Household Choices with House Value Misperception*

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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 Classification: G11, D11, D91, R21, C61.

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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. Although this misalignment is sizeable, the literature on portfolio choices with housing assumes that households accurately observe house prices (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)).[1] In this paper, we study how this misalignment, which we refer to as house value misperception, affect how households make portfolio and consumption decisions. We first show, using a simple model, that it is critical to incorporate misperception to study household choices in the presence of housing. We then use household level data to evaluate the implications of misperception on portfolio choices 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.[2] 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

[1] Davis and Van Nieuwerburgh (2015) provide a survey of the portfolio literature with housing.

[2] 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.

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.[3]

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 Malmendier and Nagel (2011), Malmendier and Nagel (2016), and Malmendier and Steiny (2017))[4]; (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 set up our empirical strategy using a stylized model that incorporates housing value misperception to a standard model of portfolio choice with transaction costs (Grossman and Laroque (1990), Cocco (2005), and Stokey (2009)). The model flexibly accounts for different sources of misperception (like rational inattention and learning, or behavioral anchoring on past experience). The main takeaway of the model is that, in an economy with misperception, households consume less, hold less risky assets, and are less levered than in an economy without misperception. Moreover, households that overvalue their house hold less risky assets, consume less, and are less levered than households that undervalue their house.[5]

Two mechanisms drive these outcomes. First, larger (perceived) housing holdings crowd

[3]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.

[4]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.

[5]Our model also delivers quantitative implications. We find that a model with no misperception (that is, the household always knows the house's 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, 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.

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.

The equilibrium of the model establishes a causal relationship between the (mis)perceived house value and household's decisions that we employ in the empirical analysis. 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, at 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.[6] 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.

Since housing holdings, portfolio, and consumption decisions are all endogenous choices, we address the endogeneity problem instrumenting X with Z. Add results [...different research designs as in Chetty et al.]

We also acknowledge that our data for housing values and therefore misperception may be subject to measurement errors. We address this by [...]

Finally, our fundamental assumption is that the only way to completely mitigate misperception is to have the house on sale continuously on sale, and receive periodic market

[6]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.

offers from buyers. 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 **??** we describe the stylized model that guides our empirical approach, we study its comparative statics, and we quantify the effects of house value misperception using numerical simulations. Section 2 describes the data, develops our measure of misperception and documents its stylized facts. In Section 3 presents and discusses our empirical results. Section 4 concludes.

2 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

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

[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.

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

[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 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.

time t is defined as:

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

where $(H_i \cdot P_{i,t})^{PSID}$ is the subjective value of the house (HV^S henceforth) 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 (HV^M henceforth). 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 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

[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.

