House Price Beliefs And Mortgage Leverage Choice*

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Abstract

We study the relationship between homebuyers' beliefs about future house price changes and their mortgage leverage choices. From a theoretical perspective, whether more pessimistic homebuyers choose more or less leverage is ambiguous and depends on their willingness to reduce the size of their housing investment. When households primarily maximize the levered return of their property investment, more pessimistic homebuyers reduce their leverage to purchase smaller houses. On the other hand, when considerations such as family size pin down the desired property size, pessimistic homebuyers reduce their financial exposure to the housing market by making smaller downpayments to buy similarly-sized homes. To determine which scenario better describes the data, we empirically investigate the cross-sectional relationship between beliefs and leverage choices in the U.S. housing market. Our data combine mortgage financing information and a housing market expectations survey with anonymized social network data from Facebook. The survey shows that an individual's belief distribution about future house price changes is affected by the recent house price experiences of her geographically distant friends, allowing us to use these experiences as quasi-exogenous shifters of individuals' house price beliefs. We find that more pessimistic homebuyers make smaller downpayments and choose higher leverage, in particular in states where default costs are relatively low, as well as during periods when house prices are expected to fall on average. Overall, our results provide evidence for an important role of heterogeneous beliefs in explaining individuals' financial decision-making.

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Aggregate leverage ratios in the economy vary substantially over time and play a key role in driving economic fluctuations (see Krishnamurthy and Muir, 2016; Mian, Sufi and Verner, 2016). Understanding the determinants of investors' leverage choices is therefore a question of central economic importance. Leverage choices in the housing market are of particular interest to policy makers (see DeFusco, Johnson and Mondragon, 2017): mortgages are the primary liability on households' balance sheets, and increased household leverage plays a key role in many accounts of the recent Financial Crisis (e.g., Mian and Sufi, 2009). In this paper, we explore the role of homebuyers' beliefs about house price growth as one potential determinant of their mortgage leverage choices.

We first develop a parsimonious model that characterizes the channels through which homebuyers' beliefs about future house price growth can affect their mortgage leverage choices. We show that the direction of the combined effect of beliefs on leverage choices is ambiguous, and depends on the willingness of relatively pessimistic homebuyers to reduce the size of their housing market investment by either renting or buying a smaller house in a cheaper neighborhood. We then empirically investigate the relationship between homebuyers' beliefs about future house price growth and their leverage choices, and find that more pessimistic homebuyers take on more leverage.

Our model adapts the portfolio choice framework of Geanakoplos (2010) and Simsek (2013) to the housing market. We consider individuals who optimally choose non-housing consumption in addition to home size and mortgage leverage given a schedule of loan-to-value ratios and interest rates offered by lenders. Introducing consumption as an additional choice margin allows households to separately determine the size of their home and their leverage. House price beliefs affect leverage choices through two forces. The first force works through the perceived expected return on housing investments ("expected return force"). More optimistic agents want to buy larger houses, since they expect each dollar invested in housing to earn a higher return. In order to afford the larger home, they need to further lever up their fixed resources. The second force works through the protection against house price declines offered by the ability to default on mortgages ("downpayment protection force").[1] Holding house size fixed, more pessimistic agents, who perceive a higher probability of defaulting on their mortgage, choose lower downpayments and higher leverage to limit the potential loss of their own funds in case of default.[2]

Our model captures an additional important feature of housing markets. Since owner-occupied housing is both an investment and a consumption good, the optimal home is not just determined by homebuyers' investment motives, but also by consumption-driven motives such as family size and neighborhood preferences. This introduces a "collateral adjustment friction" that reduces homebuyers' willingness to adjust their property size in response to changes in house price beliefs.[3] For example, a large collateral adjustment friction could be the result of pessimists not being willing to purchase in a less-safe neighborhood, or not wanting to buy a much smaller house. Our main theoretical result is to show that the strength of this friction is central to determining the relationship between homebuyers' house price beliefs and their mortgage leverage choices.

We highlight the key mechanisms in our model by considering two polar scenarios for which we can obtain explicit analytical results. We first consider a *housing-as-investment* scenario in which there is no collateral

[1] We show that this force is active independent of whether mortgage default is primarily strategic, with homeowners defaulting as soon as their home is sufficiently "underwater," or whether mortgage default only occurs when households also receive a negative income shock that makes it impossible for them to continue their monthly mortgage payments.

[2] As will become evident below, an equivalent exposition of the second force describes pessimists as perceiving a lower marginal cost of borrowing, since they expect to repay their loan in fewer states of the world. This makes higher leverage more appealing.

