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Portfolio Choice with House Value Misperception

Stefano Corradin, José L. Fillat, and Carles Vergara-Alert

Abstract:

Households systematically overvalue or undervalue their houses. We compute house value misperception as the difference between self-reported and market house values. Misperception is sizable, countercyclical, and persistent. We find that a 1 percent increase in house overvaluation results, on average, in a 4.56 percent decrease in the share of risky stock holdings for those households that participate in the stock market. We then build a rational inattention model in which households make decisions based on their perceived level of housing wealth. Numerical simulations generate the effects of house value misperception on the portfolio choices that we observe in the data.

JEL Classifications: G11, D11, D91, R21, C61

Keywords: portfolio choice, housing, transaction costs, information costs, inaction bands, rational inattention

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Stefano Corradin is a senior economist in the Directorate General Research at the European Central Bank. His email address is stefano.corradin@ecb.int. José L. Fillat is a senior economist in the research department at the Federal Reserve Bank of Boston. His email address is jose.fillat@bos.frb.org. Carles Vergara-Alert is an associate professor of finance at the University of Navarra's IESE Business School (Barcelona). His email address is cvergara@iese.edu.

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1 Introduction

Housing represents the most important asset for most households. As such, house values play a key role in decisions about portfolio choice, consumption, savings, and retirement planning. However, households' own estimates of their house values are often not aligned with market prices. We find that 25 percent of the homeowning households in our sample undervalue their house by at least 11 percent, while 25 percent of the homeowners overvalue their house by at least 9 percent. In this paper, we study how this misalignment, which we refer to as house value misperception, and the illiquid nature of housing as an investment affect how households make other portfolio and consumption decisions.

We define house value misperception as the difference between the owner's subjective valuation of her house relative to its market value, which is adjusted for home improvements.[1] We exploit a new identification mechanism based on homeowners who just purchased a house. Our key assumption is that the house's market value is known with certainty only at the time of purchase; that is, misperception is zero at the time of purchase. After purchase, the market value of the house follows a random process that the homeowner can estimate but does not accurately observe. Using this assumption, we create a novel measure of misperception by comparing data on self-reported (subjective) housing values from the Panel Study of Income Dynamics (PSID) with market house prices constructed using zip code level transaction-based house price indexes from CoreLogic.[2] Our measure of house value misperception displays four stylized facts: (i) there exists considerable dispersion across US households in terms of how accurately they estimate house values; (ii) house value misperception is countercyclical on average and negatively related to recent housing returns experience (see

[1]Throughout the paper, we use "misperception" and "house value misperception" interchangeably. This misperception is directional: positive misperception corresponds to overvaluation and negative misperception corresponds to undervaluation. We do not consider misperception in any other asset class.

[2]We use the restricted Geospatial Data Tract Level, produced and distributed by the Survey Research Center, Institute for Social Research, University of Michigan, Ann Arbor, MI (2015). This panel dataset contains the census tract info and zip code location of each household.

Malmendier and Nagel (2011), Malmendier and Nagel (2016), and Malmendier and Steiny (2017))[3]; (iii) misperception is persistent (i.e., households that overvalue or undervalue their houses keep overvaluing or undervaluing, respectively); and (iv) misperception reverts back toward zero after about six to seven years of growth.

We also establish a new relationship between house value misperception and both the share of a household's wealth invested in risky assets (stocks) and its consumption decisions. Households that self-report higher home values with respect to the true market value invest less in risky stocks and spend less on nonhousing consumption. Using the PSID household-level data from 1984 to 2013, we find that a 1 percent increase in the measure of house price misperception leads, on the household level, to a decrease in the average share of other risky assets of 1.76 percent for all households, an average decline of 4.56 percent for stock market participants, and a decrease in the average nonhousing consumption of 2.72 percent.[4] Moreover, house price misperception has a negative effect on the extensive margin of stock market participation: a 1 percent increase in overvaluation decreases the probability of participating in the stock market by 7.91 percent on average.

After documenting the main characteristics of house value misperception and its effect on a household's portfolio choices, we are interested in understanding and quantifying the mechanism behind this effect. To do so, we develop and parameterize a partial equilibrium model of portfolio choice with house value misperception. Our model accounts for the four stylized facts of misperception described above. The model also incorporates two key frictions associated with housing assets: (i) transaction costs are high, i.e., adjusting housing

[3]An emerging literature on experience effects argues that households overweight their own experiences of macroeconomic outcomes when forming expectations, particularly in the context of inflation experiences. In our context, we focus on the role that housing returns occurring in a zip code during a household's lifetime has on its overall portfolio allocation.

[4]While this effect seems to be low, the measure of consumption in the PSID captures only the amounts spent on child care, dependents outside of the family unit, education, food and medical care. It is well-known that the PSID underestimates total consumption. Although our analytical period is 1984–2013, all our empirical analyses on consumption are performed for the 1999–2013 period because some relevant PSID questions on household expenditure started in 1999.

stock is costly, as in Grossman and Laroque (1990) and Stokey (2009); and (ii) there are nonnegligible observation costs, i.e., observing the true market price of the house is costly. The homeowner knows about the possibility of house value misperception and the parameters that characterize it. However, we abstract from modeling its root causes. Our model incorporates two informational mechanisms that mitigate house price misperception. First, the homeowner has the option to pay a cost to observe the market value of the house. After observing it, the household decides whether to sell its current house to buy a new one, incurring an additional transaction cost, or keep the current house. Second, the homeowner may sporadically learn the market value of her house at no cost.[5]

Adjustment costs have been analyzed in the context of household finance. In particular, our paper can be framed within the literature on portfolio choice models in the presence of housing and transaction costs—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), Landvoigt (2017), Fischer and Stamos (2013), and Corradin, Fillat, and Vergara-Alert (2014). Davis and Van Nieuwerburgh (2015) provide a survey of major findings in the portfolio literature with housing. Our model considers these large transaction costs that cause a household to change its housing stock only on an infrequent basis. However, this literature largely assumes that households accurately observe house prices, and the models studied in these papers do not account for house value misperception.

Adjustment costs are also present in the literature related to menu costs, like Barro (1972), Golosov and Lucas Jr (2007), Alvarez, Lippi, and Paciello (2011), and Alvarez,

[5]The cost of acquiring accurate information does not need to be taken literally as the monetary cost of learning the house's market value. In reality, learning the market value of the house entails putting the house up for sale, spending time and money researching prices of similar houses, interacting with agents and buyers, and receiving binding offers which actually clear the market, which represents the house market value by definition. A home appraisal is not a guarantee of a sale value and at best may be another estimate of market value. There may be other considerations, like market illiquidity, that can have a large impact on market prices. The intuition behind the sporadic information shocks is that the homeowner can exogenously incorporate new information and reduce her house value misperception. For example, the homeowner can receive an unsolicited offer for her house or have an estate planning valuation for bequest purposes.

Lippi, and Paciello (2016), among others. Mankiw and Reis (2002) consider observation costs, which result in time-dependent rules. Menu costs models typically feature firms which do not observe the realization of an aggregate demand shock, and have to pay a cost to adjust their prices. The individual dynamics in our approach are similar: households pay a cost to observe the realization of a shock to their housing wealth—or they observe it exogenously, and transaction costs are incurred if they need to trade their house. The novelty of our approach rests on the idea that households make decisions based on their self-perception of housing wealth. Perceived wealth is costless to adjust and, consequently, households in our model continuously adjust their nonhousing consumption and nonhousing investments also during the periods between housing transactions, what we term the inaction region.

On the other hand, observation costs are present in the rational inattention literature, which offers a natural interpretation of our measure and model of misperception. Reis (2006), Duffie and Sun (1990), Gabaix et al. (2006), and Abel, Eberly, and Panageas (2007) study models of portfolio choice with rational inattention. In this literature, households update the value of their assets infrequently because it is costly to observe their market value.

The closest study to ours in the asset literature is Alvarez, Guiso, and Lippi (2012). They extend these rational inattention models by introducing durable consumption with transaction and observation costs, but they do not account for uncertainty in the durable goods' prices.[6] Our study differs on a fundamental aspect, as we consider both housing and nonhousing consumption choices. Since households make decisions based on their perceived level of total wealth, they continuously optimize nonhousing consumption and nonhousing portfolio choices even when not engaging in housing transactions (inaction region). The equilibrium of our model features the optimal rules for consumption and portfolio choices that are not constant between two consecutive housing transactions. Our novel setup allows the

[6] Their model predicts that the frequency of observing accurate prices is greater than the frequency of asset trading. This prediction is supported by the data. In Alvarez, Guiso, and Lippi (2012), the infrequently traded asset corresponds to the house in our model.

model to qualitatively generate the effects of house value misperception on the time-varying consumption and portfolio choices that we observe in the PSID data on US households.

These richer state-dependent rules add substantial complexity to the nature of the problem. Hence, we solve the problem for an individual household that takes prices as given, and restrict our analysis to partial equilibrium.

Our model delivers qualitative and quantitative implications for the household's optimal portfolio and consumption decisions subject to the presence of house value misperception and housing transaction costs. We find that if a household overvalues its home, its share of wealth invested in risky stocks is lower than that of a household that undervalues its home. We also find that a model with no misperception (meaning, the household always knows the home's true market value) would lead to optimal risky stock holdings that are 3.7, 5.7, and 6.9 percent higher than our benchmark model with a standard deviation of house price misperception of 5, 10, and 15 percent, respectively. Moreover, consumption is lower in a model with house price overvaluation than in a model with undervaluation. Compared to our benchmark model where house price misperception has a standard deviation of just 5 percent, a model with no misperception would lead to optimal nonhousing consumption that is 1 percent higher.

These results might seem puzzling at first. From a viewpoint of behavioral finance, one could argue that optimistic homeowners tend to invest more in risky stocks and consume more. However, the households in our model are perfectly rational and their choices are not a result of being optimistic or pessimistic about house values. In our model, perfectly rational households find it costly to acquire information on the current market value of their house and thus overestimate or underestimate its value over time. The existence of misperception affects their consumption and portfolio choice decisions. Two mechanisms drive our results. First, larger (perceived) housing holdings crowd out other risky stock holdings as in Cocco (2005). Since housing is also a risky asset, the overestimation of wealth allocated to housing causes a decrease in the share of wealth allocated to stocks, the other risky asset in our model. Second, state-dependent risk aversion in the presence of uncertainty about house prices decreases the overall desire for risky assets (both housing and stocks). Therefore, in a model with overvaluation, risk aversion is higher than in a model with no misperception at all, resulting in lower levels of consumption and higher levels of risk-free savings for a given level of wealth.

Finally, one could argue that the presence of online real estate databases like Zillow, professional appraisals for refinancing or home equity extraction, and municipalities' real estate tax assessments, should mitigate house price misperception. The main problem is that these estimates of market valuation are not exempt from error and rarely coincide with actual transaction prices. Zillow's website documents that 15.7 percent of the Zillow market estimates miss the subsequent transaction price by more than 20 percent and 50 percent of the estimates miss the transaction price by more than 5 percent.[7]

The paper is structured as follows. In Section 2, we first define our empirical measure of misperception and discuss stylized facts, along with the data that we employ throughout our analysis. In Section 3, we explore the empirical relationship between households' portfolio and consumption decisions and how house price misperception might affect these choices, behavior which motivates our modeling choices. We develop the optimal portfolio choice model in Section 4 and show the quantitative implications in Section 5 using numerical methods to solve the model. Section 6 concludes by outlining some possible lines for future study based on our findings.

[7]Source: https://www.zillow.com/zestimate/#acc.

2 Analysis of House Value Misperception

House value misperception has been documented for over half a century. Kish and Lansing (1954) and Kain and Quigley (1972) find large discrepancies when they compare homeowners' reported house values to values obtained from professional appraisals. These two studies implicitly assume that appraisals are free of error. Robins and West (1977) also assume that appraisals are unbiased estimates of house values and conclude that house values determined by homeowners and professional appraisals contain errors of 7 percent and 5 percent, respectively.[8] Although there is a consensus about the existence of measurement errors in house prices, there is no agreement on the sign and magnitude. Kish and Lansing (1954), Robins and West (1977), Ihlanfeldt and Martínez-Vázquez (1986), Goodman Jr. and Ittner (1992), Kiel and Zabel (1999), Agarwal (2007), and Benítez-Silva et al. (2015) document the overestimation of reported house values, which range from 3 percent to 16 percent. In contrast, the empirical analyses in Kain and Quigley (1972) and Follain and Malpezzi (1981) find that owners' self-reported house values underestimate house prices by about 2 percent.