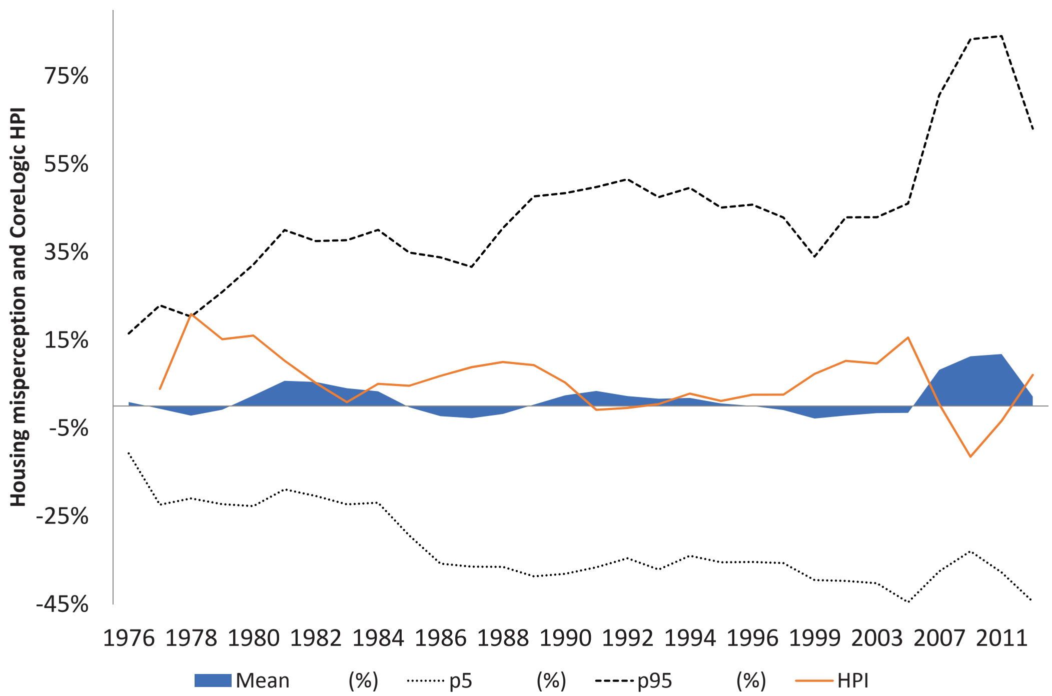

Figure 1: **House Value Misperception Over Time.** The figure plots the dynamics of the average house value misperception (mean), the percentiles 5 (p5) and 95 (p95) of the distribution of house value misperception, and the returns on the US aggregate CoreLogic House Price Index (HPI). Source CoreLogic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

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

[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.

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 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). This fact is also indicative of anchoring behavior by households. In order to identify

In Figure 2, we analyze house value misperception by cohort. The figure in the left shows misperception (vertical axis) versus tenure (horizontal axis) by the cohort that moved in 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 figure in the right displays the results of an analysis of cohorts that moved in the same year to analyze the effect of housing experience on house value misperception in subsequent years. It displays the coefficients and their 95% confidence intervals of cohort by cohort regressions with time fixed effects. This figure shows that misperception is time varying and it depends on the year that the household moved. Notice that the cohort that moved in 1999 only starts overvaluing significantly after 2007 and then overvaluation goes down after 2011. Moreover, the cohort that moved in 2005 is overvaluing more than other cohorts (i.e., the cohorts of 2005 and 2007 present a significantly different misperception).

The third, fourth, and fifth relevant stylized facts arise from Figure 2: the sign of house value misperception is persistent, the level of misperception reverts to its mean after about six to seven years on average, and the year in which the household moves affects its misperception (i.e., there is a significant level of housing experience). 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. This fact indicates that households tend to either acquire information about their house value, because they

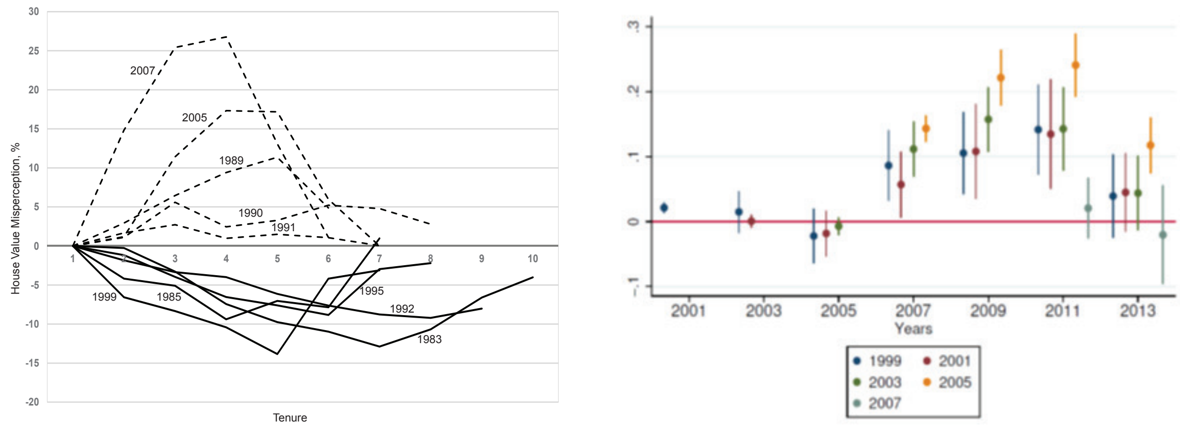

Figure 2: **House Value Misperception by Cohort.** Panel A of this figure plots the dynamics of the average house value misperception for cohorts of households that acquire a house in a selected year. When a household moves, it is dropped from the sample used in this figure. Tenure is measured in years 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. Panel B shows the analysis of the effect of housing experience on house value misperception. It displays the coefficients of housing experience in a cohort by cohort regression with time fixed effects for cohorts that moved in the same year. Source: PSID.

