperception as a constant proportion of the value of the house, up 5% and down 5% for households that undervalue and overvalue their home, respectively. The parameter σ is calibrated such that the unconditional standard deviation of our house price growth process is equal to 12.5%. Thus, σ is set to 0.124. With this, we argue that our results are not driven by an inherently riskier process, but by risk aversion. Finally, Table 2 sets the conditional probability of overvaluation for the benchmark case at 50%. Therefore, the conditional probability of undervaluation is also 50%.

In the remainder of this section, we introduce the main predictions of the model on risky stock holdings (Subsection 5.1), consumption (Subsection 5.2), risk-free holdings and leverage (Subsection 5.3), as well as housing holdings and housing adjustments (Subsection 5.4).

Table 2: **Parameters used for benchmark calibration.**

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
Housing stock depreciation	δ	0.02
Transaction cost	ϕ_a	0.06
Information cost	ϕ_o	0.01
Risky asset drift	μ_S	0.077
Standard deviation risky asset	σ_S	0.165
Correlation house price - risky asset	ρ_{PS}	0.25
Standard deviation house price	σ_P	0.125
House price drift	μ_P	0.03
Overvaluation	m_H	5%
Undervaluation	m_L	−5%
Probability	π	0.5

5.1 Risky stock holdings: Model predictions

What are the effects of house value misperception on the risky stock holdings? To answer this question, we first compare the risky stock portfolio holdings of an agent who is more likely to overvalue her house, with the risky stock portfolio holdings of an agent who is more likely to undervalue it. The top panel of of Figure 4 shows the share of wealth invested in risky stocks of an agent who overvalues with the share of risky stocks of an agent who undervalues. Specifically, the dotted line represents a household with a probability of undervaluing of 75% ($\pi = 75\%$, while the dashed line represents a household with a probability of overvaluing their house of 75% ($\pi = 25\%$). The solid line shows the results of the model with the benchmark parametrization of Table 2

The bottom panel of Figure 4 describes the optimal risky stock portfolio choices when households are subject to a more disperse distribution of misperception. The figure shows that the risky holdings in a model with costly acquisition of information are lower than in a Grossman-Laroque for any level of wealth to housing ratio. In addition, the model predicts that the higher the misperception dispersion, the lower the risky asset holdings. Finally, the bottom panel also illustrates the fact that the inaction region is narrower, as the edges of both the solid and the dashed lines determine the information boundaries.

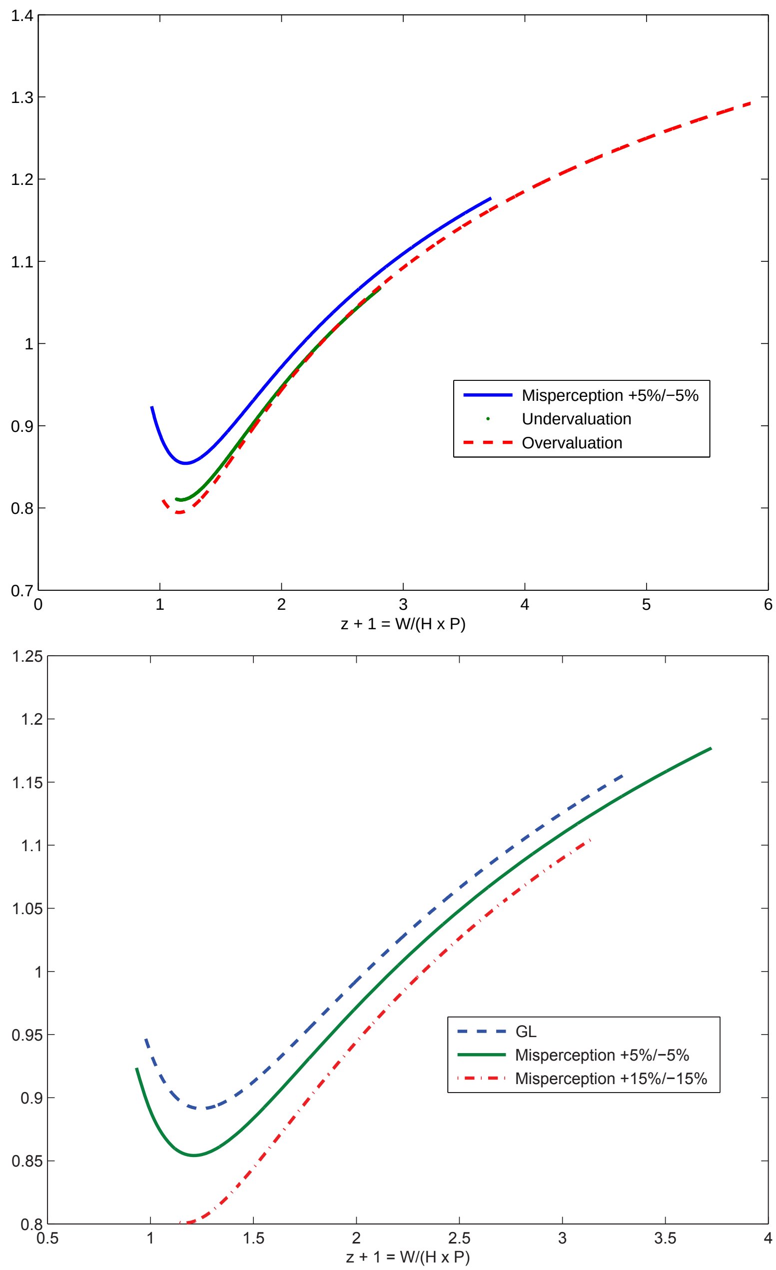

Figure 4: **Risky stock holdings and misperception.** Share of wealth invested in risky holdings, $\theta(z_t)/(z_t + 1)$ as a function of the wealth to housing ratio, $z_t + 1$. In the top panel, the benchmark model with misperception +5%/-5% is represented in solid line, the dashed line corresponds to a household that is more likely to overvalue (lower π), and the dotted line corresponds to a household that is more likely to undervalue (higher π). In the bottom panel, the solid line represents our benchmark model with misperception +5%/-5%, the dashed and dotted line represents the same model with misperception +10%/-10%, and the dashed line represents a model with costless information (no misvaluation) equivalent to the Grossman-Laroque (GL) benchmark model.

The bottom panel of Figure 4 In this particular case, we show the policy function for the share of risky stock holdings when misperception can be up to 5% versus the case in which misperception can be up to 15%. This result is a direct implication of a higher risk aversion that the households experience when misperception is more volatile. In addition, the inaction region also becomes narrower. This result also implies that households acquire information more often as misperception becomes wider.

The lower boundary is the value of the wealth-to-housing ratio z at which the household acquires information to evaluate whether to downsize the house or not. If the probability of overvaluing is higher (dashed line), it is more likely that the agent does not downsize after the information is revealed. In this case, risk aversion is higher relative to a situation where the probability of overvaluing is lower, for a given value of wealth. Therefore, we observe less risky stock holdings for households who are more likely to overvalue around the lower boundary. On the other hand, because the inaction region is larger in the overvaluation case, the agent is holding more risky stocks for high levels of financial wealth relative to the housing holdings.