In this paper, we develop a measure of house value misperception at the individual household-level, and we study its role in the household's portfolio, consumption, and housing decisions. Equation (1) defines house value misperception as the percentage difference between the household's subjectively determined house value and the house's actual market value. We use self-reported house values from the PSID as the measure of subjective house values.[9] We use the CoreLogic Home Price Index (HPI) at the zip code level to construct a

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

[9] The PSID is a household-level survey that began in 1968 and follows households and their offspring over time. Sixty percent of the initial 4,800 surveyed households belong to a cross-national sample from the 48 contiguous states, while the other portion is a national sample of low-income families from the Survey of Economic Opportunity. The survey was conducted annually through 1997 and biennially thereafter. The supplemental wealth module was introduced in 1984 and was conducted on a periodic basis prior to 1999 (the 1984, 1989, and 1994 waves). Since 1997 the basic PSID survey has been conducted biennially and, starting on 1999, the survey collects comprehensive consumption measures, wealth, and active saving questions in each wave. Housing data were collected annually in every survey until 1997, and biennially thereafter. We

proxy for the house's market value.[10] Formally, misperception $m_{i,t}$ for each household i at time t is defined as:

$$m_{i,t} = \frac{\left((H_i \cdot P_{i,t})^{PSID} - \sum_{s=t_0}^{t} I_{i,s}\right) - (H_i \cdot P_{i,t_0})^{PSID} \cdot \Delta HPI^{CL}_{zip,t_0 \to t}}{(H_i \cdot P_{i,t_0})^{PSID} \cdot \Delta HPI^{CL}_{zip,t_0 \to t}}, \quad (1)$$

where $(H_i \cdot P_{i,t})^{PSID}$ is the subjective value of the house the owner reported in the PSID;[11] $\sum_{s=t_0}^{t} I_{i,s}$ is the sum of the self-reported value of home improvements from the time the house was purchased (t_0) to time t; $(H_i \cdot P_{i,t_0})^{PSID}$ is the house's value at the time of purchase (t_0) reported by household i; and $\Delta HPI^{CL}_{zip,t_0 \to t}$ is the price growth rate in zip code zip from the time of purchase to time t computed with the corresponding CoreLogic House Price Index. Notice that $(H_i \cdot P_{i,t_0})^{PSID} \cdot \Delta HPI^{CL}_{zip,t_0 \to t}$ is the house's market value at time t. A positive value of $m_{i,t}$ indicates overvaluation, while a negative value indicates undervaluation. Throughout the paper, we refer to more misperception as a higher positive value of misperception or, equivalently, more overvaluation.

We make one key assumption to build our measure of house value misperception: each

merge four datasets to create our sample: PSID individual files, PSID family files, PSID Geospatial Data Tract Level data, and the CoreLogic House Price Indexes (HPI) at the zip code level. We merge the first three datasets using the PSID family ID variable and then we merge these three datasets into the CoreLogic HPI using the zip code of the household. We use data only about the head of the household from the PSID individual files. We clean the data from the observations that PSID defines as "excluding variables". For example, we disregard the observations that take the values of 9999998 and 9999999 for house values; the observations that take the values of 998 and 999 for the age of the head of the household; and the observations that take the value of 9 for marital status of the head of the household. Finally, we winsorize by above the variables stock holdings over total wealth, total wealth over housing wealth, debt over total wealth, and consumption over total wealth by five times their interquartile range. By doing so, these variables lay in a range defined by their median minus five times their interquartile range, and their median plus five times their interquartile range.

[10] The CoreLogic measure is a repeat-sales index that matches house price changes on the same properties in the public record files from First American, a title insurer with property information on about 99 percent of the US housing stock. Since the data are from public records, the HPI is representative of all houses in the market, not just the houses with a conforming loan, as is the case for house price indexes such as the Federal Housing Finance Agency (FHFA) index. The HPI is a monthly series beginning in 1975. With the HPI at the zip code level, we construct the proxy for the market value of the properties by applying the growth rate of the HPI to the purchase price of the house.

[11] We observe only total expenditure in the PSID, not the quantity of housing, H_i, and the price per unit of housing, P_t, separately.

household knows the true market value of its house at the time of purchase; that is, household i's house value misperception is zero at the time of the housing transaction (i.e., $m_{i,t_0} = 0$). This assumption allows us to use a repeat-sales index at a very granular level (i.e., at the zip code level) as opposed to using a hedonic pricing model to account for the house's market price. Nonetheless, this assumption reduces the sample size, as we consider only households that relocated during the period of study. In practical terms, we set house value misperception to zero when household i purchases a house at time t_0 and estimate misperception for each time $t > t_0$ in which the household remains in the house using equation (1).

Figure 1 displays the average house value misperception from 1976 to 2013 for the US households in our database.[12] We observe two relevant facts. First, there is a large dispersion of house value misperception. The zip codes at the 95th percentile of house price misperception have misperception values of around 40 percent for most of the sample, but reach values above 75 percent during the height of the financial crisis around 2009. The homeowners in zip codes at the 5th percentile of misperception undervalue their house by about 30 percent for most of the sample period after 1985, reaching undervaluation levels of 45 percent immediately before the 2008 start of the financial crisis. Although the average of the US aggregate house value misperception for the 1976–2013 period is close to zero (1.84 percent), its standard deviation is high (27.3 percent). This empirical fact is important for our study because it allows us to exploit the cross-sectional variation of house value misperception for the households in our dataset.

Second, the average value of house price misperception is countercyclical when this value is compared to the housing market cycle. On average, households that bought a house during periods when house prices were declining, i.e., during a housing bust, tend to overestimate the

[12] Despite having data going back to 1976, our empirical results use data starting on 1984, as we are constrained by the PSID starting year. Our results on consumption are further constrained because the PSID asks comprehensive questions on consumption starting in 1999.

value of their house. In contrast, those households that bought in periods of substantially positive house price growth tend to underestimate the value of their house. Notice that periods of house overvaluation (i.e., positive misperception) usually occur when returns in the US Aggregate CoreLogic House Price Index (HPI) are decreasing or negative. For the 1976–2013 period, the correlation between the house value misperception and the HPI growth at the zip code level is –0.72. This fact is consistent with the findings in Genesove and Mayer (2001) and Piazzesi and Schneider (2009).

In Figure 2, we analyze house value misperception by cohort and tenure for a set of selected years. Each line represents the house value misperception of a cohort of households that purchased a home in a given year. We observe that individual households that bought a new house in years of elevated house prices—like 1989, 1990, 1991, 2005, and 2007—overvalued their house beginning in the year after buying it. Contrarily, households that purchased a new house in years when house prices were depressed—1983, 1985, 1992, 1995, and 1999—undervalued their house starting the year after it was acquired.

The third and fourth relevant stylized facts arise from Figure 2: the sign of house value misperception is persistent, and the level of misperception reverts to its mean after about six to seven years, on average. Households that overvalued their houses immediately after the acquisition *keep* overvaluing their houses over time. The same argument applies to households that undervalue their homes. The fact that misperception reverts to zero after some time suggests that households eventually learn the market value of their houses. In Figure 2, we observe that, although misperception reverts to zero, the vast majority of the households in our sample do not change houses, suggesting that households do not necessarily move every time that they acquire information. Mean reversion is at odds with the evidence in Kuzmenko and Timmins (2011), who 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. Here is where the discrepancy between the prior findings in the literature and our results arise: we find that this cohort effect tends to dissipate, on average, after six or seven years of tenure. Our model reflects the persistence of the house value misperception direction and also the mean-reversion that we observe in our measure of house value misperception.

3 Empirical Evidence of the Effects of House Value Misperception on Portfolio Choices

The effects of changes in house values on consumption and portfolio choices are sizable. Recently, Chetty, Sándor, and Szeidl (2017) found empirical evidence that the impact of variation in house prices on households' portfolios is of the same order of magnitude as is variation in income. The main objective in this section is to use our measure of house price misperception to perform a preliminary analysis of the effect that this misperception has on portfolio and consumption choices.

Our work does not explicitly study the portfolio choices of renters, since the decision to rent is equivalent to holding zero equity in a house, as in Stokey (2009). We focus our study on understanding the portfolio decisions of homeowners. 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 renters facing lower transaction costs than homeowners. The percentage of movers to a different US census region or state is also very low among homeowners. Finally, new homeowners represent 3.79 percent of the total homeowner households in the PSID.

PSID contains data on asset holdings, consumption and housing wealth for individual households that are followed over time. While our period of analysis is 1984–2013, all our empirical results based on consumption data use the 1999–2013 period. Although the PSID questions about spending on childcare and food expenditures start in 1970 and 1994, respectively, questions about expenditures on education and healthcare start in 1999. Consequently, we calculate consumption as the sum of the amounts spent on childcare, dependents outside the family unit, education, food used at home, food used away from home, food delivered at home, and all medical care. We calculate total wealth, W_{it}, as the sum of individual i's primary residence value, its second home 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 from 1984 to 2013.[13] We divide the households' assets into 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, minus the outstanding mortgage principal on the primary residence.

Housing holdings are measured as the self-reported value of the primary residence. The variables regarding financial wealth are net of debt, which also includes the mortgage. However, we do not subtract the outstanding mortgage from the reported value of the house used to compute the wealth-to-housing ratio.

In Table 1, we report the descriptive statistics for the main variables that we use in the empirical analysis. We also report statistics on income; family size (number of family members); the head of household's age, gender, education, marital, and employment status; and housing wealth and tenure (i.e., years living in the current house) of the household. We observe that, on average, households tend to slightly overestimate the value of their homes, by about 1.4 percent in our sample.[14] The variation across households and zip codes

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

[14]Our measure of misperception, $m_{i,t}$, accounts for cumulative home improvements, made at any point in time between the last purchase time t_0 and time t by household i. There are 2,150 observations of home

is quite large. In our sample, households' wealth is, on average, 1.65 times the value of their house. Households' stock holdings represent an average of 3.9 percent of their total wealth. Most households do not own stocks; an average of only 26.7 percent participate in the stock market. Of the households that do own stocks, this risky asset class comprises a 14.4 percent share of total wealth on average. Finally, we report statistics on the measure of housing return experience based on the measures of experienced stock returns in Malmendier and Nagel (2011) and inflation in Malmendier and Steiny (2017). This measure is a weighted average of the past housing returns in the same zip code, and more recent returns carry a higher weight with linearly decreasing weights.[15]

Prompted by the results in Malmendier and Nagel (2011) and Malmendier and Steiny (2017), we investigate whether a household's tenure and the housing returns it experiences affect its house value misperception and its portfolio choices. In the previous section, we observed that misperception is persistent and displays a countercyclical behavior. In light of these properties, we relate an individual household's past housing return experience to its misperception of house prices. Table 2 shows, in addition to the effects of past housing returns experience, the relationship between misperception and a set of driving factors like tenure, income, family size, and other demographics. The negative and significant sign for *housing return experience* in specifications [2] and [4] in Table 2 indicates that households that have experienced high housing returns tend to undervalue their home. We are also interested in understanding whether house value misperception is related to how long the household has been living in the same house. In Table 2, specifications [3] and [4] suggest that the relationship between misperception and *tenure* is not significant. In Sections 4 and 5, we will consider the negative relationship between misperception and housing return

improvements in our data, with a mean of $33,417. The average time between home improvements is 14.1 years.

[15]For robustness, Malmendier and Steiny (2017) also construct a measure of past housing return experience. Our measure of housing return experience differs from theirs in that we construct it at a local (zip code) level using the corresponding CoreLogic House Price Index as a market reference for that zip code.

experience, as well as the lack of a statistical relationship between misperception and the tenure of the household.

In the remainder of this section, we establish an empirical relationship between the measure of house price misperception at the individual household level and households' decisions on consumption and portfolio choices. We first estimate a panel regression for risky stock holdings scaled by total wealth. In addition, we follow the existing literature on portfolio choice with durable goods showing that the ratio of total wealth to housing wealth, z, plays a key role as the state variable in these types of models.[16] Therefore, our empirical specification uses portfolio and consumption choices as the dependent variable, and m and z as the independent variable, in line with the model's equilibrium that will be developed in Section 4.

An empirical analysis of the effect that house value misperception has on a household's portfolio choices might be subject to endogeneity concerns. It is very likely that some variables determine simultaneously the misperception and portfolio or consumption decisions. The panel structure of the PSID data provides us with an ideal potential candidate for an instrument for house value misperception. Because homeowners self-report their house values in consecutive periods, we conjecture that past reported house values are correlated with more recent self-reported house values, but are uncorrelated with the disturbances in the current portfolio choices. Therefore, we use the two-year lagged misperception as the instrumental variable (IV) for misperception.[17] This instrument has a strong first stage because past house value misperception is highly correlated with the current amount of misperception, 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

[16] For example, Grossman and Laroque (1990) and subsequent literature.

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

in the explanatory equation, conditional on the other independent variables.

It is also very likely that households suffer exogenous shocks that force them to move to a different house. To account for this type of move, we control for variables that capture changes in household characteristics that are not related to the wealth-to-housing ratio, such as changes in employment status, family size, and marital status.[18]

Table 3 summarizes our empirical findings. Columns [2], [3], [5], and [6] show that higher overvaluation results in a lower amount of stock holdings. Columns [1]–[3] use the entire PSID sample, while columns [4]–[6] use the subsample of households that report holding stocks. There are differences in the results across the various subsamples, but the sign of the misperception coefficient remains negative and significant across all the subsamples. This consistent result implies that a higher overvaluation of housing wealth is associated with lower stock holdings. The economic interpretation is significant, considering that the average share of stocks held (among stockholders) is about 3.80 percent of total wealth: a 1 percent increase in misperception results in a 1.97 percent decrease in the share of other risky assets (for all households, including both stockholders and nonstockholders) or a decrease of 4.63 percent (for stockholders), when the house price misperception is instrumented with lagged values. These specifications also show that a household's total wealth-to-housing ratio is positively related to risky holdings, as expected.