are selling or refinancing, or because the household learns from a neighboring property being sold. 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, consistent with rational behavior and observation costs. The empirical evidence that we find in Section **??** is also consistent with these assumptions, but does leave the door open to the alternative drivers of misperception described before, namely anchoring and past house returns experience.

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

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

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 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]

We have studied the main characteristics of house value misperception, but what are their determinants? Does misperception come from the fact that: (i) households' subjective house value growth may not be aligned with the corresponding growth of the market house value; (ii) housing return experience affects misperception?; and/or (iii) tenure in the house

[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 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.

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
Experience	0.045	0.029	0.005	0.091	51,670

affects the perception about the house value?

Misperception may decrease because homeowners adjust the subjective valuation of their house in the direction of its market value. Alternatively, misperception may vary just because market values move, which would be consistent with homeowners anchoring their house value at their purchase price, for example. The recent history of house price changes experienced by a household may have an impact on the way it form subjective valuation of their house. And finally, the time that homeowners have spent living in the house may affect how far from the market value the subjective valuation is. This is not an exhaustive list of misperception drivers. These are plausible and measurable drivers, and Table 2 reports the extent to which these drivers determine house value misperception. We run OLS panel regressions of house value misperception at the household level on variables that can affect misperception, and we do it for different subsamples too.

We find that both changes in the subjective and market valuations of the house have a significant impact on misperception: misperception tends to increase when the household changes the subjective value, and misperception tends to decrease when market values grow. The positive sign in $growth(HV^S)$ means that if a household increases the subjective valuation of its house, then misperception tends to increase. The negative sign in $growth(HV^M)$ means that an increase in the market value of house prices tends to decrease its overvaluation (or increase its undervaluation). These results are indicative of a certain level of anchoring, since the negative sign on the coefficient for the market value growth suggests that households subjective values do not change one-to-one with market values. However, when we consider the absolute value of misperception, market value changes do not significantly change misperception. Subjective value changes do increase misperception in both directions: households that overvalue, overvalue more, and households who undervalue, undervalue more after changing their subjective valuation.

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. Previously, 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. The market house values that households have experienced in the past also have a negative effect on misperception: households living in zipcodes that have experience higher housing returns in the past five years tend to display less misperception.

All these effects are stronger when we include only those households that overvalue its house (column [2]) than we include only the households that undervalue (column [3]) and when we include only boom years (column [4]) when compared when we only include bust years (column [5]).

Our specification also includes a measure of how long a household has lived in the current house. We find that, for all households, there is no significant effect of tenure but, when we split the sample in households that overvalue and households that undervalue, tenure becomes relevant. For households that overvalue, tenure has a positive but decreasing effect on misperception while, for households that undervalue, tenure has an increasingly negative effect on misperception. The interpretation is clearer in column [6], where we explain the absolute value of misperception (i.e., absolute deviations from the market value in either direction). Column [6] confirm the results in Kuzmenko and Timmins (2011), who find that households that have been living in the same house for longer tend to have worse estimates of the value of their house.

The objective of this section was to answer the question of what determines misperception. We have explored several drivers and we find that they all play a significant role in explaining the variation of misperception within zip codes, across households.

In the appendix, we provide a principal component analysis for house value misperception. We transform a set of observations of 5 possibly correlated variables (i.e., growth(HV^S), growth(HV^M), Experience, Tenure, and Transactions) into a set of values of 5 linearly uncorrelated principal components. The first 5 principal components explain 27.8%, 21.4%, 19.8%, 18.0%, and 13.1% of the variance of house value misperception, respectively. We conclude that there are several sources that explain the variation in house variance misestimation, which verifies the fact that there are several determinants of misestimation.