5.2 Consumption: Model predictions

The equilibrium of the model provides the consumption of non-housing goods or numeraire consumption. Therefore, we can analyze the effect of misperception in house prices on the consumption. Figure 5 shows the numeraire consumption as a function of the wealth-to-housing ratio. The top panel of Figure 5 shows that higher probability of overvaluation (equivalently, lower undervaluation) leads to lower consumption. This effect is stronger for low values of the wealth-to-housing ratio, that is, closer to the lower boundary of the inaction region and it is weaker for high values of the wealth-to-housing ratio, that is, closer to the upper boundary. Note that the higher the overvaluation probability, the higher the upper boundary of the inaction region. Therefore, the highest values of numeraire consumption occur in cases in which the agent is more likely overvalue her house and presents a high value of wealth-to-housing ratio.

The bottom panel shows that if the acquisition of information is costly, then the agent consumes less goods than in an economy with no information costs. The argument is analogous to the one for the earlier results on risky stock holdings. For any given level of wealth, the higher the dispersion in misperception, the higher the risk aversion. As a result, nonhousing consumption is lower.

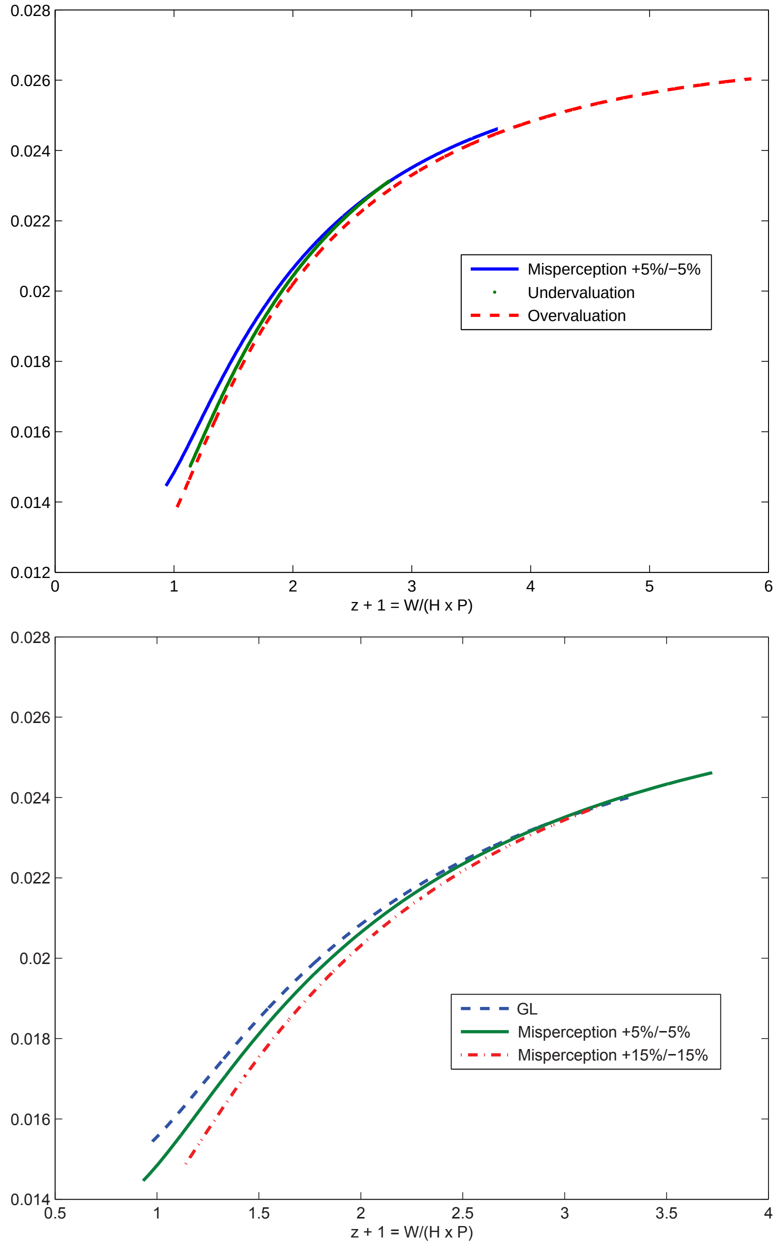

Figure 5: **Consumption and mispeception.** Numeraire consumption, $c(z_t)/(z_t+1)$, as a function of wealth to housing ratio, z_t+1. In the top panel, the benchmark model with misperception +5%/-5% is represented in solid line, the dashed line corresponds to a household that is more likely to overvalue (lower π), and the dotted line corresponds to a household that is more likely to undervalue (higher π). In the bottom panel, the solid line represents our benchmark model with misperception +5%/-5%, the dashed and dotted line represents the same model with misperception +10%/-10%, and the dashed line represents a model with costless information (no misvaluation) equivalent to the Grossman-Laroque (GL) benchmark model.

5.3 Risk-free holdings and leverage: Model predictions

The equilibrium of the model provides the risk-free holdings and the leverage position of the agent. Figure 6 exhibits the effects of house value misperception in the risk-free holdings and the leverage of the agent. In the model, negative risk-free holdings is equivalent to a leverage position, that is, for simplicity we assume that the agent can borrow at the risk-free rate. The top panel of Figure 6 shows that a higher likelihood of overvaluation leads to lower leverage. It also shows that the higher undervaluation probability leads to lower leverage. Note also that the higher values of leverage (that is, the lower risk-free holdings) are obtained in situations of lower values of the wealth-to-housing ratio and lower likelihood of overvaluation. This means that the agents are willing to leverage up to avoid moving to a smaller house.

The bottom panel of Figure 6 shows that if the acquisition of information is costly, then the agent has less leverage than in an economy with no information costs. Therefore, the mode predicts that higher misperception dispersion leads to lower leverage. The mechanism driving these results is again risk aversion. Note also that the share of wealth invested in the risk-free holdings is always negative. This means that the agent is borrowing in all the models.

5.4 Housing holdings and housing adjustments: Model predictions

The solution of the model, as described in Section 4, consists of a policy function that takes the shape of action boundaries to: (1) acquire costly information about the market value of the house, and (2) engage in a costly housing adjustment. Figure 7 summarizes the numerical solution of the model for the policy function. The solid line in the figure shows the difference between the indirect utility function of not acquiring information and not making a housing adjustment (i.e., not moving), versus acquiring information and updating the house value and making a housing adjustment or not, depending on the sign of the misperception. When this difference goes to zero, it is optimal for the agent to pay the cost of acquiring information, which brings her to, either the housing adjustment boundary, or back into the inaction region. If the housing adjustment boundary is hit, the agent moves to a new house and the wealth to housing ratio returns to the optimal point on the dotted line.