We also document the effects of misperception on the likelihood that a household will participate in the stock market. Figure 3 shows that there is a negative and significant relationship between house value misperception and stock market participation. The probability of participating in the stock market is lower for households that overvalue their houses. Specifically, a 1 percent increase in misperception decreases the probability of participating

[18] The goal is to identify those moves that are triggered by the evolution of wealth and house prices, and then 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 household's 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.

in the stock market by 7.91 percent on average. This result is consistent with the negative relationship between house value misperception and stock holdings documented in Table 3. This seemingly puzzling result is perfectly rational as Section 4 will establish. To anticipate the result, higher amounts of house price overvaluation may crowd out stock holdings, even to the point where a household may not have any stock market investments.

4 A Portfolio Choice Model with House Value Misperception

Having documented the main characteristics of house value misperception and its effect on a household's portfolio choices, we are interested in understanding the mechanism behind this effect. To do so, we develop a model of portfolio choice with house value misperception. Our model accounts for the main stylized facts about misperception that we documented in Section 2. The model also incorporates two key frictions that characterize housing assets: (i) there are nonnegligible observation costs, i.e., observing the house's true market price is costly, and (ii) transaction costs are high, i.e., it is costly for households to adjust their housing stock.

In the existing literature on portfolio choice models with costly observation and rational inattention—e.g., Duffie and Sun (1990), Gabaix et al. (2006), Reis (2006), and Abel, Eberly, and Panageas (2007))—observing the household's wealth is costly. In these models, households make decisions about nonhousing consumption and portfolio allocation over time. In equilibrium, the optimal decision rules are constant between two consecutive observations. Alvarez, Guiso, and Lippi (2012), the closest study to ours in this literature, extend these rational inattention models by introducing durable consumption with transaction and observation costs, but they do not account for house price uncertainty.[19]

[19]The model in Alvarez, Guiso, and Lippi (2012) predicts that the frequency of observing wealth is greater

Our model differs from the existing literature in many dimensions, the most important ones being the presence of nonhousing and housing consumption, and the existence of house price uncertainty. Instead of assuming that wealth is not observable, as do these prior models, we assume that the house's value is not observable by the households. In our model, the household makes portfolio and nonhousing consumption decisions using its own subjectively determined house value, which may differ from its current true market value. Thus, the optimal rules for nonhousing consumption and portfolio choices are not constant between two consecutive house price observations. These richer optimal rules allow us to analyze the effects of house value misperception on the time-varying nonhousing consumption and portfolio choices that we observe in the data.

Our model studies the consumption and portfolio decisions of a household in an economy with observation costs, housing transaction costs, a risk-free asset, a risky asset, and two types of consumption goods: nonhousing and housing goods. Transactions in the housing market are costly. The agent has nonseparable Cobb-Douglas preferences over housing and nonhousing goods. She derives utility from a deterministic flow of services generated by the house.[20] The utility function can be expressed as:

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

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

We assume that a riskless bond is the only risk-free asset in this economy. The price of

than the frequency with which an asset is traded. This prediction is supported by the data.

[20]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.

this bond, B, follows the deterministic process:

$$\frac{dB}{B} = rdt, \tag{3}$$

where the real interest rate, r, is constant.

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

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

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

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

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

for a given initial endowment of housing assets, H_0.

We model house value misperception by assuming that the household obtains information about house prices only on an infrequent basis. We assume that house price formation is characterized by two components: there is a continuous flow of information that is factored into costless household decisions and some information that is incorporated only infrequently—either for exogenous reasons or due to information gathering and processing costs.

Our model combines the two informational mechanisms. First, the household has the option to pay an observation cost that is a fraction ϕ_o of the house's market value. After paying this cost, the subjectively perceived house value is hit by a shock drawn from the random variable $\bar{J}$, which reveals the house's market value. Once this true market value is observed at time τ_o, the household decides whether to sell the current house in order to buy a new one, incurring an additional transaction cost which is a fraction ϕ_a of the current house value. Second, information shocks may also arrive costlessly, characterized by sporadic disturbances. In fact, the information is also released according to the realization of a Poisson process $(\bar{J}-1)dQ(\lambda)$. This feature of the model is consistent with the stylized facts reported in Figure 2, where misperception, on average, reverts back to zero after some years, and the reversion is not triggered by housing transactions in the vast majority of the cases.

Therefore, the process by which subjective house values are formed follows a geometric Brownian motion with jumps:

$$\frac{dP}{P} = \mu_P dt + \sigma_{P,1}\rho_{PS} dZ_S + \sigma_{P,1}\sqrt{1-\rho_{PS}^2}dZ_P + (\bar{J}-1)dQ(\lambda), \tag{6}$$

where μ_P, $\sigma_{P,1}$, and ρ are constant parameters. Q is a Poisson process with intensity λ, and $(\bar{J}-1)$ is the random jump amplitude that determines the percentage change in the house price if the Poisson event occurs. We also assume that the diffusion shock, the Poisson jump, and the random variable J are independent and that $J = \log(\bar{J})$ has a normal distribution with zero mean and variance $\sigma_{P,2}^2$, implying that the distribution of the jump's size is house-price-specific.

The information framework generates an optimal decision rule for adjusting the housing stock that is similar to s-S models. Our optimal decision rules are purely state-dependent, characterized by an inaction region which is time invariant as in Grossman and Laroque (1990), Damgaard, Fuglsbjerg, and Munk (2003), and Stokey (2009). Our assumption that the variance of the J shock is not proportional to the time elapsed since the most recent information was obtained implies that our optimal decision rules are not time-dependent. This assumption is partly justified by the results from our previous empirical analysis, documented in Table 2, that length of tenure is not a first-order determinant of misperception.

This assumption also allows us to preserve the ordinary differential equation (ODE) characterization of our problem keeping its numerical solution feasible.

Let W denote the value of the household's total wealth in units of nonhousing consumption. When there is no new information about the house value, the household's wealth is composed of investments in financial assets (stocks and bonds) and the subjective value of the current housing stock:

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

where B is the wealth held in the bonds, and Θ is the amount invested in the risky stocks. A household's perception of its total wealth changes when new information about the house price is revealed. First, when information arrives according to the Poisson process at time τ, a wealth gain or loss occurs:

$$W(\tau) = W(\tau^-) + \underbrace{\tilde{J} \times H(\tau^-)P(\tau^-)}_{\text{Gain or Loss}}, \tag{8}$$

where $\tilde{J} = \bar{J} - 1$ is the shock realization. Second, the household acquires information at time τ_o incurring the observation cost of $\phi_o H(\tau_o^-)P(\tau_o^-)$,

$$W(\tau_o) = W(\tau_o^-) + \underbrace{\tilde{J} \times H(\tau_o^-)P(\tau_o^-)}_{\text{Gain or Loss}} - \underbrace{\phi_o H(\tau_o^-)P(\tau_o^-)}_{\text{Information Cost}}. \tag{9}$$

Third, conditional on observing the house price at time τ_o, the household decides whether to adjust its housing stock, which, if done, will incur the transaction cost of $\phi_a H(\tau_o^-)P(\tau_o^-)$:

$$W(\tau_o) = W(\tau_o^-) + \underbrace{\tilde{J} \times H(\tau_o^-)P(\tau_o^-)}_{\text{Gain or Loss}} - \underbrace{\phi_o H(\tau_o^-)P(\tau_o^-)}_{\text{Information Cost}} - \underbrace{\phi_a H(\tau_o^-)P(\tau_o^-)}_{\text{Transaction Cost}}. \tag{10}$$

Therefore, the evolution of a household's wealth accumulation is given by the following process:

$$dW = [r(W - HP) + \Theta(\mu_S - r) + (\mu_P - \delta)HP - C]dt$$
$$+ \Theta\sigma_S dZ_S + HP\sigma_{P,1}\rho_{PS} dZ_S + HP\sigma_{P,1}\sqrt{1-\rho_{PS}^2}dZ_P + \tilde{J} \times HPdQ(\lambda). \qquad (11)$$

The household continuously decides the optimal numeraire consumption, C, and the risky stock market holdings, Θ.

The value function of this problem is $V(W, H, P)$. We can use the homogeneity properties of the value function to formulate the optimization problem in terms of the wealth-to-housing ratio, $z = W/(PH)$, as follows:

$$V(W, H, P) = H^{1-\gamma} P^{\beta(1-\gamma)} \; V\left(\frac{W}{PH}, 1, 1\right) = H^{1-\gamma} P^{\beta(1-\gamma)} v\left(z\right). \qquad (12)$$

This formulation simplifies the problem to solving for just $v(z)$. The homogeneity properties are shared by V, which allows us to use equation (12) to solve the problem at its boundaries, where the household decides to acquire information and eventually to adjust its housing stock. Furthermore, let c denote the scaled control for the numeraire consumption, $c = C/(PH)$, and let θ denote the scaled control for the stock market holdings, $\theta = \Theta/(PH)$. In the Appendix, we provide the derivation of the Hamilton-Jacobi-Bellman equation for this problem.

The wealth-to-housing ratio, z, is this problem's only state variable. This state variable determines the optimal timing for rebalancing the household's portfolio and the adjustment to the size of its housing and nonhousing consumption. The model's solution consists of a value function, $v(z)$, defined on the state space where the boundaries $\underline{z}_o$ and $\overline{z}_o$ define an inaction region in which no housing transaction occurs, and z^* is the optimal return point for the wealth-to-housing ratio after a housing transaction occurs. Finally, the consumption and portfolio policies, c^* and θ^*, are defined in the inaction region $(\underline{z}_o,\ \overline{z}_o)$. The function $v(z)$ satisfies the Hamilton-Jacobi-Bellman equation on the inaction region. Value-matching conditions hold at the upper and lower boundaries, and an optimality condition holds at the return point.

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

1. *In the inaction region, $v(z)$ satisfies*

$$\widetilde{\rho} v(z) = \sup_{c,\theta} \{u(c) + \mathcal{D}v(z)\} + \lambda E[v(z + \tilde{J}) - v(z)], \quad z \in (\underline{z}_o, \overline{z}_o), \tag{13}$$

where

$$\begin{aligned}\mathcal{D}v(z) =& (z(r + \delta - \mu_P + \sigma_{P,1}^2(1 + \beta(\gamma - 1))) \\ &+ \theta(\mu_S - r - (1 + \beta(\gamma - 1))\rho_{PS}\ \sigma_S\sigma_{P,1}) - c)v_z(z) \\ &+ \frac{1}{2}(z^2\sigma_{P,1}^2 - 2z\hat{\theta}\ \rho_{PS}\ \sigma_{P,1}\sigma_S + \theta^2\sigma_S^2)v_{zz}(z).\end{aligned} \tag{14}$$

Outside the inaction region, $v(z)$ satisfies

$$E\left[M\frac{(z + \tilde{J} - \phi_a - \phi_o)^{(1-\gamma)}}{1-\gamma}\right] \quad z \notin (\underline{z}_o, \overline{z}_o), \tag{15}$$

where M is defined as

$$M = (1 - \gamma)\sup_z z^{\gamma-1}v(z). \tag{16}$$

2. *The optimal return point, z^*, attains its maximum value in*

$$v(z^*) = M\frac{z^{*(1-\gamma)}}{1-\gamma}. \tag{17}$$

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

$$v(\underline{z}) = E\left[M\frac{(\underline{z}+\tilde{J}-\phi_a-\phi_o)^{(1-\gamma)}}{1-\gamma}\right], \tag{18}$$

$$v(\overline{z}) = E\left[M\frac{(\overline{z}+\tilde{J}-\phi_a-\phi_o)^{(1-\gamma)}}{1-\gamma}\right]. \tag{19}$$

4. Given a wealth-to-housing ratio z *in the interval* $(\underline{z}_o, \overline{z}_o)$*, the household chooses an optimal nonhousing consumption* $c^*(z)$ *and portfolio* $\theta^*(z)$

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

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

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

Proof. See Appendix A-II.

The interpretation of equation (13) is standard in the literature. The first term on the right-side of the equation is the current utility flow from nonhousing consumption. The second term, $\mathcal{D}v(z)$, is the expected "capital gain" from changes in the state variable z and comes from an application of Ito's lemma. The final term is the expected net loss from the exogenous house price shock. For any ratio z inside the inaction region, the optimal portfolio θ and nonhousing consumption c maximizes the right-side of equation (13), and the first-order conditions are provided in equations (20) and (21). The condition for nonhousing consumption c states that the marginal utility of nonhousing consumption, with the housing stock fixed, must equal the marginal value of wealth. Nonhousing consumption increases with wealth, and the slope of the function depends on the substitution elasticity β and the risk aversion parameter, γ. A higher elasticity of substitution implies a stronger response for nonhousing consumption. The optimal portfolio choice of stocks, θ, is characterized by two terms. The first one depends on the relative risk aversion of the value function, $-zv_{zz}(z)/v_z(z)$, that varies with the wealth-to-housing ratio, z. The second term corresponds to the portfolio hedging for house price volatility represented by $\rho_{PS}\sigma_P/\sigma_S$. In a frictionless world without transaction and/or observation costs, the nonhousing consumption and optimal portfolio shares of all three assets would be constant.