Table 2: **The Determinants of House Value Misperception by Subsamples.** This table shows analysis of the determinants of house value misperception. The dependent variable for specifications [1]-[5] in Panel A is the measure of misperception, m_{it}. and the absolute value of misperception for specification [6]. The dependent variable in Panel B is change in misperception, Δm_{it}. 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.

	All Households	Only Overvaluers	Only Undervaluers	Only Boom Years	Only Bust Years	All Households
Panel A.	m_{it}	m_{it}	m_{it}	m_{it}	m_{it}	$abs(m_{it})$
	[1]	[2]	[3]	[4]	[5]	[6]
growth(HV^S)	0.329***	0.266***	0.154***	0.269***	0.490**	0.109**
	(8.47)	(7.89)	(8.70)	(15.36)	(14.11)	(3.57)
growth(HV^M)	-0.674***	-0.548***	-0.325***	-0.562***	-0.730	-0.0663
	(-9.95)	(-8.91)	(-13.88)	(-8.01)	(-6.01)	(-0.90)
Experience	-6.410***	-5.884***	-2.345***	-5.100***	-1.861	-3.063**
	(-7.74)	(-5.67)	(-6.93)	(-6.18)	(-0.79)	(-3.06)
Tenure	0.00926	0.0397***	-0.0161***	0.00293	0.0223	0.0334***
	(1.50)	(7.39)	(-6.28)	(0.48)	(2.84)	(9.70)
Tenure^2	-0.000448	-0.00129***	0.000393**	-0.000259	-0.000884	-0.00104***
	(-1.91)	(-5.75)	(3.73)	(-0.99)	(-3.16)	(-7.10)
Transactions						-0.00466
						(-0.51)
Observations	4,465	2,381	2,017	2,765	1,648	4,235
R^2	0.469	0.447	0.567	0.486	0.533	0.296
Panel B.	Δm_{it}	Δm_{it}	Δm_{it}	Δm_{it}	Δm_{it}	
	[1]	[2]	[3]	[4]	[5]	
growth(HV^S)	0.654***	0.707***	0.518***	0.528***	0.928*	
	(8.32)	(7.59)	(8.92)	(25.54)	(10.65)	
growth(HV^M)	-0.810***	-1.044***	-0.521***	-0.674***	-1.165*	
	(-8.52)	(-8.16)	(-11.15)	(-12.53)	(-6.55)	
Experience	0.744	0.873	1.651***	0.788	4.480	
	(1.62)	(1.31)	(4.18)	(1.30)	(2.06)	
Tenure	0.00870***	0.0118**	0.0111***	0.0101*	0.00792	
	(4.04)	(2.99)	(6.90)	(2.88)	(1.98)	
Tenure^2	-0.000320**	-0.000406**	-0.000403***	-0.000382*	-0.000283	
	(-3.51)	(-2.61)	(-6.51)	(-3.03)	(-2.12)	
Observations	4,405	2,327	2,009	2,710	1,643	
R-squared	0.518	0.466	0.620	0.575	0.594	

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.

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 **??**.

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

[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

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 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

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.

[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.

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

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.