The relevant magnitudes of the solution to this calibration of the model are summarized in

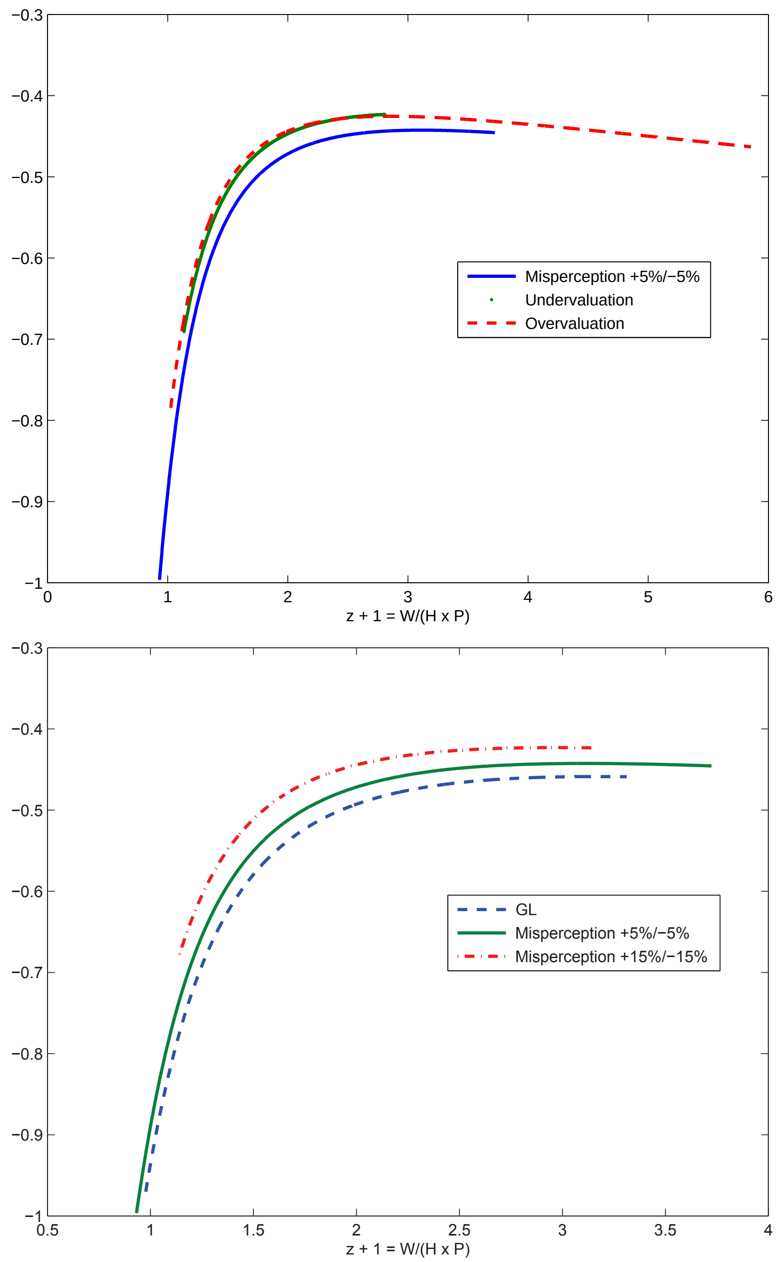

Figure 6: **Risk-free holdings, leverage and misperception.** Share of wealth invested in the risk-free holdings, $(z_t - \theta(z_t))/(z_t + 1)$, as a function of wealth to housing ratio, $z_t + 1$. Negative risk-free holdings means that the household is leveraged. In the top panel, the benchmark model with misperception +5%/-5% is represented in solid line, the dashed line corresponds to a household that is more likely to overvalue (lower π), and the dotted line corresponds to a household that is more likely to undervalue (higher π). In the bottom panel, the solid line represents our benchmark model with misperception +5%/-5%, the dashed and dotted line represents the same model with misperception +10%/-10%, and the dashed line represents a model with costless information (no misvaluation) equivalent to the Grossman-Laroque (GL) benchmark model.

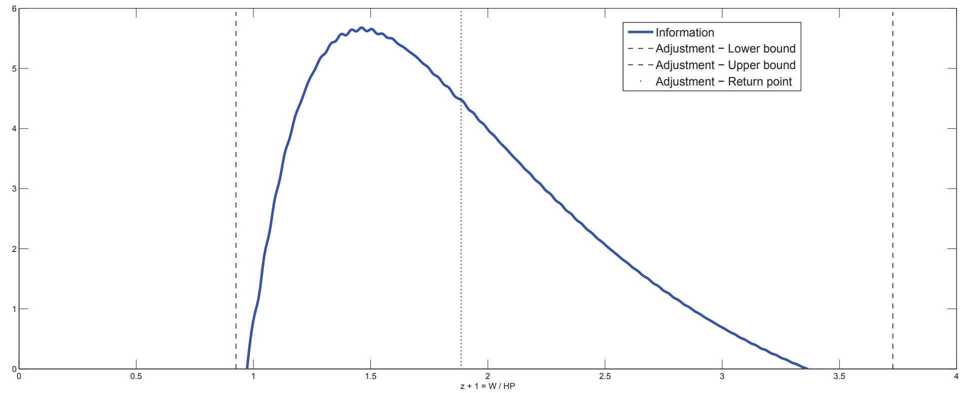

Figure 7: **The inaction regions for information acquisition and housing adjustments.** The solid line represents the values for the difference between the (scaled) value function in the continuation region and the value function of acquiring information and potentially adjusting the housing holdings. The boundaries for acquiring information lie at the points where the solid line crosses zero. The vertical dashed lines represent the boundaries for housing adjustments, that is, for moving houses. The vertical dotted line represents the optimal return point after the household moves to a new house.

Table 3. This table presents five sets of results, all in terms of values of wealth to housing ratios. The first one displays the boundaries for the case with no information acquisition costs and the same parameterization as in our benchmark case. The second row displays our benchmark results. We observe that the inaction region in the presence of costly acquisition of information is wider than in the case with perfect information. Agents move to a bigger (smaller) house when their wealth to housing ratio is higher (lower) than with perfect information. If they plan on moving to a bigger house and realize that they were undervaluing their house (m^h is realized), they do not engage in a transaction. In terms of the model, their wealth-to-housing ratio reverts back to the inaction region. An analogous argument holds for the lower boundary and agents wishing to downsize their house.

In summary, the model has a prediction on the size of the inaction region as we have seen in Table 3, the general effect is that the presence of misperception results in a larger inaction region. The model predicts that, the higher the likelihood of house overvaluation, the more often agents will acquire information, and also they will adjust housing consumption more often, everything else equal.