The household immediately adjusts its housing stock if z is outside the inaction region, defined by the interval $(\underline{z}_o, \overline{z}_o)$. Hence, the value function that lies outside the inaction region is described by equation (3). The household sells its house but is exposed to the exogenous house price shock. The optimal wealth-to-housing ratio immediately after a transaction, z^*, does not depend on the state that existed just prior to the housing transaction. Thus, equation (16) defines the optimized value when the household buys a new house, and z^* is the wealth-to-housing ratio it chooses (see equation (17)). The optimal thresholds ($\underline{z}_o$ and $\overline{z}_o$) satisfy the value-matching conditions (see equations (18) and (19)). Since house price information arrives after paying the observation cost ϕ_o, the wealth-to-housing ratio z experiences a shock. Equations (18) and (19) depart from the usual boundary conditions of differential equations because they provide the values of the solution not only at the barriers, but also beyond the barriers. This is an important feature of the nonlocal behavior of our value function $v(z)$, and it is due to the integral term $E[v(z + \tilde{J})]$.

Figure 4 shows a simple setup to provide intuition for the model's solution. 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 total wealth at the initial time (i.e., initial point $P(0)$ in Figure 4). The agent pays an observation cost every time she decides to acquire accurate information on the house's current market value. Conditional on the realization of the house's market value that depends on the size of the jump, the agent sells the current home, moves to a bigger or smaller house, and incurs a transaction cost to change her housing stock. When her wealth-to-housing ratio—the solid line in the figure—reaches the upper boundary of the inaction region for information acquisition, she pays the observation cost to acquire information about the true market price of her house, which affects her total wealth-to-housing ratio. She sells the current house to buy a new one if the wealth-to-housing ratio is higher than the upper bound (point 1 in the figure). She chooses her new housing stock such that the wealth-to-housing ratio reaches its optimal return point. If the wealth-to-housing ratio is lower than the upper bound (point 2 in the figure), the wealth-to-housing ratio falls inside the inaction region, and she does not sell her current house. Eventually, new information arrives via the Poisson process (point 3 in the figure). In this specific example, the wealth-to-housing ratio is still inside the inaction region after this shock.

5 Quantitative Analysis

The problem described in Section 4 cannot be solved in closed-form. Therefore, in this section we solve the model numerically, and we analyze the solution's main quantitative implications. We implement a finite-difference approach to derive the solution of this optimal control problem. First, we discuss the parameters used to solve the model. Second, we describe the decision rules and solve the model for different parameter values of house price misperception. We then develop some comparative statics to illustrate its workings. Finally, we use the numerical solution to relate the model to the findings discussed in Sections 2 and 3.

Table 4 reports the values used to parameterize the baseline model. Regarding the preference parameters, we assume a curvature of the utility function γ of 2, a rate of time preference ρ equal to 2.5 percent, and a degree of house flow services $(1 - \beta)$ equal to 40 percent of total consumption, roughly comparable to the ratio of housing services to the consumption of nondurable goods and services from the National Income and Product

Accounts. We set the annual risk-free rate to 1.5 percent and the drift and standard deviation of the annualized risky-asset price growth process to 5.1 and 16.55 percent, respectively. These values are consistent with the long-term return and standard deviation of US aggregate stock indexes. We assume that the transaction cost of adjusting housing ϕ_a is 4.5 percent of the house's total value, while the information cost ϕ_o is 0.5 percent. The former includes the agent's commissions, legal fees, and the direct cost of moving the consumer's possessions. We set the house's annual depreciation rate at 2 percent and the standard deviation $\sigma_{P,1}$ of the house price growth to 5 percent. We also set the standard deviation of the shock $\sigma_{P,2}$ at 5 percent as a baseline parameter, but we perform a sensitivity analysis to changes in this fundamental parameter. Finally, we set the arrival parameter of the Poisson shock, λ, at 16.66 percent, which corresponds to an average frequency of arrival of six years.

A household's optimal decision rule for adjusting its housing stock is of the s-S type. In Figure 5, the horizontal axis displays the value of the ratio of total wealth to housing wealth $z = W/(HP)$, a value that we obtain for the benchmark model defined by the parameter values, shown in Table 4. The two vertical lines at the boundaries, $\underline{z}$ and $\overline{z}$, denote the threshold values that delimit the inaction region existing between them. The vertical dashed line inside the inaction region denotes the household's optimal wealth-to-housing ratio after a housing adjustment, z^*, i.e., the optimal return point. The household's decision to adjust its housing stock depends on the value of the state variable z and the observed house price. Outside the inaction region, the household is willing to pay the information and transaction costs and, by selling the house and buying a new one, adjust its housing stock to its optimal return point, z^*. The adjustments that occur to the left of $\underline{z}$ involve selling the current house to buy a smaller one, while those to the right of $\overline{z}$ involve selling the current house to buy a larger one. The solid line in Figure 5 depicts the optimal decision, defined as the difference between the value function, $v(z)$, and the expected value of changing housing consumption, $E(\bar{v}(z))$, against the value of the wealth-to-housing ratio, z. If this difference is positive, then the household does not move to a bigger or smaller house. The household moves only when this difference is zero, i.e., when the value function from not moving given by $v(z)$ is equal to the value from moving given by $E(\bar{v}(z))$.

As was characterized in Section 4, our model accounts for two information mechanisms. First, the Poisson process may result in a jump in value, a shock that causes the wealth-to-housing ratio z to lie outside the inaction region, triggering a housing adjustment that returns the wealth-to-housing ratio to the optimal value, z^*. There are other instances in which a Poisson jump to the subjective house price does not cause the wealth-to-housing ratio to fall outside the inaction region. In such cases, there is no housing adjustment. Second, there is also the possibility that households will adjust their housing stock in the absence of a Poisson shock when the wealth-to-housing ratio reaches the lower or upper bound due to a Brownian innovation, triggering the adjustment as in Grossman and Laroque (1990).

Figure 6 illustrates our paper's main result and answers the question of how house value misperception affects a household's other portfolio choices, in particular, risky stock holdings. Figure 6 shows the fraction of wealth invested in risky assets, $\theta^*/z = \Theta/W$, for different values of the state variable, z. Each curve is drawn only for the realizations of z within the inaction bounds, as any z outside the inaction region would result in an adjustment back to z^*. Figure 6 illustrates two cases. In the first case, depicted by the dashed line, information gathering and the processing of house prices is costless and continuous, as in Damgaard, Fuglsbjerg, and Munk (2003). We define this first case as the *nonmisperception* case. The second case, the solid line, describes our model with misperception.

In the case of no misperception—as in Grossman and Laroque (1990), Damgaard, Fuglsbjerg, and Munk (2003) and Stokey (2009)—the share of total wealth that the household keeps in risky assets reflects the idea that the household is more risk-tolerant when it is close to the bounds, and is more risk-averse in the middle of the inaction region. Closer to the boundaries of the inaction region, the household's need to pay transaction costs is offset by an increase in marginal utility associated with returning to the optimal wealth-to-housing ratio. Lower risk aversion leads to higher fractions of wealth invested in risky assets. In order to compare the two models, we solve the nonmisperception model by matching the first and second moments of the house price process with jumps in equation (6).[21] This approach ensures that the unconditional mean and variance of the process with jumps is the same as the process without jumps in order to make the two cases comparable.

The existence of house price misperception generates richer portfolio rules regarding stock holdings. Our novel mechanism affects the investment in risky stocks by introducing an additional source of risk for household portfolio choice. First, the agent is more risk averse overall, investing a lower amount of its portfolio in risky stocks compared to the nonmisperception case because information on house prices arrives infrequently. This is particularly true for high values of the household's wealth-to-housing ratio z. Second, closer to the lower boundary of the inaction region, our model generates a different prediction compared to Grossman and Laroque (1990), Damgaard, Fuglsbjerg, and Munk (2003) and Stokey (2009). The agent becomes locally more risk averse, choosing overall portfolios that are less risky, given the lower amount of stocks being held.

Figure 7 shows the share of wealth that the agent devotes to nonhousing consumption. This ratio is approximately linear in the wealth-to-housing ratio z. In the absence of transaction costs, a constant fraction of wealth is used for housing services and nonhousing consumption. These results are implied by the first-order conditions of the consumption-investment problem, in which the marginal utility of nonhousing consumption equals both the marginal utility of wealth and the marginal utility of housing consumption. When transaction costs are added, it is infinitely expensive, and hence suboptimal, to keep these consumption ratios

[21] Consider a jump-diffusion specification as $dX_t = \mu dt + \sigma dZ_t + J dN_t$, where X_t denotes the log-return of an asset. Z_t denotes a standard Brownian motion and N_t a Poisson process with arrival rate λ. The log-jump size J_t is a Gaussian random variable with mean $\tilde{\mu}$ and variance $\tilde{\sigma}^2$. The corresponding asset price $P_t = P_0 \exp(X_t)$ is $dP_t/P_{t^-} = \left(\mu + \sigma^2/2\right) dt + \sigma dZ_t + \left(\exp(J_t) - 1\right) dN_t$. The first two moments of the process are $\mu + \tilde{\mu}\lambda$ and $\sigma^2 + \lambda(\tilde{\mu}^2 + \tilde{\sigma}^2)$.

continuously aligned. The figure shows that in the presence of house price misperception, the household consumes fewer goods than it would in an economy with no misperception. The argument is analogous to that used to explain the previous results on risky stock holdings. For any given level of wealth, the higher the degree of dispersion in misperception, the higher the risk aversion. As a result, nonhousing consumption is lower.

Table 5 reports the numerical results that we obtain from the model when using the parameter values in Table 4. Table 5 also reports the sensitivity of the results to varying the standard deviation $\sigma_{P,2}$ of the shock from 5 percent to 15 percent. We provide the main results of our model in the last row of each panel. Each panel also provides the results for the model without misperception when we match the first and second moment of the house price process in equation (6). We define the matched parameters of the house price process as $\tilde{\mu}_P$ for the first and $\tilde{\sigma}^2_{P,1}$ for second moment, and we report the parameters in the table's corresponding footnotes. Finally, to gauge how the infrequent arrival of information on house prices affects the optimal portfolio allocation and consumption rules, we shut down the Poisson process ($\lambda = 0$). This model corresponds to the situation where uncertainty about the house's true market value affects the household's decisions at the lower $\underline{z}$ and upper $\overline{z}$ bounds, respectively. These results are to be compared with the numbers reported in Panel A.

We use the numerical results presented in Table 5 to illustrate the quantitative properties of our model with house value misperception. Columns (1), (2) and (4) report the lower bound $\underline{z}$, the optimal return point z^*, and the upper bound $\overline{z}$, respectively, while Column (3) reports the optimal return point for the model without observation and transaction costs. As in Grossman and Laroque (1990), transaction costs make housing a more expensive asset so less housing stock is purchased, which produces a higher ratio of total wealth to housing (see Columns (2) and (3)). Misperception affects the inaction region. The model generates more inaction when misperception increases due to an increase in the standard deviation of the house price shock, $\sigma_{P,2}$. Both boundaries shift to the right, but the upper bound $\overline{z}$ increases more than the lower bound $\underline{z}$. In fact, the wider inaction region leads to longer time periods between adjustment, with the average housing tenure, $E(\tau^*)$, rising from 24.1 to 38.4 years (see Column (5)).[22] The average tenure is computed as the expected time to the next housing transaction that occurs immediately after the household adjusts its housing stock to the optimal return point, z^*. Note that, compared to the nonmisperception case, the average tenure is substantially lower when misperception is present. This difference can be seen by comparing the misperception row with the nonmisperception row. The main reason is that the Poisson process causes the arrival of infrequent information of true house prices to also occur inside the inaction region. When we shut down this channel ($\lambda = 0$), we find that the average tenure is higher. Thus, our model with house value misperception predicts a higher probability of a housing adjustment than it does for the nonmisperception model.

The next three columns of Table 5 show the results for the share of wealth held in risky stocks. To quantify the consequences of house price misperception on risky stock holdings, we compare the outcomes of our model with the ones produced by two special cases: i) the frictionless benchmark model without information and transaction costs (Column (7)); and ii) the nonmisperception case (Column (8)). Column (6) presents the average holdings of the risky asset after a home purchase, denoted by $E(\theta^*/z)/E(\tau)$, to emphasize that this is the average of θ^*/z over the expected time before another home purchase occurs. Transaction costs have the effect of making the household more risk averse. As a result, the average share of risky stock holdings are lower than the average share of risky stocks

[22]The expected time between house purchases is large compared with the home tenure we measure in the PSID data. The main reason is that we exclusively model voluntary housing adjustments. One natural extension would be to incorporate moves that are required for exogenous reasons. Marital status changes that involve relocating to a new house, changes in family size, or unemployment shocks are possible interpretations of the exogenous moves. Such moves can be modelled assuming that this shock follows a Poisson distribution as in Stokey (2009) and Corradin, Fillat, and Vergara-Alert (2014).

chosen by a household facing no observation and transaction costs associated with housing (see Column (7)). Our analysis shows that the impact of house price misperception on risky stock holdings is significant. We reach this conclusion by comparing the difference between the average holdings of the risky stocks with and without misperception in the inaction region shared by the two models (see Column (8)). Such a comparison allows us to quantify the welfare consequences of misperception and to directly compare the model's predictions with the empirical findings presented in Section 3. As the standard deviation $\sigma_{P,2}$ increases, the average holdings of risky stocks decrease. Moreover, the decline in risky stock holdings is larger in the full model with Poisson shocks, suggesting that the arrival of infrequent information about house prices inside the inaction region via the Poisson shock is a key driver of house price risk for the household. Our model's predictions are qualitatively consistent with the empirical results regarding the negative correlation between risky stock holdings and house price misperception that we provided in Section 3.