[3] We use the term friction to capture any force that reduces the willingness of individuals to adjust their exposure to the housing collateral for pure investment motives. In our setting, this force comes from the preferences of homebuyers, who view their house not just as an investment, but also as a place to live, which puts additional constraints on house size. Our discussion of the collateral adjustment friction focuses on the intensive margin of housing investment. In housing markets, renting rather than buying can give individuals the option to separate their decision of what house to live in from the decision of the size of their housing market investment. However, in many cases, the set of properties available for rent is very different from the set of properties available for sale; indeed, large single-family residences are almost exclusively owner-occupied. Therefore, reducing one's housing market exposure through renting will usually also involve a potentially costly adjustment to the type of housing that can be consumed. This force will have the same effect as the collateral adjustment friction we consider for the intensive margin adjustment.

adjustment friction and property size and leverage are determined by both the expected return force and the downpayment protection force. Under the appropriate definition of optimism, this scenario recovers the predictions from the portfolio choice problem in Simsek (2013): more pessimistic homebuyers reduce their leverage to purchase smaller houses because the expected return force dominates the downpayment protection force.

We then consider a *housing-as-consumption* scenario, in which the size of the housing investment is completely pinned down by factors such as family size, and households allocate their resources between consumption and making a downpayment to purchase the house. In this scenario, which corresponds to an infinite collateral adjustment friction, the expected return force is inactive, but the downpayment protection force continues to operate. As a result, more pessimistic agents make smaller downpayments to protect their assets against losses in case of house price declines. In particular, a pessimistic homebuyer might think: "I need at least a 3-bedroom house given my family size, but I think house prices are likely to fall, so I do not want to invest much of my own money." Such a borrower would then naturally choose higher leverage. As a reader explained to the Washington Post (2011): "An acquaintance once told me he doesn't believe in putting much money down on a mortgage loan because that way he can 'just walk away' if things ever get bad. And walk away he did. His property is now in foreclosure." In the paper, we provide extensive evidence for the prevalence of such thinking among homebuyers.

When we move away from these polar cases, whether more pessimistic agents take on more or less leverage depends on the magnitude of the collateral adjustment friction that captures the extent to which optimal home size is determined by investment or consumption motives. The empirical contribution of this paper is to investigate which of these forces dominates in practice. This analysis faces a number of challenges. Testing the implications of models with belief heterogeneity is difficult because individuals' beliefs are high-dimensional and hard-to-observe objects. In addition, even if we could cleanly elicit homebuyers' house price beliefs, we rarely observe forces that induce heterogeneity in these beliefs without also inducing variation in their economic resources or other variables that might independently affect their leverage choices.

Our empirical approach builds on Bailey et al. (2017*a*), who document that the recent house price experiences in an individual's geographically distant social network affect her beliefs about the attractiveness of local housing market investments. Indeed, we verify that the recent house price experiences of geographically distant friends can be used as shifters of individuals' beliefs about the distribution of expected future house price changes. We also show that friends' house price experiences are unlikely to affect leverage choices through channels other than beliefs. This allows us to explore the empirical relationship between beliefs and leverage by analyzing the cross-sectional relationship between the leverage choices of individuals borrowing from the same lender to purchase homes at the same time and in the same neighborhood, and the house price experiences of these homebuyers' geographically distant friends.

In our data, we observe an anonymized snapshot of U.S. individuals' friendship networks on Facebook, the largest online social network, with over 231 million users in the U.S. and Canada. Our first empirical step combines these data with responses to a housing market expectation survey that was conducted by Facebook in April 2017. The survey, which targeted Facebook users in Los Angeles through their News Feeds, elicited a distribution of respondents' expectations for future house price changes in their own zip codes. Individuals whose friends experienced more recent house price increases expect higher average future house price growth. Quantitatively, a one-percentage-point higher house price appreciation among an individual's friends over the previous 24 months is associated with individuals expecting a 33 basis points higher house price growth over the subsequent year. We also find that individuals whose friends experienced more heterogeneous recent house price changes report a more dispersed distribution of expected future house price growth. This suggests that the house price experiences within an individual's social network do not just affect her beliefs on average, but that other moments of the distribution

of friends' experiences affect the corresponding moments of the belief distribution.

To study the role of house price beliefs in shaping mortgage leverage choice, we match anonymized social network data on Facebook users from 2,900 U.S. zip codes to public record housing deeds data, which contain information on both transaction prices and mortgage choices. We observe information on homebuyers' leverage choices for about 1.35 million housing transactions between 2008 and 2014.