Moreover, we perform sensitivity analysis to the dispersion of misperception and to the probability of overvaluation. These are the same additional specifications that we used for risky holdings,

Table 3: **Acquisition of information, housing adjustments, and misperception.** Model outcomes for the information acquisition boundaries, the housing adjustment boundaries, and the return points under different parameterizations. The first row represents the equilibrium results in an economy with no information costs, and therefore no misperception. Benchmark displays the results of the model with the benchmark parameterization of Table 2, that is, with a house value misperception of +5%/-5%. Increase misperception shows the results of the benchmark model with an increase of house value misperception to +15%/-15%. Overvaluation and undervaluation represent the benchmark model with a probability of 75% of overvaluing and undervaluing, respectively.

	Adjust Lower Bound	Info. Lower Bound	Return Point	Info. Upper Bound	Adjust Upper Bound
No info. costs	-0.025		0.955		2.311
Benchmark (+5%/-5%)	-0.074	-0.070	0.885	2.432	2.867
Increase misperception	0.120	0.138	0.773	2.160	2.542
Overvaluation - $\nabla\pi$	0.022	0.023	0.709	4.855	5.111
Undervaluation - $\Delta\pi$	0.127	0.134	0.948	1.807	1.902

consumption, and leverage. The third row shows the relevant boundaries when the market value of the house can be 15% above or below the subjective valuation, as opposed to 5% in the benchmark case. The last two rows show sensitivity to the probability of being over or under evaluating. The model shows that when misperception dispersion is higher, the inaction region is overall narrower than in the benchmark case. Therefore, agents will acquire information more often than in the benchmark case. Regarding housing adjustments, households will move to a bigger house sooner, yet they will delay a downsize of the house. Finally, an increase in the probability of overvaluing has an effect of shifting up the inaction region and it does enlarge the inaction band for information acquisition. The return point is lower, which means that after changing the house, the value of the house relative to the household's wealth is higher than in the benchmark case. Differently, an increase in the probability of undervaluing has an effect of shrinking the information acquisition region and the return point is higher than in the benchmark case.

6 Empirical Results

In our empirical analysis, we use household level data from the Panel Study of Income Dynamics (PSID) from 1984 to 2013 and CoreLogic single-family detached house price index at the postal zip code level. As we have described in the previous section, the model links portfolio decisions to levels of misperception. Our objective in the empirical section is to show that the data supports the model predictions on risky asset holdings, consumption and housing size, all relative to total financial wealth. PSID contains data on asset holdings and housing wealth for individual households that are followed over time. We calculate financial wealth as the sum of an individual's house value, their second house value (net of debt), business value (net of debt), bonds and insurance assets (net of debt), stock holdings (net of debt), checking and savings balances, IRAs and annuities less the mortgage principal on the primary residence.[5] Consistent with the model, we divide the households' assets in three classes: stocks, risk-free assets, and housing holdings. Stocks include stock holdings, IRAs, and annuity holdings. Risk free assets comprise bonds, insurance (both net of debt), checking and savings balances, less the outstanding mortgage principal on the primary residence. Housing holdings are measured as the self-reported value of the home. The variables regarding financial wealth are net of debt, with the sole exception of the housing value that we use to calculate the wealth-to-housing ratio.

In Table 6, we report the descriptive statistics for the main variables that we use in the empirical analysis. As discussed in Section 2, we use two different measures of house value misperception. The first one, denoted by *overvaluation* (m^o_{it}) is defined by the difference between the subjective, self-reported value of the house in PSID and the market value constructed from CoreLogic's zipcode level home price index:

$$m^o_{i,t} = \frac{(H_i \cdot P_{i,t})^{PSID} - (H_i \cdot P_{i,t_0})^{PSID} \cdot \Delta HPI^{CL}_{zip,t_0 \to t}}{(H_i \cdot P_{i,t_0})^{PSID} \cdot \Delta HPI^{CL}_{zip,t_0 \to t}} \tag{22}$$

We observe that, on average, households tend to slightly overestimate the value of their homes, about 1.84% in our sample. The variation across households is considerably large. Second, *dispersion* (m^d_{it}) denotes the absolute value of the distance to the mean of the misperception within the zip code. This alternative measure of misperception is meant to capture the dispersion that exists within a zipcode, given by:

$$m^d_{i,t,zip} = m^o_{i,t,zip} - \frac{1}{N_{zip}} \sum_{i=1}^{N_{zip}} m^o_{i,t,zip} \tag{23}$$

The dispersion within zipcode may indicate the level of heterogeneity of information that house-

[5]For comparability across different survey waves, we exclusively focus on first mortgages.

holds in a given zipcode have. The more dispersion, the less relevant information a potential seller has. [6] Thus, the household faces more uncertainty when gathering the information about the market value of the house. A narrower range of misperception within a zipcode indicates that there may be less asymmetries in terms of information available at selling time. On average, there is a 10% dispersion in the difference between the household's misperception and the average zipcode level misperception across all zipcodes in the sample.

The state variable of the model is the wealth-to-housing ratio, z. In our sample, households' wealth is, on average, 1.6 times larger than the value of their house. Stock holdings are approximately 1.1% of financial wealth for the entire subsample but only 29.2% of households own stocks. For the selection of stockholders, stock holdings represent 4% of their financial wealth in our sample. We report statistics on stock holdings without retirement assets (IRA, 401k). The model also has implications on the household's consumption and leverage (as a fraction of their total wealth). In our sample, households consume an average of 3.6% of their net wealth annually and have debts for 7.2% of their net wealth.

Our work does not explicitly study the portfolio choices of renters. We focus our study on understanding the portfolio decisions of homeowners. In our model, renting would be equivalent to holding zero equity in a house, as in Stokey (2009). We identify the households moving to a different house in the PSID because this survey explicitly reports whether there has been a move since the previous interview. The percentage of owners who move is much lower than the percentage of renters who move. This finding is consistent with the fact that renters face lower transaction costs than homeowners. The percentage of movers to a different U.S. census region or U.S. state is also very low among owners. Finally, new homeowners represent 3.79% of the total homeowners in the PSID.

In the reminder of the section, we use the household survey data that we described above to empirically evaluate the main predictions of the model that we developed in Section 5. We evaluate the effects of misperception on shares of risky stock holdings, on household consumption, and on risk-free holdings and leverage in section. Finally, we show how housing choices depend on misperception.

Our empirical approach is also subject to endogeneity concerns. Our goal is to establish a

[6] As a result, also the buyer has less relevant information, but we are not modeling the buy side of the transactions.

Table 4: **Descriptive statistics**. Sample averages and standard deviations (in parenthesis) for the main variables used in our analysis from PSID. The first measure of misperception (m^o_{it} overvaluation) is is defined as the subjective value of the house minus its market value, in percentage points. The second measure (m^d_{it} dispersion) is defined as the absolute value of the distance to the mean of misperception within the zip code. The ratio $z = W/(P \cdot H)$ corresponds to the ratio of financial wealth net of debt over housing value. Financial wealth is the summation of individual's house value, their second house value (net of debt), business value (net of debt), other assets (net of debt), stock holdings (net of debt), checking and savings balances, IRAs and annuities less the mortgage principal on the primary residence. Stock share is the share of equity in stocks and mutual funds including (not including) equity in IRAs, equity in 401k and thrifts (retirement assets) over total financial wealth. Age corresponds to the age of the household head.