It is important to recognize that while the optimizing behavior characterized above is that of a hypothetical agent living infinitely, the data we use to describe the motivational facts are drawn from a cross-section of demographically heterogeneous agents. Therefore, to assess the descriptive value of our model, our regressions also include demographic characteristics and wealth variables, which may include other factors that are exogenous to our model.

The last three columns of Table 5 report the results for the share of wealth devoted to nonhousing consumption. Columns (9) and (10) represent the average nonhousing consumption rate just after a housing trade and the optimal consumption rate in the absence of transaction costs. The average consumption rate with housing transaction costs is lower than the constant rate in the frictionless case with the same preference parameters. In the last column, we report the difference between the average nonhousing consumption rate with and without house value misperception in the inaction region shared by the two models. We find that misperception negatively affects nonhousing consumption. This model prediction is again consistent with our empirical findings on nonhousing consumption.

Finally, we analyze the cross-sectional effects of different values of house value misperception across households. For simplicity, we compare household O and household U that live in the same zip code. The two households are identical except that O overvalues its house, while U undervalues its house: $\mu_P^O > \mu_P > \mu_P^U$, where μ_P is the expected housing return in case of no misperception (e.g., expected return of the house price index in the same zip code). For simplicity, we set μ_P at the baseline value of 2 percent and μ_P^O and μ_P^U at 3 and 1 percent, respectively. In order to compare the two households, we follow the same approach we use to compare the nonmisperception and misperception case. We solve the misperception model with overvaluation and undervaluation by matching the first and second moments of the house price formation process with nonmisperception by adjusting the mean and the standard deviation of the house price shock, $\tilde{\mu}_P^i$ and $\tilde{\sigma}_P^i$, respectively, where $i = O, U$, and keeping the house price volatility parameter, σ_P, fixed.[23]

Figure 8 depicts the portfolio decisions made by the two households regarding the amount of stocks to hold given two scenarios: when house price misperception is present and when it is absent. We observe that a small variation in the house price parameters substantially affects the inaction regions and leads to different policies about the risky holdings in a household's portfolio. First, the inaction region for the household that overvalues (undervalues) is larger (narrower) than in the nonmisperception case. The main reason is that the mean of the house price shock is negative (positive) for the household that overvalues (undervalues) housing in order to reconcile the two house price dynamics in the case when misperception exists with the house price dynamics when misperception is not present.[24] A negative mean for the house price shock implicitly increases the cost of purchasing a new house by enlarging the

[23]So the parameters have to satisfy the following conditions: i) $\mu_P = \mu_P^O + \lambda\tilde{\mu}_P^O$; ii) $\mu_P = \mu_P^U + \lambda\tilde{\mu}_P^U$; iii) $\sigma_P^2 = \sigma_P^{O,2} + \lambda\left(\tilde{\mu}_P^O + \tilde{\sigma}_P^{O,2}\right)$; and iv) $\sigma_P^2 = \sigma_P^{U,2} + \lambda\left(\tilde{\mu}_P^U + \tilde{\sigma}_P^{U,2}\right)$ where $\sigma_P^O = \sigma_P^U$.

[24]In fact, $\tilde{\mu}_P^O = (\mu_P - \mu_P^O)/\lambda < 0$ if $\mu_P^O > \mu_P$ and $\tilde{\mu}_P^U = (\mu_P - \mu_P^U)/\lambda > 0$ if $\mu_P^U < \mu_P$.

inaction region. Second, this comparison illustrates our empirical analysis in Section 3, where we find that a 1 percent increase in house overvaluation results, on average, in a 1.76 percent decrease in the share of risky stock holdings and a 4.56 percent decline in stock market participation. Our numerical simulations generate the effects of house value misperception on portfolio choices that we observe in the data. Given the same value of the wealth-to-housing ratio, the household that overvalues its housing asset has lower risky holdings than the household that undervalues its home, highlighting that the sign of misperception—overvaluation versus undervaluation—has a specific role in affecting the risk composition of the household's remaining portfolio.

6 Conclusions

House price misperception affects the optimal behavior of households. When households overvalue their houses, they invest less in risky stocks and consume fewer nonhousing goods. To reach these conclusions, this paper extends the portfolio choice model with transaction costs proposed in Grossman and Laroque (1990) by considering that individual households may overestimate or underestimate the value of their houses. We set up and solve a model that accounts for four important stylized facts of house value misperception that we document using US household-level data from 1984 to 2013: (i) there exists considerable dispersion across households in the United States in terms of how accurately they estimate house values; (ii) house value misperception is countercyclical on average; (iii) its sign is persistent (those households that overvalue their housing keep doing so); and (iv) house price misperception reverts back towards zero about six to seven years after the house was purchased at its true market value.

In our model, perfectly rational households find it costly to acquire information on the current market value of their house and thus overestimate or underestimate its value over time. This approach draws from the literature on rational inattention. The existence of misperception affects the households' consumption and portfolio choice decisions, which are based on the perceived level of housing wealth. Two mechanisms drive our results. First, a larger (perceived) percentage of total wealth allocated to housing crowd out risky stock holdings. A household who overestimates the value of its house also overestimates the total wealth allocated to risky assets—because housing is a risky asset. This overestimation of the wealth held in housing assets causes a substitution effect in the share of wealth allocated to risky stocks. Second, risk aversion in the presence of house price uncertainty decreases the appetite for risky assets. Hence, it is important to emphasize that a household's consumption and portfolio choices are driven by uncertainty and higher risk aversion, not overconfidence or optimism. Our empirical analysis confirms the main implications of the model.

Our paper focuses on the analysis of a household's portfolio and consumption decisions using a partial equilibrium model that accounts for the main stylized facts on house value misperception. Studying the aggregate general equilibrium implications of house value misperception would be an interesting line of future research. For example, it would be interesting to quantify the general equilibrium effects of house value misperception on asset prices or the welfare gains from eliminating the costs of observing market house prices.

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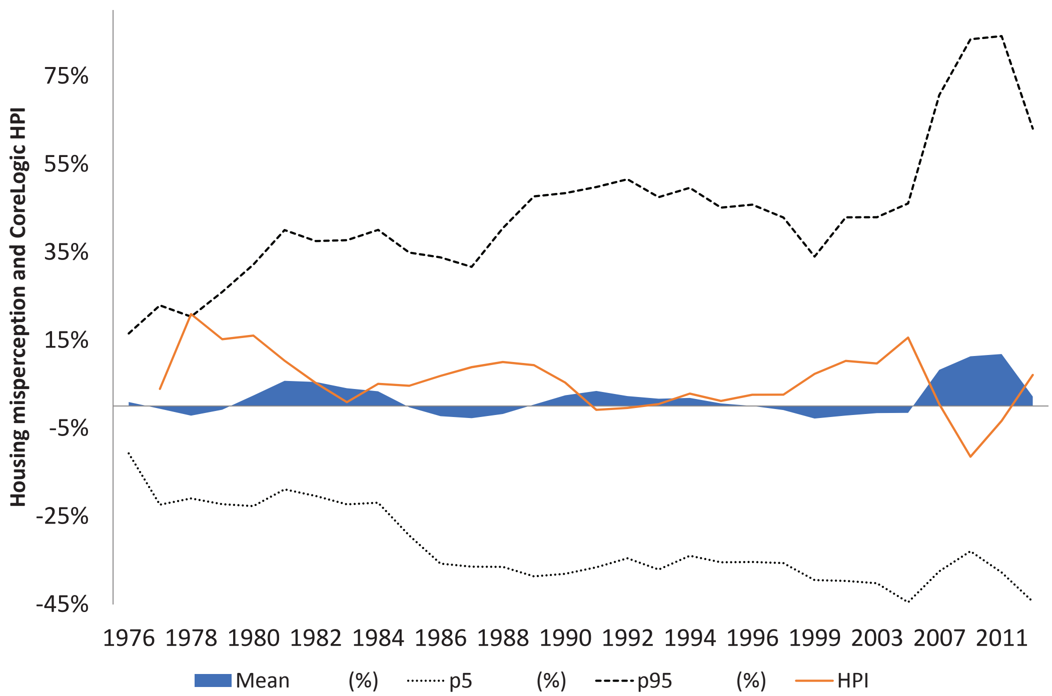

Figure 1: **House Value Misperception Over Time.** The figure plots the dynamics of the average house value misperception (mean), the percentiles 5 (p5) and 95 (p95) of the distribution of house value misperception, and the returns on the US aggregate CoreLogic House Price Index (HPI). Source CoreLogic House Price Index.

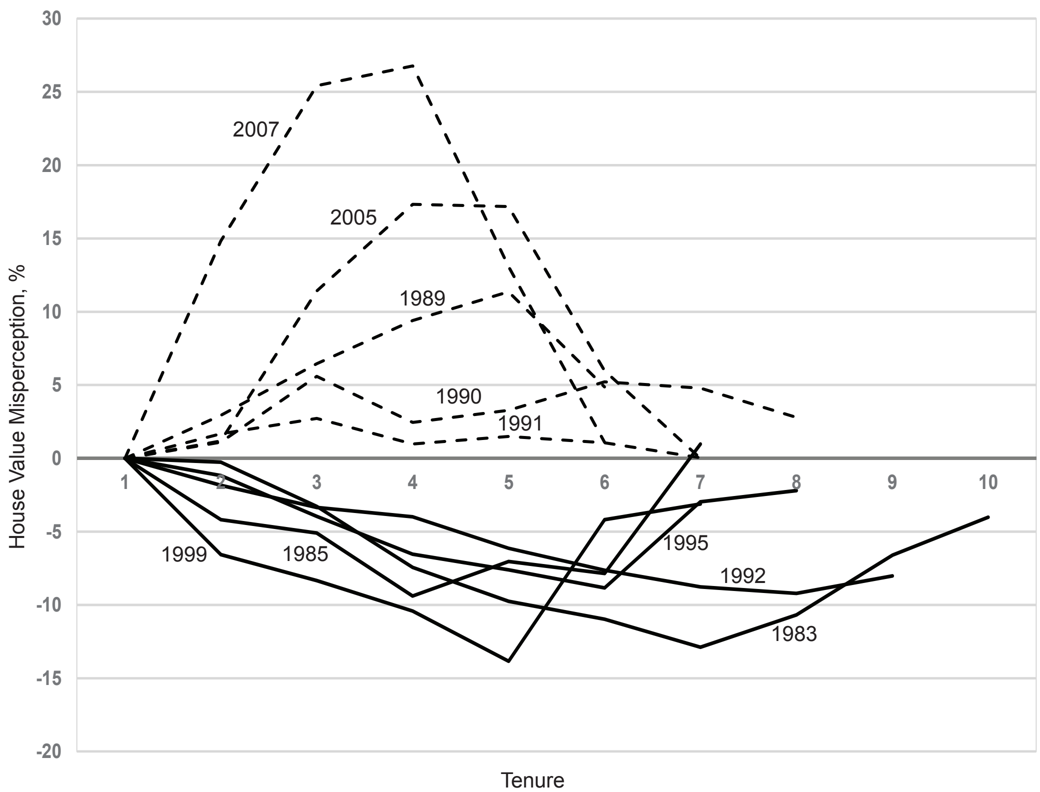

Figure 2: **Persistence of House Value Misperception.** The figure plots the dynamics of the average house value misperception for cohorts of households that acquire a house in a selected year. When a household moves, it is dropped from the sample used in this figure. Tenure is measured in years since the purchase of the current home, and it is represented on the x-axis. The dashed lines represent the cohorts that overvalued their house from acquisition, while the solid lines represent the cohorts that undervalued their house. Source: PSID.

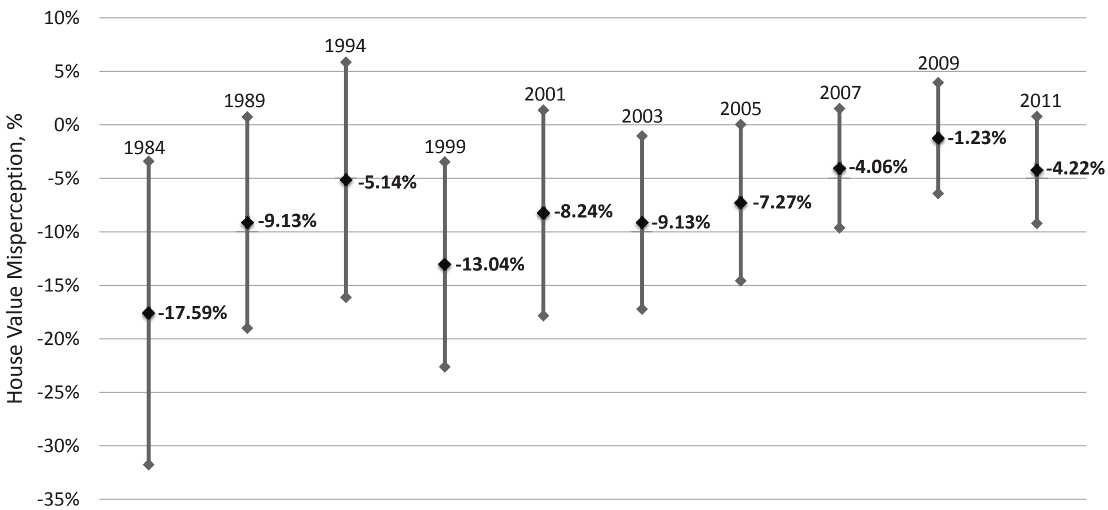

Figure 3: **House Value Misperception and Stock Market Participation.** This figure plots the marginal effects of house value misperception on households' stock market participation by year. These marginal effects are obtained with a probit model that includes as control variables log(income), age, gender, education, marital status, employment status, family size, and log(housing). This figure also displays the 5 (p5) and 95 (p95) percentiles of the distribution of these marginal effects for each year. Source: PSID.