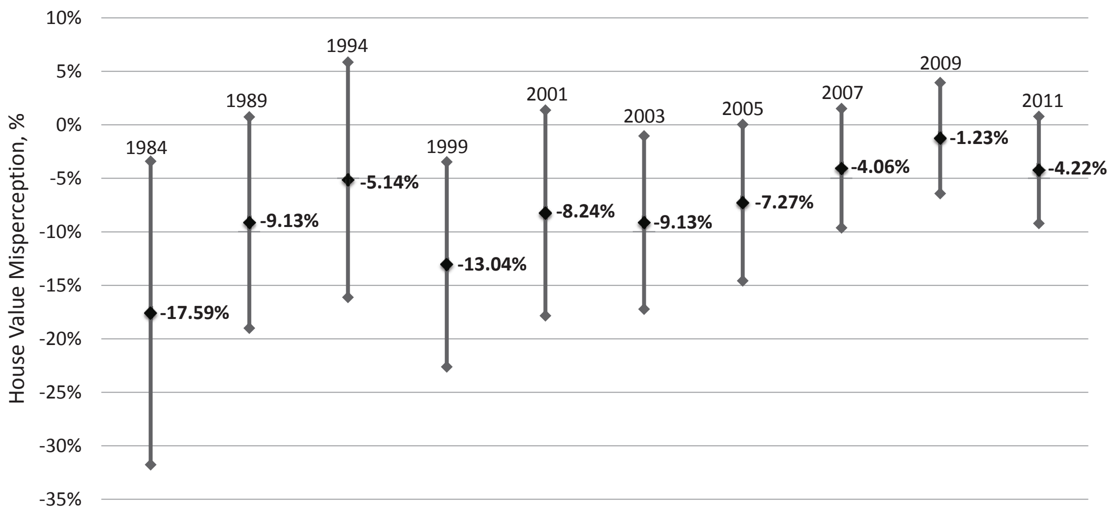

Figure 3: **House Value Misperception and Stock Market Participation.** This figure plots the marginal effects of house value misperception on households' stock market participation by year. These marginal effects are obtained with a probit model that includes as control variables log(income), age, gender, 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.

Specifically, a 1 percent increase in misperception decreases the probability of participating 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 **??** 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 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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Appendix

A-I Principal Component Analysis for House Value Misperception

In this section, we provide a principal component analysis for house value misperception. We implement an orthogonal transformation to convert a set of observations of 5 possibly correlated variables (i.e., growth(HV^S), growth(HV^M), Experience, Tenure, and Transactions) into a set of values of 5 linearly uncorrelated principal components. In this transformation, the first principal component has the largest possible variance and each following component has the highest variance possible under the constraint that it is orthogonal to the preceding components. Therefore, we obtain an uncorrelated orthogonal set of vectors.

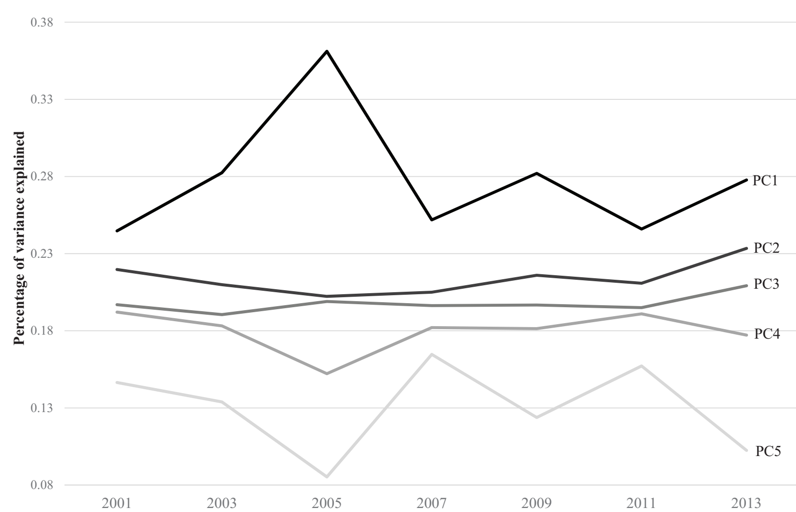

Figure A-1: **Principal Component Analysis.** This figure plots the output of a principal component analysis for house value misperception using the 5 following variables: growth(HV^S), growth(HV^M), Experience, Tenure, and Transaction. It shows the distribution of the variance explained by the first 5 principal components for the period 2001-2013.

Figure A-1 displays the distribution of the variance explained by the first 5 principal components for the period 2001-2013. It shows that there is no a single component that explains most of the variation in house value misperception. The first 5 principal components of this analysis show that these 5 principal components explain 27.8%, 21.4%, 19.8%, 18.0%, and 13.1% of the variance of house value misperception, respectively. In summary, there are several sources that explain the variation in house variance misestimation, which verifies that there are several determinants of misestimation.

A-II 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 **??**). 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

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

the measure of consumption in the PSID mostly captures food consumption.

A-III 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

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

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

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

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

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,

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

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

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

where

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

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

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-IV 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 (**??**) and (**??**) 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 (**??**) 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 (**??**). 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 $(\underline{z}, \overline{z}, M, z^*)$.