	Mean	Std. Dev	Min	Max	Obs.
m^o_{it} (overvaluation) (%)	1.843	27.267	−99.399	430.262	42,180
m^d_{it} (dispersion) (%)	10.196	15.582	0.000	357.037	42,180
z (wealth-to-housing ratio)	1.643	0.985	−2.410	4.923	20,299
Stock share (total) (%)	1.1	2.0	−5.1	5.1	20,298
Stockholders share (%)	29.2	45.5	0.000	100	20,298
Stock share (stockholders) (%)	3.8	1.8	−5.1	5.1	5,922
Net debt-to-wealth ratio	0.072	0.107	−0.356	0.419	11,339
Consumption-to-wealth ratio (%)	3.6	3.6	0.00	19.3	11,631
Age	39.739	12.559	16	100	183,055

relationship between misperception and portfolio and consumption decisions. It is very likely that some variables determine simultaneously the households' home price misperception and portfolio or consumption decisions. The panel structure of the PSID data provides us with an ideal potential candidate for an instrument for our two variables of misperception. Because homeowners self-report their house values in consecutive periods, we conjecture that reported house values in the past are correlated with the recent self-reported house values, but are uncorrelated with the disturbances in the current portfolio choices. Therefore, we use the 2-year lagged misperception as the IV for misperception.[7] This instrument has a strong first stage because past misperception is highly correlated with the current mispercetion, conditional on the other independent variables. Moreover, this instrument satisfies the exclusion restriction because misperception in the past is not correlated with the error term in the explanatory equation, conditional on the other independent variables.

All our estimations use household level fixed effects and standard errors are clustered at the

[7] We use a 2-year lag because the PSID surveys are performed every 2 years after 1999. The use of lagged endogenous variables in IV estimations has been widely used since (Hansen and Singleton 1983). In our analysis, both measures of misperception follow a highly autoregressive process, which allows us to reject that we have a weak instrument. Our instrument also passes the standard over-identification test.

zipcode level.

6.1 Risky stock holdings: Empirical results

The model predicts that higher overvaluation results in lower risky stock holdings, as described in the top panel of Figure 4. The optimal household behavior is described in section 3. Households become more risk averse with more overvaluation, which results in a lower share of risky investment. In addition, the bottom panel of Figure 4 shows that the more disperse is the misperception, the lower the risky stock holding. We run the following specification:

$$\frac{\theta_{it}}{z_{it}} = \gamma_0 + \gamma_1 \cdot z_{it} + \gamma_2 \cdot m_{it} + \gamma_3 \cdot z_{it} \cdot m_{it} + \Gamma \cdot X_{it} + u_{it}, \tag{24}$$

where z_{it} is the fraction of housing wealth to total wealth; m_{it} represents the two different measures associated with misperception, *overvaluation* and *dipersion* as defined above, and X_{it} is a vector of controls. We control for ex ante changes in the housing stock for reasons not related to the wealth-to-housing ratio such as changes in employment status, family size and marital status, all included in X_{it}.[8]

Table 5 reports the results of this test. In particular, Panel A shows the results of the relationship between risky assets holding and misperception. The empirical results support the implied relationship displayed in the top panel of Figure 4. Panel B shows the results of the same regressions, using *dispersion*. Columns (1)-(3) in both panels use the whole sample in PSID while columns (4)-(6) use the subsample of households who report positive stock holdings. There are differences in the results across subsamples, but the signs remain consistent across subsamples. The bias imposed by the households who do not participate in the stock market washes out the effects of misperception. We only obtain significant results when we restrict our sample to stockholders. On the contrary, all the signs are as expected in the specifications limited to stockholders. The sign on misperception, by any of the three measures, is negative, implying that more misperception is associated with lower risky stock holdings. The economic interpretation is not negligible, considering

[8]The goal is to identify those moves that are triggered by the evolution of wealth and house prices and control for those moves that result from an increase or decrease in family size alone, such as births, deaths, divorces, and emancipations. The identification is not perfect, as having children may be correlated with the wealth level, but the results are robust to the inclusion or exclusion of changes in family size. This parameter also includes age and gender of the head of the household.

Table 5: **Risky stock holdings and misperception.** This table shows the effects of misperception on risky stock holdings. The dependent variable for all the specifications is the share of risky stock holdings over total wealth. m_{it} represents the measure of misperception. In Panel A, misperception is the difference between the subjective valuation and the market value of the house measured at the zip code level. In Panel B, misperception is measured as the absolute value of the distance to the mean of the misperception within the zip code. Columns 1-3 include all households in the sample while columns 4-6 only include stockholders. Columns 1, 2, 4, & 5 show the results from OLS regressions that include fixed effects and cluster the errors at the zip code level. Column 3 & 6 shows the equivalent results when using the IV.

Panel A: Misperception (overvaluation)

	All households			Only stockholders		
	OLS [1]	OLS [2]	IV [3]	OLS [4]	OLS [5]	IV [6]
m_{it}	-0.00026	-0.00095	0.00148	-0.00338	-0.00795^{***}	-0.00156
	[-0.28]	[-0.65]	[0.63]	[-1.61]	[-1.99]	[-0.35]
z		0.00360^{***}	0.00675^{***}		0.00112^{*}	0.00230^{***}
		[9.87]	[32.36]		[1.82]	[7.99]
$m_{it} * z$		0.00082	-0.00077		0.00238	-0.00090
		[1.03]	[-0.73]		[1.62]	[-0.55]
constant	0.26113^{***}	0.25535^{***}	0.40848^{***}	-0.04626	-0.03433	0.04908
	[2.90]	[2.91]	[7.20]	[-0.20]	[-0.15]	[0.53]
R^2	53.22%	54.32%	13.42%	56.98%	57.18%	5.50%
Obs.	13,275	13,275	11,092	4,198	4,198	3,683

Panel B: Misperception (dispersion)

	All households			Only stockholders		
	OLS [1]	OLS [2]	IV [3]	OLS [4]	OLS [5]	IV [6]
m_{it}	-0.00197	-0.00041	-0.00098	-0.00468	-0.01073^{*}	-0.00364
	[-1.35]	[-0.20]	[-0.23]	[-1.48]	[-1.88]	[-0.51]
z		0.00367^{***}	0.00702^{***}		0.00078	0.00240^{***}
		[8.92]	[21.12]		[1.15]	[5.39]
$m_{it} * z$		-0.00076	-0.00154		0.00287	0.00054
		[-0.75]	[-0.87]		[1.39]	[0.22]
constant	0.24391^{***}	0.24177^{***}	0.38058^{***}	-0.09109	-0.07679	0.04062
	[2.68]	[2.72]	[6.56]	[-0.38]	[-0.33]	[0.43]
R^2	53.23%	54.32%	13.51%	56.94%	57.14%	5.17%
Obs.	13,275	13,275	11,092	4,198	4,198	3,683

that the average stock holdings (among stockholders) is about 3.80%: an increase in misperception by 1% results in a new share of risky holdings of 3.01% or 3.64% when the misperception is instrumented with lagged values. Panel B, where the measure of misperception is the dispersion within zipcode shows similar results. An increase in the dispersion measure of 1% results in risky shares ranging from 2.73% to 3.34% when using lagged dispersion as an instrument. The results are much weaker for the whole sample (including both stock holders and non stock holders).