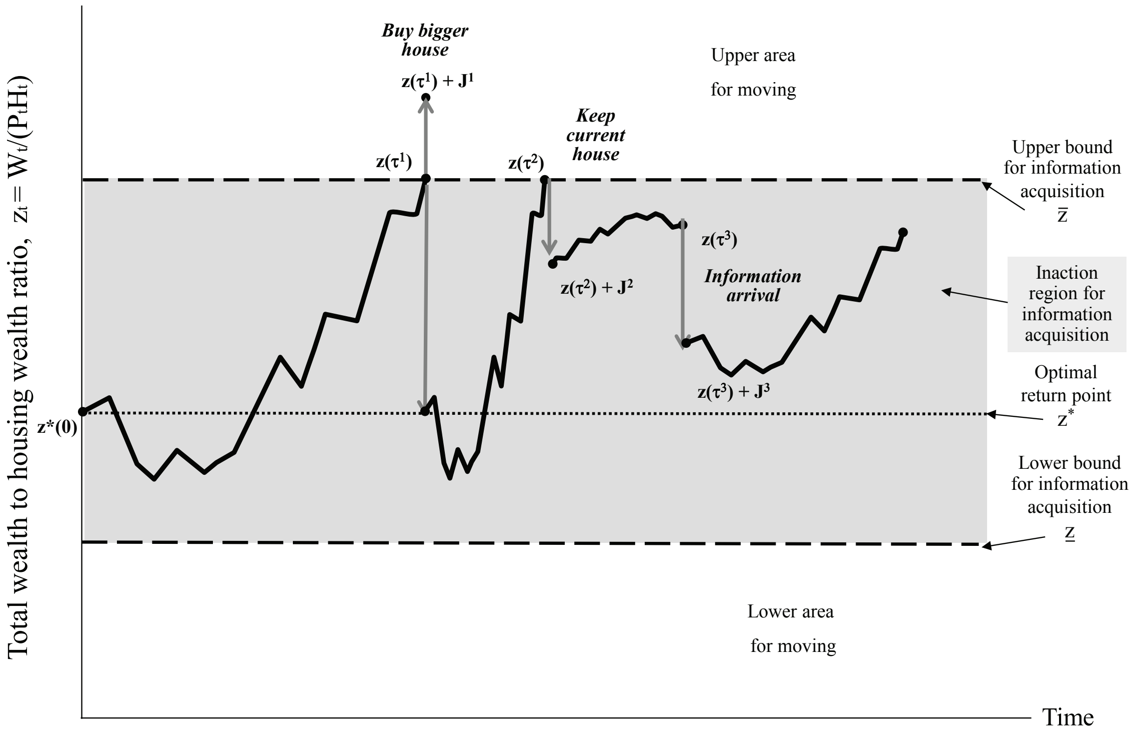

Figure 4: **Illustration of the Mechanism.** Hypothetical path of a household's wealth-to-housing ratio with upper and lower bounds. Source: authors' calculations.

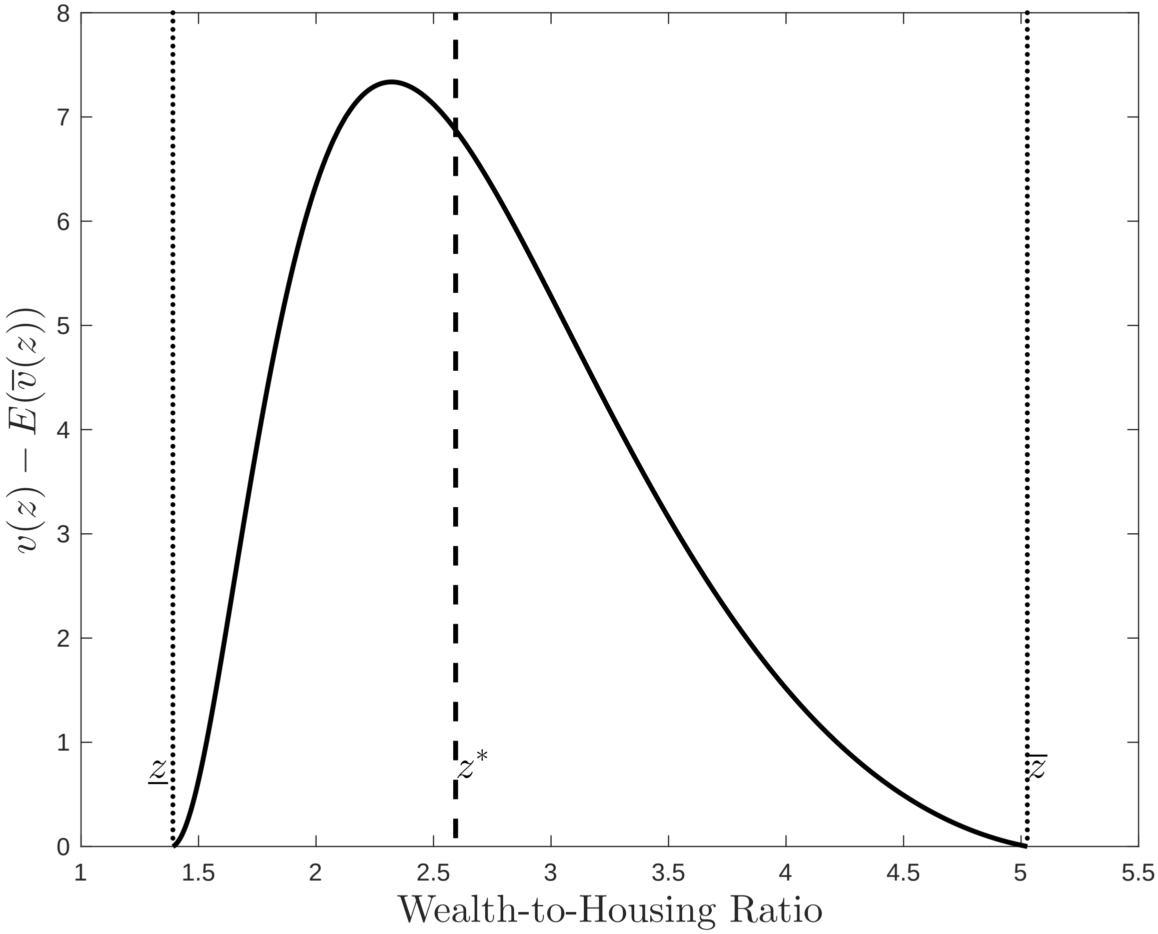

Figure 5: **Value Function and Value of Changing the Home.** The difference between the value function, $v(z)$, and the value of changing housing consumption, $E(\bar{v}(z))$, is plotted against the wealth-to-housing ratio, z, where $z = W/(HP)$. The two vertical lines at $\underline{z}$ and $\overline{z}$ denote the threshold value that delimit the inaction region. The vertical dashed line z^*, inside the inaction region, denotes the optimal return point after an adjustment. Source: authors' calculations.

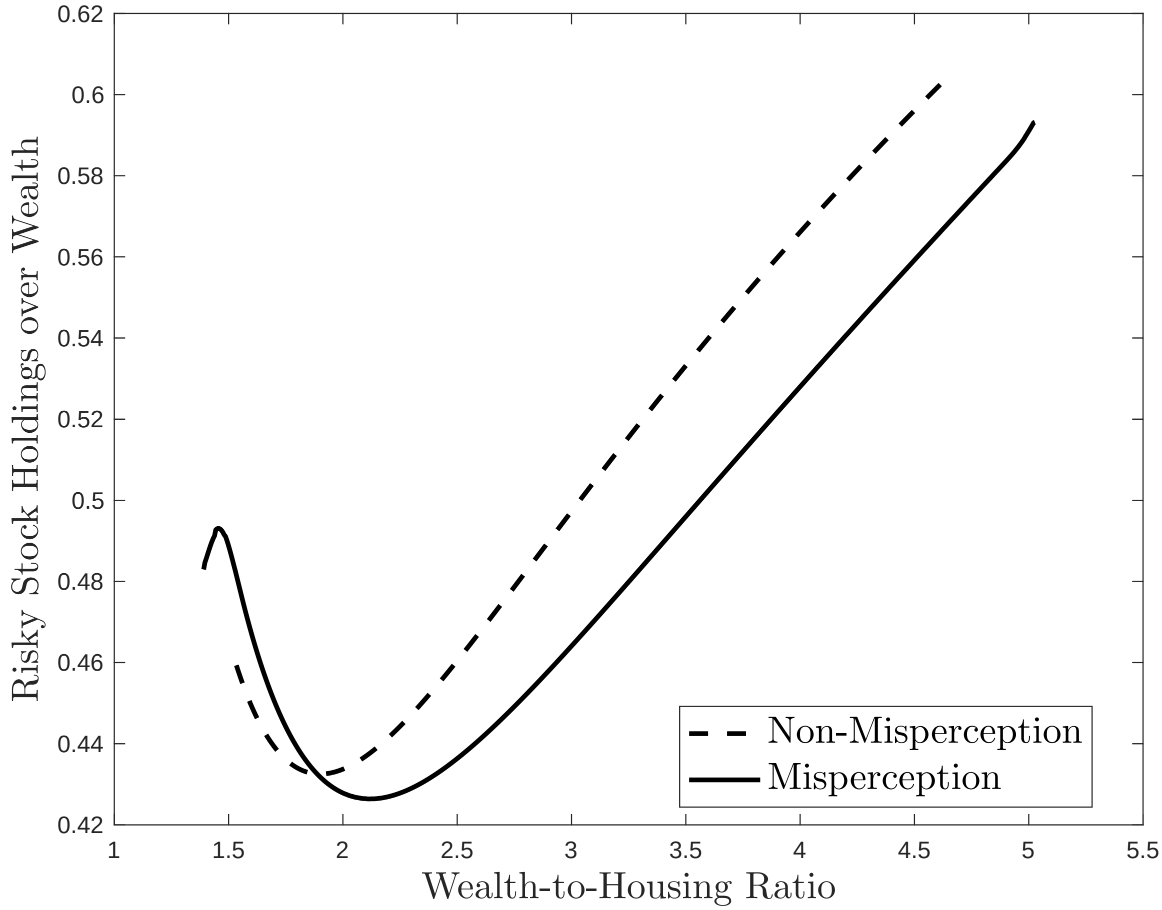

Figure 6: **Risky Stock Holdings and Misperception.** The share of wealth invested in risky holdings, $\theta(z_t)/z_t$ as a function of the wealth-to-housing ratio, z_t. The dashed line represents the solution of the model with adjustment costs only. The dotted line represents the solution of the misperception model with costly acquisition of information on house prices at the boundaries and information on house prices being released according to the Poisson process. Source: authors' calculations.