6.2 Consumption: Empirical results

According to the model, households with a higher level of misperception tend to have lower levels consumption for a given value of wealth-to-housing ratio, which determines the state of the household. Figure 5 shows the model results relative to consumption and in Table 6 we present the empirical counterpart. To test the model implications described in Section 5.2, we estimate the following empirical relationship:

$$\frac{C_{it}}{z_{it}} = \gamma_0 + \gamma_1 \cdot z_{it} + \gamma_2 \cdot m_{it} + \gamma_3 \cdot z_{it} \cdot m_{it} + \Gamma \cdot X_{it} + u_{it}, \tag{25}$$

where m_{it} represents misperception according to the two measures described above, z_{it} is the wealth-to-housing ratio, and X_{it} is the same set of controls that have been used in the previous estimation.

The signs on m_{it} are all negative and significant for any of the two definitions of misperception, in panel A and B, respectively, and for the three specifications in columns (1)-(3). The results are also economically significant and show that consumption is much more sensitive to misperception than investments in risky assets. As a result of a 1% increase in misperception, consumption-to-wealth ratio decreases to 1.42% with no instruments in the regression (column (2) of panel A), or slightly higher, 2.36% when we instrument misperception in column (3). Changes in misperception measured as the dispersion within zipcode have a similar effect on consumption. Column (1) shows that a 1% increase in dispersion results in a consumption ratio of 2.34%, in column (2) with no instruments, and an even lower 2.14% when we use instruments in column (3). Unlike in the previous results, we do not differentiate between stockholders and non stockholders for the consumption results.

6.3 Risk-free holdings and leverage: Empirical results

The model predicts that higher misperception leads to lower leverage. Figure 6 and the analysis in Section 5.3 indicates that leverage decreases as a result of an increase in misperception (i.e., negative risk-free holdings are less negative). We use for this purpose a reduced form approach

Table 6: **Consumption and misperception.** This table shows the effects of misperception on consmpion. The depedent variable for all the secifications is the ratio of consumption to total wealth. m_{it} represents the measure of misperception. In Panel A, misperception is the difference between the subjective valuation and the market value of the house measured at the zip code level. In Panel B, misperception is measured as the absolute value of the distance to the mean of the misperception within the zip code. The table includes all households in the sample. Columns 1 and 2 are OLS specifications that include fixed effects and cluster errors at the zip code level. Column 3 reports the equivalent results when using the IV.

Panel A: Misperception (overvaluation)

	OLS [1]	OLS [2]	IV [3]
m_{it}	-0.01562^{***}	-0.02428^{***}	-0.01242^{***}
	[−8.94]	[−8.73]	[−2.90]
z		-0.00988^{***}	-0.01049^{***}
		[−19.52]	[−26.66]
$m_{it} * z$		0.00407^{***}	-0.00254
		[4.22]	[−1.40]
constant	0.82885^{***}	1.18324^{***}	1.71830^{***}
	[2.86]	[4.40]	[6.33]
R^2	80.01%	82.58%	19.52%
Obs.	8,028	8,028	6,976

Panel B: Misperception (dispersion)

	OLS [1]	OLS [2]	IV [3]
m_{it}	-0.00651^{***}	-0.01260^{***}	-0.01456^{*}
	[−2.78]	[−3.64]	[1.88]
z		-0.01034^{***}	-0.00970^{***}
		[−17.73]	[−15.01]
$m_{it} * z$		0.00388^{***}	-0.00153
		[3.20]	[−0.48]
constant	1.03507^{***}	1.43739^{***}	2.33263^{***}
	[3.52]	[5.26]	[8.50]
R^2	79.38%	81.76%	16.37%
Obs.	8,028	8,028	6,976

similar to the one in the previous sections:

$$\frac{B_{it}}{z_{it}} = \gamma_0 + \gamma_1 \cdot z_{it} + \gamma_2 \cdot m_{it} + \gamma_3 \cdot z_{it} \cdot m_{it} + \Gamma \cdot X_{it} + u_{it}, \tag{26}$$

Table 7 exhibits the results of the tests for risk-free holdings and leverage. The results are not significant for all measures of misperception. They are only significant for misperception measured as the percentage deviation from the average misperception within a zip code. And, in this case, the economic significance is substantial. A 1% increase in house overvaluation results in a decrease of leverage of 14%, turning leverage negative (i.e., net lending of 7.4%, when using the specification with instrumental variables. Although not statistically significant, the specification in which misperception is measured as the difference between subjective and market values yield more conservative results. A 1% increase in misperception leads to a decrease of leverage to an average of 3.20% when using instruments for misperception.

6.4 Housing holdings and housing adjustments: Empirical results

The model predicts that the higher the misperception, the lower the housing holdings. Table 3 in Section 5.4 shows that the housing holdings are lower at the return point and also at the boundaries with respect to the benchmark with no misperception. We employ the following reduced form model to test this hypothesis:

$$z_{it} = \gamma_0 + \gamma_1 \cdot m_{it} + \Gamma \cdot X_{it} + u_{it}, \tag{27}$$

Table 8 reports the results of the reduced form estimation introduced in equation (27). We use the two measures of misperception that have been previously described. Results are in line with the model predictions as well, but only when we use misperception as the overvaluation -dispersion does not have a significant effect on housing holdings. As misperception increases, the overall share of housing wealth to total wealth is lower. A 1% increase in misperception leads to a ratio of housing to wealth of 31.76%, down from 60.86% of housing holdings on average, when using instruments (Column 2). In this specification, the instrumental variable plays a significant role. The results in Panel A are substantially different with and without IV, highlighting the necessity of addressing the endogeneity that may arise throughout our empirical analysis. Results in column 1, with no instruments, are less substantial: the same 1% increase in misperception decreases the housing share in wealth from 60.86% to 54.40%.

Table 7: **Leverage and misperception.** This table reports the effects of misperception on leverage. The dependent varable for all the specifications is the ratio of borrowing to total wealth. m_{it} represents the measure of misperception. In Panel A, misperception is the difference between the subjective valuation and the market value of the house measured at the zip code level. In Panel B, misperception is measured as the absolute value of the distance to the mean of the misperception within the zip code. Columns 1-3 include all households in the sample while columns 4-6 only include stockholders. Columns 1, 2, 4, & 5 include fixed effect and cluster the errors at the zip code level. Column 3 & 6 show the equivalent results when using the IV.