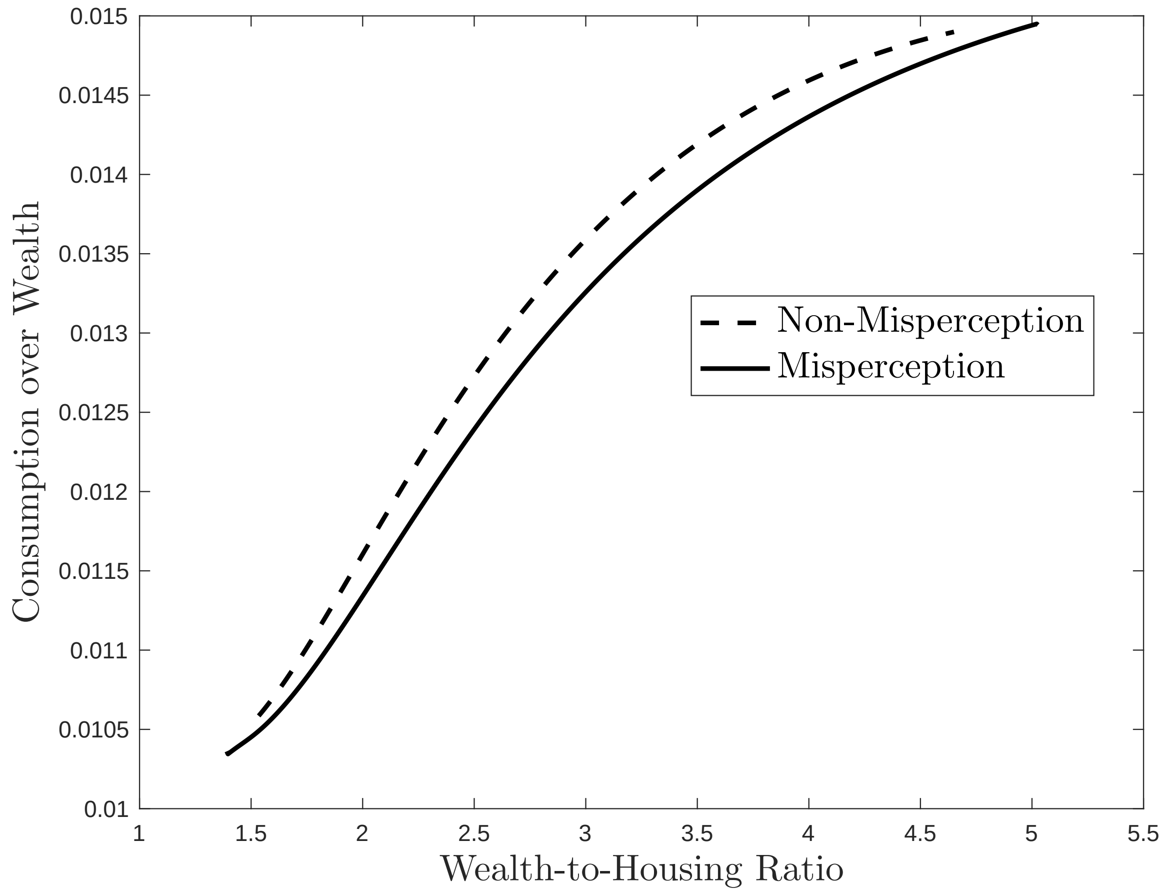

Figure 7: **No-Housing Consumption and Misperception.** The share of wealth consumed in nonhousing consumption, $c(z_t)/z_t$, as a function of the wealth-to-housing ratio, z_t. The dashed line represents the solution of the model with adjustment costs only. The dotted line represents the solution of the misperception model with costly acquisition of information on house prices at the boundaries and information on house prices being released according to the Poisson process. Source: authors' calculations.

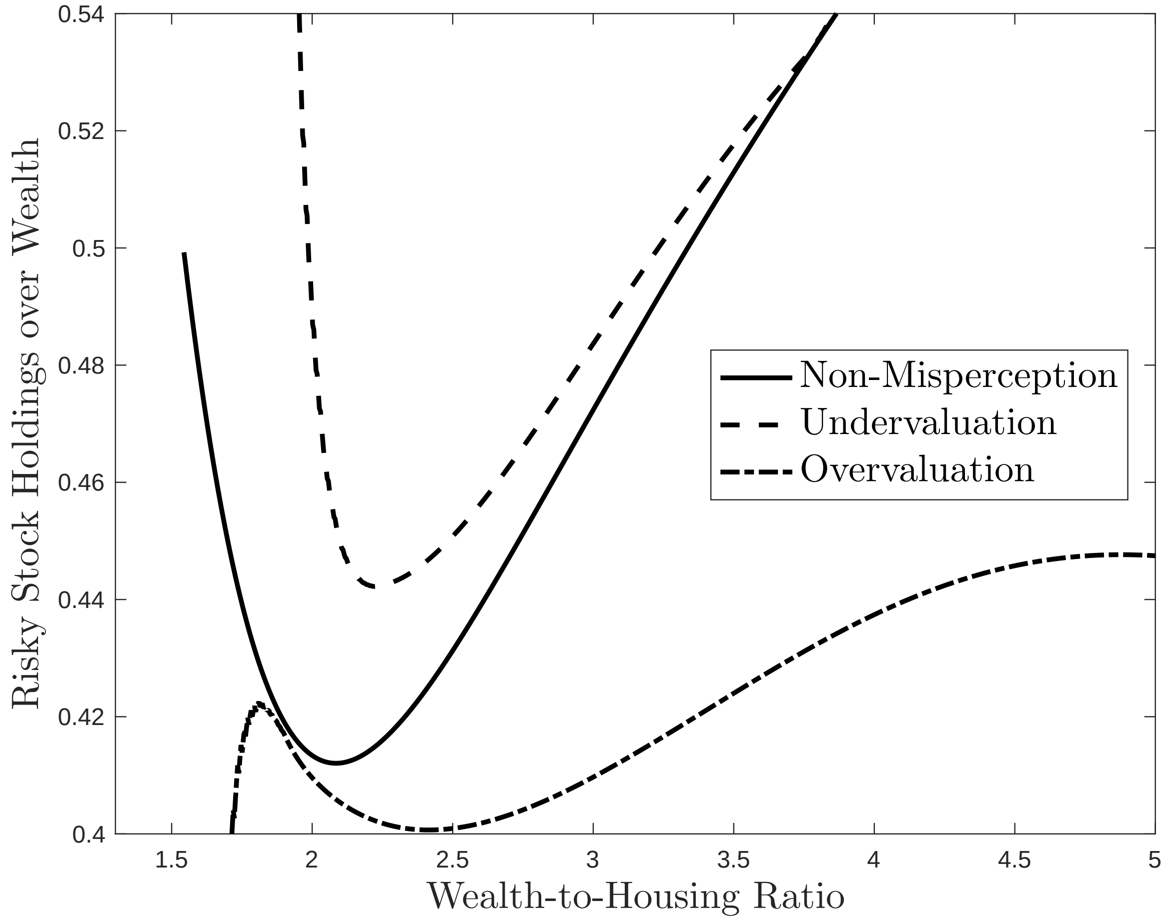

Figure 8: **Risky Stock Holdings, Overvaluation and Undervaluation.** The share of wealth invested in risky holdings, $\theta(z_t)/z_t$ as a function of the wealth-to-housing ratio, z_t. The dashed line represents the solution of the model with adjustment costs only. The dotted (solid) line represents the solution of the misperception model with undervaluation (overvaluation). The misperception model features costly acquisition of house prices information at the boundaries and discrete arrivals of information on house prices following the Poisson process described in Section 4. Source: authors' calculations.

Table 1: **Descriptive Statistics, 1984–2013.** Sample average, standard deviation, percentiles 5 percent and 95 percent, and number of observations for the main variables. The measure of misperception for each household i at any time t, m_{it}, is calculated as per equation (1). Risky stock share, Θ_{it}/W_{it}, is the share of equity in stocks and mutual funds, including equity in IRAs, 401ks, and thrifts (savings plans), over total wealth. The variable x_{it} is a dummy variable that is equal to one if household i is participating in the stock market at time t. Income is the household's total annual income in dollars. Family size is the number of the family members in the household. Age corresponds to the age of the household head. Gender, education, married, and employed are dummy variables that are equal to one if the head of the household is male, has a high school diploma or a higher educational degree, is married, and is employed, respectively. Housing wealth is expressed in dollars. Tenure is the number of years that the household has been living in the current house. Housing return experience (experience) is defined as in Malmendier and Nagel (2011) and Malmendier and Steiny (2017). Source: PSID and CoreLogic zip code HPI.

	Mean	Std. Dev.	p5	p95	Obs.
House Price Misperception, m_{it}	0.014	0.270	−0.360	0.458	42,090
Total Wealth Net of Debt/Housing Wealth, z_{it}	1.648	1.031	0.883	4.339	27,958
Risky Stock Share, Θ_{it}/W_{it}	0.039	0.109	0.000	0.270	27,955
Stock Market Participation, x_{it} (yes=1)	0.267	0.443	0.000	1.000	27,955
Θ_{it}/W_{it} if $x_{it} = 1$	0.144	0.170	0.002	0.504	7,473
Income	75,440	647,742	3,144	103,878	184,244
Log(Income)	9.901	1.209	8.077	11.552	183,802
Family Size	4.0	2.2	1.0	8.0	178,119
Age	39.7	12.6	22.0	63.0	182,966
Gender (Male=1)	1.291	0.454	1.000	2.000	182,984
Education (High School Or More=1)	0.122	0.327	0.000	1.000	266,595
Married (Married =1)	1.835	1.318	1.000	5.000	178,112
Employed (Employed=1)	1.653	1.401	1.000	5.000	178,092
Housing Wealth	92,989	118,562	9,000	300,000	88,187
Log(Housing)	10.907	1.073	9.105	12.612	88,187
Tenure	5.2	5.7	1.0	18.0	157,878
Housing Return Experience	0.045	0.029	0.005	0.091	51,670

Table 2: **Misperception and the Household's Housing Return Experience.** This table shows the effects that past housing return experience have on house value misperception. The dependent variable for all specifications is the measure of misperception, which is defined as the difference between the subjective valuation and the market value of the house measured at the zip code level. Tenure denotes the years that the household has been living in the same house. We control for the logarithm of family income and the number of family members. We also control for the age, gender (male=1), education (high school or more=1) , marital status (married=1), employment status of the head of the household (employed=1) and the logarithm of housing wealth. All our estimations use household-level fixed effects. The $t-$statistics are reported in parentheses. The symbols***, **, and * denote the statistical significance of the coefficients at the 99, 95, and 90 percent level of confidence. Standard errors are clustered at the year and zip code level.

	[1]	[2]	[3]	[4]
Housing Return Experience		-2.0380^{***}		-2.0350^{***}
		(−4.66)		(−4.66)
Tenure			0.0019	0.0006
			(1.39)	(0.35)
Log(Income)	-0.0284^{***}	-0.0504^{***}	-0.0291^{***}	-0.0507^{***}
	(−3.94)	(−5.14)	(−3.99)	(−5.19)
Family Size	0.0025	0.0025	0.0023	0.0024
	(0.92)	(0.61)	(0.84)	(0.60)
Age	−0.0008	−0.0008	-0.0012^{**}	−0.0009
	(−1.39)	(−0.95)	(−2.16)	(−1.09)
Gender	−0.0038	0.0315	−0.0048	0.0312
	(−0.27)	(1.60)	(−0.33)	(1.60)
Education	-0.0315^{***}	−0.0193	-0.0311^{***}	−0.0191
	(−3.23)	(−1.44)	(−3.21)	(−1.43)
Married	−0.0045	-0.0134^{*}	−0.0042	-0.0132^{*}
	(−0.98)	(−1.85)	(−0.89)	(−1.85)
Employed	−0.0014	−0.0019	−0.0010	−0.0017
	(−0.42)	(−0.42)	(−0.29)	(−0.38)
Log(Housing)	0.1510^{***}	0.1820^{***}	0.1520^{***}	0.1820^{***}
	(14.71)	(8.56)	(14.57)	(8.59)
Observations	39,975	10,537	39,975	10,537
R^2	0.271	0.316	0.272	0.316

Table 3: **Portfolio Choices and Misperception.** This table shows the effects that house price misperception has on a household's other portfolio choices. The dependent variable for all specifications is the share of risky stock holdings over total wealth. The measure of misperception, m_{it}, is defined as the difference between the subjective valuation and the market value of the house measured at the zip code level. The variable z_{it} denotes the total wealth to housing wealth ratio. Columns [1]–[3] include all households in the sample while columns [4]–[6] only include stockholders. Columns [1], [2], [4], and [5] show the results from OLS regressions. Columns [3] and [6] show the equivalent results when using the IV. We control for log(income) and number of family members. We also control for the age, gender (male=1), education, marital status and employment status of the head of the household. All our estimations use household-level fixed effects. The $t-$statistics are reported in parenthesis. The symbols ***, **, and * denote statistical significance of the coefficients at the 99, 95, and 90 percent level of confidence. Standard errors are clustered at the year and zip code level.

	All Households			Only Stockholders		
	OLS	OLS	IV	OLS	OLS	IV
	[1]	[2]	[3]	[4]	[5]	[6]
m_{it}		-0.0131^{***}	-0.0197^{**}		-0.0356^{**}	-0.0463^{**}
		(−3.73)	(−2.84)		(−2.43)	(−2.32)
z_{it}	0.0377^{***}	0.0390^{***}	0.0407^{***}	0.0502^{***}	0.0538^{***}	0.0549^{***}
	(12.91)	(11.54)	(10.90)	(11.66)	(10.11)	(9.56)
Log(Income)	0.0117^{***}	0.0130^{***}	0.0149^{***}	0.00377	0.00756	0.00989
	(6.46)	(6.59)	(6.32)	(0.99)	(1.57)	(1.72)
Family Size	-0.00261^{***}	-0.00213^{**}	-0.00233^{**}	−0.00112	−0.00225	−0.00109
	(−3.58)	(−2.84)	(−2.72)	(−0.48)	(−0.98)	(−0.38)
Age	0.000526^{***}	0.000553^{***}	0.000535^{**}	0.00143^{***}	0.00147^{***}	0.00146^{***}
	(4.55)	(3.73)	(3.21)	(5.92)	(3.82)	(3.42)
Gender	0.00289	0.000477	0.00260	0.00643	−0.00175	0.0120
	(0.65)	(0.09)	(0.35)	(0.49)	(−0.09)	(0.45)
Education	0.0188^{***}	0.0144^{**}	0.0150^{**}	0.0179^{**}	0.00640	0.00657
	(4.05)	(2.98)	(3.01)	(2.38)	(0.74)	(0.74)
Married	0.000432	0.000656	0.000523	0.00561	0.00509	0.00460
	(0.29)	(0.34)	(0.21)	(1.18)	(0.84)	(0.56)
Employed	0.00528^{**}	0.00466^{**}	0.00509^{**}	0.0101^{**}	0.00985^{**}	0.00896
	(2.79)	(2.52)	(2.30)	(2.76)	(2.42)	(1.77)
Observations	23,415	16,821	14,146	6,707	4,995	4,402
R^2	0.332	0.362	0.378	0.410	0.445	0.450

Table 4: **Parameters for the Benchmark Model**

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	0.045
Information Cost	ϕ_o	0.005
Risky Asset Drift	μ_S	0.051
Standard Deviation Risky Asset	σ_S	0.165
Correlation House Price – Risky Asset	ρ_{PS}	0.25
Standard Deviation House Price – GBM	$\sigma_{P,1}$	0.025
House Price Drift	μ_P	0.02
Standard Deviation House Price – Shock	$\sigma_{P,2}$	0.05
Poisson Arrival House Price – Shock	λ	16.66%

Table 5: **Acquisition of Information, Housing Adjustments, and Misperception.** Model outcomes for the information acquisition boundaries, columns (1) and (4); the optimal return points, columns (2) and (3); expected tenure in the house, column (5); stock holdings, columns (6) and (7); the difference in stock holdings between the model with and without misperception, column (8); nonhousing consumption, columns (9) and (10); and the difference in nonhousing consumption between the model with and without misperception, column (11), under different parameterizations of the model. Columns (3), (7), and (10) report the outcomes in parametrizations with no transaction (NT) costs of the optimal return point, stock holdings, and nonhousing consumption, respectively. Panel A shows the results for the nonmisperception model. Panels B, C, and D report the outcomes of the model with 5, 10, and 15 percent standard deviations of house value misperception, respectively. Each of these panels compares the baseline model with misperception to the equivalent model with no misperception (nonmisperception), and the equivalent model with misperception but no Poisson jumps ($\lambda = 0$).