Panel A: Misperception (overvaluation)

	All households			Only stockholders		
	OLS	OLS	IV	OLS	OLS	IV
	[1]	[2]	[3]	[4]	[5]	[6]
m_{it}	-0.02541^{***}	-0.02390	0.01544	-0.03881^{***}	-0.00900	0.04004
	[−3.63]	[−1.57]	[0.79]	[−2.76]	[−0.31]	[1.11]
z		-0.02793^{***}	-0.03063^{***}		-0.03777^{***}	-0.04433^{***}
		[−8.85]	[−14.81]		[−6.05]	[−13.29]
$m_{it} * z$		-0.00367	-0.02425^{***}		-0.02612	-0.06096^{***}
		[−0.48]	[−2.86]		[−1.44]	[−3.05]
constant	-2.98687^{***}	-2.90847^{***}	-2.37786	1.33181	1.51727	1.63326
	[−4.05]	[−3.97]	[−1.47]	[0.80]	[0.90]	[0.70]
R^2	57.71%	59.65%	9.66%	68.49%	70.51%	14.13%
Obs.	7,883	7,883	3,517	3,857	3,857	2,062

Panel B: Misperception (dispersion)

	All households			Only stockholders		
	OLS	OLS	IV	OLS	OLS	IV
	[1]	[2]	[3]	[4]	[5]	[6]
m_{it}	-0.00019	-0.07942^{***}	-0.00094^{***}	-0.00047^{*}	-0.17124^{***}	-0.00196^{***}
	[−1.50]	[−2.94]	[−2.85]	[−1.73]	[−3.90]	[−3.61]
z		-0.03308^{***}	-0.03806^{***}		-0.05159^{***}	-0.05819^{***}
		[−10.69]	[−11.66]		[−9.14]	[−10.76]
$m_{it} * z$		0.03842^{***}	0.00049^{***}		0.09920^{***}	0.00112^{***}
		[2.98]	[3.66]		[4.03]	[4.39]
constant	-3.11020^{***}	-3.01933^{***}	-1.36181	1.12387	1.38313	3.42084
	[−4.17]	[−4.10]	[−0.86]	[0.68]	[0.85]	[1.47]
R^2	57.56%	59.69%	9.55%	68.36%	71.01%	12.96%
Obs.	7,883	7,883	3,517	3,857	3,857	2,062

Table 8: **Housing holdings and misperception:** This table shows the effects of misperception on housing holdings. The dependet variable for all the specificaitons is the wealth-to-housing ratio, z_{it}. m_{it} represents the measure of misperception. In Panel A, misperception is the difference between the subjective valuation and the market value of the house measured at the zip code level. In Panel B, misperception is measured as the absolute value of the distance to the mean of the misperception within the zip code. Column 1 reports the OLS specification that include fixed effects and cluster errors at the zip code level. Column 2 shows the equivalent results when using the IV.

Panel A: Misperception (overvaluation)

	OLS [1]	IV [2]
m_{it}	-0.06462	-0.29109^{***}
	[-0.77]	[-5.40]
constant	48.84472^{***}	68.83824^{***}
	[3.84]	[5.76]
R^2	73.16%	10.94%
Obs.	7,055	5,989

Panel B: Misperception (dispersion)

	OLS [1]	IV [2]
m_{it}	0.14483	0.11343
	[1.06]	[1.15]
constant	51.00041^{***}	67.16637^{***}
	[3.98]	[6.03]
R^2	73.17%	10.67%
Obs.	7,055	5,989

7 Conclusions

House price misperception affects the optimal behavior of households. When households tend to overvalue, they invest less in risky stocks, they consume less, they have lower leverage, and house wealth is also lower.

To reach these conclusions, this paper extends the seminal work in Grossman and Laroque (1990) by considering that households may overestimate or underestimate the value of their houses. We document important differences in the magnitude of house value misperception across U.S. states. In our model, households find costly to acquire information on the market value of their house and thus overestimate or underestimate. The existence of misperception affects their consumption and portfolio choice decisions. The model shows that this behavior is a result of state dependent risk aversion. The driving force is that risk aversion is higher the higher the potential for house overvaluation, for any given level of wealth.

Empirical tests using household level data confirm the main implications of the model. Our empirical results illustrate that the over- and underestimation of house values affects the likelihood of buying a new home and the households' investments in housing. We also confirm that housing price misperception has substantial effects on financial portfolios. In sum, our paper demonstrates that the effects of transaction costs and costly acquisition of information are key elements of both housing and non-housing portfolio allocation decisions. We focus on the analysis of these decisions using a partial equilibrium model that takes house value misperception as given. Studying the aggregate general equilibrium implications of house value misperception is an interesting line of future research.

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Appendix

A-I Proof of Proposition 1

A-I.1 Preliminary calculations

In this appendix, we show the proof for an economy with only a risk free asset, housing, and two types of consumption: housing and nonhousing consumption goods. We start by taking second order Taylor expansion on v around $t = \tau$ and plug it into the HJB equation:

$$\begin{aligned} v(z) &= \sup \left\{ E \left(\int_0^\tau e^{-\rho s} u(C,H)dt + e^{-\rho\tau} v(z(\tau)) \right) \right\} \\ &= \sup \left\{ E \left(\int_0^\tau e^{-\rho s} u(C,H)dt + e^{-\rho\tau} v(z) + e^{-\rho\tau} v_z dz + e^{-\rho\tau} \frac{1}{2} v_{zz} dz dz \right) \right\}, \end{aligned} \tag{A-1}$$

and Ito's lemma for dz, that is, $dz = \left[(\mu_P - \delta) + r \frac{B}{P \cdot H} - \hat{c} + z\delta - \frac{1}{2}\sigma^2 \right] dt + \sigma dZ_P$. Therefore, the HJB equation becomes:

$$\begin{aligned} \left(1 - e^{-\rho\tau}\right) v(z) = \sup \left\{ E \left(\int_0^\tau e^{-\rho s} u(C,H)dt \right) \right\} + \\ + e^{-\rho\tau} \sup \left\{ v_z \left[(\mu_P - \delta) + \frac{rB}{P \cdot H} - \hat{c} + z\delta - \frac{1}{2}\sigma^2 \right] + v_{zz} \frac{1}{2} \sigma^2 \right\}. \end{aligned} \tag{A-2}$$

A-I.2 Continuation region

In the continuation region, the HJB equation is such that:

$$\begin{aligned} & v(z_0) H_0^{1-\gamma} P_0^{\beta(1-\gamma)} \approx u(C,H)dt + \\ & e^{-\rho\tau} H_\tau^{1-\gamma} P_\tau^{\beta(1-\gamma)} \left(v(z_\tau) + dt v_z \left(\mu_P - \delta + \frac{rB}{H} - \hat{C} + z\delta - \frac{\sigma^2}{2} \right) + dt v_{zz} \frac{\sigma^2}{2} \right) \\ & \frac{v(z_0) H_0^{1-\gamma} P_0^{\beta(1-\gamma)} - e^{-\rho\tau} H_\tau^{1-\gamma} P_\tau^{\beta(1-\gamma)} v(z_\tau)}{dt} \approx u(C,H) + \\ & e^{-\rho\tau} H_\tau^{1-\gamma} P_\tau^{\beta(1-\gamma)} \left(v_z \left(\mu_P - \delta + \frac{rB}{H} - \hat{C} + z\delta - \frac{\sigma^2}{2} \right) + v_{zz} \frac{\sigma^2}{2} \right), \end{aligned}$$

and taking the limit as $dt \to 0$,

$$
\begin{aligned}
&\rho v(z) H^{1-\gamma} P^{\beta(1-\gamma)} \approx u(C,H) + \\
&\quad H^{1-\gamma} P^{\beta(1-\gamma)} \left(v_z \left(\mu_P - \delta + \frac{rB}{H} - \hat{C} + z\delta - \frac{\sigma^2}{2} \right) + v_{zz} \frac{\sigma^2}{2} \right) \\
&\rho v(z) = u(\hat{C}) + \left(v_z \left(\mu_P - \delta + \frac{rB}{H} - \hat{C} + z\delta - \frac{\sigma^2}{2} \right) + v_{zz} \frac{\sigma^2}{2} \right),
\end{aligned} \tag{A-3}
$$

which corresponds to the expression for the continuation region in the first part of the proposition.

A-I.3 Boundaries to acquire information. Case 1: The agent decides to move

The optimal return point $z^* = z(\tau)$, that is, $z(\tau)$ right after acquiring information, learning that the value of the house has grown by $1 + m^i$ and deciding to move to a different house is given by:

$$
\begin{aligned}
z(\tau) &= \frac{W(\tau)}{P(\tau)H(\tau)} = \frac{W(\tau^-) - \phi_H P(\tau) H(\tau^-) - \phi_o P(\tau) H(\tau^-)}{H(\tau)P(\tau)} = \\
&\frac{W(\tau-)}{P(\tau^-)H(\tau^-)} \frac{H(\tau^-)P(\tau^-)}{H(\tau)P(\tau)} - (\phi_H + \phi_o) \frac{H(\tau^-)}{H(\tau)} = \\
&= \frac{H(\tau^-)}{H(\tau)} \left[\frac{W(\tau-)}{P(\tau^-)H(\tau^-)} \frac{1}{1+m^i} - \phi_H - \phi_o \right] = \frac{H(\tau^-)}{H(\tau)} \left(\frac{z(\tau^-)}{1+m^i} - \phi_H - \phi_o \right)
\end{aligned} \tag{A-4}
$$

and we can use this expression to obtain the value at the return point $z^* = z(\tau)$ from the general value function:

$$
\begin{aligned}
&e^{-\rho\tau} P(\tau)^{\beta(1-\gamma)} H(\tau)^{1-\gamma} v(z(\tau)) = e^{-\rho\tau} P(\tau)^{\beta(1-\gamma)} H(\tau^-)^{1-\gamma} \left(\frac{H(\tau)}{H(\tau^-)} \right)^{1-\gamma} v \left[\frac{H(\tau^-)}{H(\tau)} \left(\frac{z(\tau^-)}{1+m^i} - \phi_H - \phi_o \right) \right] = \\
&= e^{-\rho\tau} P(\tau)^{\beta(1-\gamma)} H(\tau^-)^{1-\gamma} \left(\frac{z(\tau^-)}{1+m^i} - \phi_H - \phi_o \right)^{1-\gamma} \left(\frac{H(\tau^-)}{H(\tau)} \left(\frac{z(\tau^-)}{1+m^i} - \phi_H - \phi_o \right) \right)^{\gamma-1} \cdot \\
&\cdot v \left[\frac{H(\tau^-)}{H(\tau)} \left(\frac{z(\tau^-)}{1+m^i} - \phi_H - \phi_o \right) \right] = \\
&= e^{-\rho\tau} P(\tau)^{\beta(1-\gamma)} H(\tau^-)^{1-\gamma} \frac{M_i}{1-\gamma},
\end{aligned} \tag{A-5}
$$

where

$$
M_i \equiv (1-\gamma) \left(\frac{H(\tau^-)}{H(\tau)} \left(\frac{z(\tau^-)}{1+m^i} - \phi_H - \phi_o \right) \right)^{\gamma-1} v \left[\frac{H(\tau^-)}{H(\tau)} \left(\frac{z(\tau^-)}{1+m^i} - \phi_H - \phi_o \right) \right]. \tag{A-6}
$$

Recall $\hat{V}(W(t), H(t), P(t))$ as the value of an agent who just received the information on the value of the house and decides to move to a new house at this instant. If we use the homogeneity properties of the value function, then we obtain the following expression for the homogenized value function $\hat{v}(z(t))$ of an agent who just learnt that the value of the house has grown by $1 + m^i$ and decides to move:

$$e^{-\rho\tau^-} P(\tau^-)^{\beta(1-\gamma)} H(\tau^-)^{1-\gamma} \hat{v}(z(\tau^-)) = \max_{C(t+s)_{\forall s \in [0,\tau)}, \tau, H(\tau)} E\left[e^{-\rho\tau} P(\tau)^{\beta(1-\gamma)} H(\tau)^{1-\gamma} v(z(\tau))\right]$$

If we plug equation (A-5) and simplify terms, then we othatin that:

$$\hat{v}(z(\tau^-)) = \max_{C(t+s)_{\forall s \in [0,\tau)}, \tau, H(\tau)} E\left[(1 + m^i)^{\beta(1-\gamma)} \frac{M_i}{1-\gamma}\right] \tag{A-7}$$

A-I.4 Boundaries to acquire information. Case 2: The agent decides not to move

Recall $\bar{V}(W(t), H(t), P(t))$ as the value of an agent who just received the information on the value of the house and decides not to move to a new house at this instant. If we use the homogeneity properties of the value function, then we obtain the following expression for the homogenized value function $\bar{v}(z(t))$ of an agent who just learnt that the value of the house has grown by $1 + m^i$ and decides not to move:

$$e^{-\rho\tau^-} P(\tau^-)^{\beta(1-\gamma)} H(\tau^-)^{1-\gamma} \bar{v}(z(\tau^-)) = \max_{C(t+s)_{\forall s \in [0,\tau)}, \tau} E\left[e^{-\rho\tau} P(\tau)^{\beta(1-\gamma)} H(\tau^-)^{1-\gamma} v(z(\tau))\right]$$

After simplifying terms and solving for $\bar{v}(z(\tau^-))$ we obtain that:

$$\bar{v}(z(\tau^-)) = \max_{C(t+s)_{\forall s \in [0,\tau)}, \tau} E\left[(1 + m^i)^{\beta(1-\gamma)} \frac{\bar{M}_i}{1-\gamma}\right] \tag{A-8}$$

where

$$\bar{M}_i \equiv (1-\gamma)\left(\frac{z(\tau^-)}{1+m^i} - \phi_o\right)^{\gamma-1} v\left[\frac{z(\tau^-)}{1+m^i} - \phi_o\right]. \tag{A-9}$$