	(1) Lower Bound	(2) Return Point	(3) Return Point (NT)	(4) Upper Bound	(5) $E(\tau)$	(6) $\frac{E(\theta/z)}{E(\tau)}$	(7) θ/z (NT)	(8) Stock Hold. Diff. with Nonmisper.	(9) $\frac{E(c/z)}{E(\tau)}$	(10) c/z (NT)	(11) Consum. Diff. with Nonmisper.
Panel A. Non-misper.											
	1.687	2.753	2.342	4.820	40.837	0.491	0.524		0.013	0.013	
Panel B. $\sigma_{P,2} = 5\%$											
Nonmisperception[1]	1.528	2.705	2.357	4.655	41.487	0.490	0.524		0.013	0.013	
Misperception ($\lambda = 0$)	1.385	2.747	2.342	4.634	46.131	0.489	0.524	−0.346%	0.013	0.013	−0.932%
Misperception	1.390	2.594	2.357	5.026	24.105	0.495	0.524	−3.683%	0.013	0.013	−0.936%
Panel C. $\sigma_{P,2} = 10\%$											
Nonmisperception[2]	1.661	2.774	2.398	4.904	37.457	0.495	0.525		0.013	0.013	
Misperception ($\lambda = 0$)	1.380	2.779	2.342	4.708	48.485	0.488	0.524	−1.340%	0.013	0.013	−2.119%
Misperception	1.417	2.541	2.398	5.153	28.405	0.483	0.525	−5.738%	0.013	0.013	−2.798%
Panel D. $\sigma_{P,2} = 15\%$											
Nonmisperception[3]	1.359	2.800	2.458	5.016	34.784	0.498	0.526		0.013	0.013	
Misperception ($\lambda = 0$)	1.359	2.790	2.342	4.279	42.798	0.475	0.524	−3.655%	0.012	0.013	−2.880%
Misperception	1.438	2.519	2.458	5.668	38.351	0.478	0.526	−6.947%	0.013	0.013	−2.623%

[1].$\tilde{\mu}_P = 2\%$, $\tilde{\sigma}_{P,1} = 3.22\%$
[2].$\tilde{\mu}_P = 2\%$, $\tilde{\sigma}_{P,1} = 4.78\%$
[3].$\tilde{\mu}_P = 2\%$, $\tilde{\sigma}_{P,1} = 6.61\%$

Appendix

A-I Misperception: Further Empirical Results

We observe geographical differences in house value misperception. Table A-1 shows that while the mean of house value misperception is positive in some states such as Ohio (7.8 percent), Mississippi (6.1 percent), Missouri (5.7 percent), and Indiana (4.6 percent), it is negative in other states such as Virginia (–7.2 percent), Georgia (–6.4 percent), Florida (–5.6 percent), and California (–5.2 percent). Note that the median of this variable is close to zero in most states, which suggests that misperception is widely dispersed. 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.

We also analyze the effects of house value misperception on nonhousing consumption. Table A-2 shows the results of this analysis using PSID data from 1984 to 2013. We find that a negative relationship exists between misperception and nonhousing consumption. We also find that a positive relationship is present between nonhousing consumption and the wealth-to-housing ratio, z. These results are consistent with the nonhousing consumption that we obtained from the equilibrium of the model (see figure 7). Specifically, we find that a 1 percent increase in misperception leads to a decrease in the average nonhousing consumption of 2.72 percent. Notice that this effect may seem to be low. This is because the measure of consumption in the PSID mostly captures food consumption.

A-II Derivation of the Model

We first solve for the equilibrium of the model in the inaction region. We characterize the upper and lower bounds of the inaction region and the optimal return point. The value function of the problem is defined by

$$V(W(0), P(0), H(0)) = \sup_{C,\Theta,H(\tau),\tau} E\left[\int_0^\tau e^{-\rho t}u(C,H)dt + e^{-\rho\tau}V(W(\tau), P(\tau), H(\tau))\right]. \tag{A-1}$$

Its associated Hamilton-Jacobi-Bellman equation is

$$\rho V = \sup_{C,\Theta}\left\{U(C,H) + \mathcal{D}V + \lambda E\left[V(W + HP \times J, H, P + P \times J) - V\right]\right\}, \tag{A-2}$$

where

$$\begin{aligned}\mathcal{D}V &= [r(W - HP) + \Theta(\alpha_S - r) + (\mu_P - \delta)HP - C]V_W \\ &+ \mu_P P V_P - \delta H V_H + \frac{1}{2}(\Theta^2\sigma_S^2 + 2HP\Theta\rho_{PS}\sigma_S\sigma_P + H^2P^2\sigma_P^2)V_{WW} \\ &+ \frac{1}{2}P^2\sigma_P^2 V_{PP} + (\Theta P\rho_{PS}\sigma_S\sigma_P + HP^2\sigma_P^2)V_{WP}.\end{aligned} \tag{A-3}$$

The component $\lambda E\left[V(W + HP \times J, H, P + P \times J) - V\right]$ reflects the impact of the house price jump on the value function. We can use the homogeneity properties of the value function to reduce the problem with three state variables (W, P, H) to one with two state variables, $z = W/(PH)$. Hence,

$$V(W, P, H) = H^{1-\gamma}P^{\beta(1-\gamma)}V\left(\frac{W}{PH}, 1, 1\right) = H^{1-\gamma}P^{\beta(1-\gamma)}v(z). \tag{A-4}$$

Let us introduce the scaled controls $\hat{c} = C/(PH)$ and $\hat{\theta} = \Theta/(PH)$. After plugging in equation (A-4) into (A-2) and rearranging terms, we obtain that

$$\widetilde{\rho}_i v(z) = \sup_{\hat{c},\hat{\theta}}\left\{u(\hat{c}) + \mathcal{D}v(z) + \lambda E\left[v(z + J) - v(z)\right]\right\}, \tag{A-5}$$

where

$$u(\hat{c}) = \frac{\hat{c}^{\beta(1-\gamma)}}{1-\gamma}, \tag{A-6}$$

$$\begin{aligned}\mathcal{D}v(z) =& ((z-1)(r+\delta-\mu_P+\sigma_P^2(1+\beta(\gamma-1))) \\ &+ \hat{\theta}(\alpha_S - r - (1+\beta(\gamma-1))\rho_{PS}\sigma_S\sigma_P) - \hat{c})v_z(z) \\ &+ \frac{1}{2}((z-1)^2\sigma_P^2 - 2(z-1)\hat{\theta}\rho_{PS}\sigma_P\sigma_S + \hat{\theta}^2\sigma_S^2)v_{zz}(z),\end{aligned} \tag{A-7}$$

and

$$\widetilde{\rho} = 0.5(-2\rho - 2(\gamma-1)(\mu_P - \delta + \beta(\gamma-1)(1+\beta(\gamma-1))\sigma_P^2). \tag{A-8}$$

We obtain the following first-order conditions from equation (A-5):

$$\hat{c}^*(z) = \left(\frac{v_z(z)}{\beta}\right)^{1/(\beta(1-\gamma)-1)}, \tag{A-9}$$

$$\hat{\theta}^*(z) = -(\alpha_S - r)\frac{v_z(z)}{\sigma_S^2 v_{zz}(z)} - (1-\beta(1-\gamma))\rho_{PS}\sigma_P\frac{v_z(z)}{\sigma_S^2 v_{zz}(z)} + (z-1)\frac{\rho_{PS}\sigma_P}{\sigma_S}. \tag{A-10}$$

In order to identify the properties of the inaction region, we use equation (A-1) to study the value function of the agent when she hits the upper or lower bound of the inaction region following Damgaard, Fuglsbjerg, and Munk (2003).

A-III 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 $(M_i, \underline{z}_i, \overline{z}_i, z_i^*)$:

1. Guess $M = M_0$.

2. Solve the two point boundary value problem as follows:

   (i) Guess $\underline{z}_0$ and $\overline{z}_0$.

(ii) Compute the value matching conditions (18) and (19) using a discretization of the normal distribution. In all solutions presented in this paper we use a 120−mass-point discretization of the normal distribution.

(iii) Solve the ODE in equation (13) adopting a finite difference scheme.

(iv) Compute the candidate value functions $v_{M_0}(z)$.

3. Compute the value function outside the inaction region using the same discretization of the normal distribution of point (ii).

4. Compute the implied $M_0^* = (1-\gamma)\sup_z z^{\gamma-1} v_{M_0}(z) = (1-\gamma) z^{*(\gamma-1)} v(z^*)$ using equation (16). The problem is solved when $M_0^* = M_0$ and M_0^* is the minimum possible value and

$$v_{M_0}(z) \geq E\left[M \frac{(z + \tilde{J} - \phi_a - \phi_o)^{(1-\gamma)}}{1-\gamma} \right]. \tag{A-11}$$

Otherwise repeat steps 1, 2, and 3.

As a starting point, we use the solution to the problem of no transaction costs, $\phi_a = \phi_o = 0$. This solution consists of the optimal housing-to-wealth ratio, α_h, the optimal risky assets ratio, α_θ, and the optimal numeraire consumption ratio, α_c. The first set of iterations uses a fixed portfolio policy. We use $M = \alpha_v$ and $z^* = 1/\alpha_h$, as the set of initial values of M and z^*. The initial values for $\underline{z}$ and $\overline{z}$ must accomplish that $\underline{z} < z^*$ and $\overline{z} > z^*$. Once the iterative procedure has converged, we use the solution that we obtain to construct an approximation to the policy function $\hat{\theta}^*(z)$. Finally, we adopt a value iteration procedure to obtain $(\underline{z}, \overline{z}, M, z^*)$.

Table A-1: **House Value Misperception for Key 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 percent, 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

Table A-2: **Nonhousing Consumption and Misperception.** This table shows the effects of house value misperception on household consumption. The dependent variable for all specifications is the ratio of nonhousing good consumption over housing wealth. Here, m_{it} represents the measure of misperception, which is defined as the difference between the subjective valuation and the market value of the house measured at the zip code level, while z_{it} denotes the total wealth to housing wealth ratio. Columns [1] and [2] show the results from OLS regressions. Column [3] show the equivalent results when using the IV. We control for log(income) and number of family members. We also control for the age, gender (male=1), education, marital status and employment status of the head of the household. All our estimations use household-level fixed effects. Standard errors are clustered at the year and zip code level. The sample starts in 1999 and ends in 2013. The PSID survey is conducted biennially for these years.

	OLS [1]	OLS [2]	IV [3]
m_{it}		-0.0257^{***}	-0.0272^{**}
		(-4.69)	(-3.06)
z_{it}	0.00401^{**}	0.00353	0.00355
	(2.45)	(1.69)	(1.55)
Log(Income)	-0.00942^{***}	-0.00883^{***}	-0.00789^{**}
	(-5.81)	(-4.63)	(-3.67)
Family Size	0.00538^{***}	0.00544^{***}	0.00551^{***}
	(6.22)	(6.36)	(5.78)
Age	-0.00024^{**}	-0.00025^{*}	-0.00032^{*}
	(-3.12)	(-2.39)	(-2.37)
Gender	-0.00687^{*}	-0.00700^{*}	-0.00638
	(-2.42)	(-2.01)	(-1.62)
Education	-0.0096^{***}	-0.0101^{***}	-0.0103^{***}
	(-4.67)	(-4.36)	(-3.94)
Married	0.00057	-0.00026	-0.00094
	(0.50)	(-0.23)	(-0.78)
Employed	-0.00198^{**}	-0.00071	-0.00058
	(-2.48)	(-0.71)	(-0.57)
Observations	15,073	11,476	9,954
R^2	0.348	0.381	0.414