We first test the predictions of our model under the assumption that beliefs over future house price changes are normally distributed.[4] We find that individuals whose friends have experienced lower recent house price growth, and who are thus more pessimistic about future house price growth, take on more leverage. Quantitatively, a one-percentage-point decrease in the average house price experiences among an individual's friends over the prior two years is associated with an increase in the loan-to-value ratio of about 9 basis points. Combined with the estimates from the survey, this suggests that a one-percentage-point decrease in the expected house price appreciation over the next twelve months leads individuals to increase their loan-to-value ratio by 26 basis points. These findings are aligned with the predictions of the housing-as-consumption scenario, and suggest a sizable collateral adjustment friction in the choice of financing owner-occupied housing. Consistent with predictions from this scenario, we also find that a higher cross-sectional variance of friends' house price experiences is associated with choosing higher leverage: holding mean beliefs fixed, individuals who have a more dispersed belief distribution perceive a higher probability of default, and thus reduce their downpayment.

We test a number of additional predictions from the model about the relationship between beliefs and leverage choice in the housing-as-consumption scenario. First, the model suggests that the effects of beliefs on leverage choices should be particularly large when the cost of default is relatively small, so that household would consider defaulting in response to declining house prices a less costly proposition. Consistent with this, we find that more pessimistic individuals in non-recourse states, where lenders cannot recover losses on a mortgage by going after borrowers' non-housing assets, are more likely to reduce their downpayments than pessimistic individuals in recourse states, where the ability of lenders to go after non-housing assets translates into a higher cost of default.

Second, in the housing-as-consumption scenario, changes in beliefs have larger effects on leverage choices for individuals that are relatively pessimistic to begin with. This is because, in this scenario, the key driver of differences in leverage choice is disagreement about the probability of default. Following large house price increases, even relatively pessimistic individuals assign small probabilities to default states of the world. The quantitative effects of cross-sectional differences in beliefs on optimal leverage are therefore relatively small. Consistent with this, we find the magnitude of the relationship between house price beliefs and leverage choice to be the strongest among individuals who are relatively more pessimistic and during periods of declining house prices.

Third, the relative strength of the downpayment protection force compared to the expected return force should be increasing in the collateral adjustment friction faced by homebuyers. Consistent with this, we find that pessimists reduce their downpayment more when buying homes in areas with a high homeownership rate, where they have fewer opportunities to reduce their exposure to the housing market by renting instead of buying.

Throughout the analysis, we argue that the house price experiences of a homebuyer's geographically distant friends affect her mortgage leverage choice only through influencing her beliefs about future house price changes. We rule out other channels that could have explained the observed relationship. For example, we show that the results are not driven by wealth effects whereby a higher house price appreciation in areas where an individual has friends increases her resources for making downpayments. Our results are also not explained by correlated shocks to individuals and their friends, or by individuals learning about the cost of default from their friends.

[4] By studying the case of normally distributed beliefs, we can derive unambiguous predictions for changes in the level and dispersion of beliefs (the mean and standard deviation of beliefs about house price growth). Our non-parametric results highlight the importance of using the appropriate definitions of optimism to generate unambiguous predictions about the effect of beliefs on leverage.

We provide ancillary for the mechanisms described above. First, we show that, in a correlational sense, the negative relationship between optimism and leverage can also be detected in the New York Fed Survey of Consumer Expectations. Second, we conduct an additional survey on SurveyMonkey in which we presented 1,600 individuals with hypothetical house price scenarios, and asked them to recommend a mortgage option to a friend who has already decided on a particular house to buy. Survey respondents were more likely to recommend making smaller downpayments under scenarios with a higher probability of large house price declines, even though this entailed paying higher interest rates. When asked to explain their reasoning, many individuals described a thought process consistent with the downpayment protection force (e.g., "If he defaults and housing prices decrease so that he cannot sell to recoup his investment, he loses less deposit if he puts less down"). We also document that a similar logic is often described on financial advice websites and blogs that discuss what downpayments individuals should make. We then show that many individuals do not consider mortgage default particularly costly, another requirement for a strong downpayment protection force. Lastly, we present evidence for a substantial collateral adjustment friction. In particular, we explore Zillow's *Consumer Housing Trends Report 2017*, which highlights how consumption aspects such as location and home size are usually the most important determinants of individuals' property choice, and that potential investment returns are much less important.

Overall, our evidence points to an important role for house price beliefs in determining individuals' mortgage leverage choices. In the presence of sizable collateral adjustment frictions, more pessimistic individuals do not buy substantially smaller houses, but instead reduce their exposure to the housing market by making a smaller downpayment, particularly when the costs of mortgage default are relatively small.

Our paper contributes to the theoretical literature on collateralized credit with heterogeneous beliefs developed by Geanakoplos (1997, 2003, 2010) and Fostel and Geanakoplos (2008, 2012, 2015, 2016).[5] Within that literature, which has focused on environments in which investors exclusively make levered purchases of risky assets, our model is most closely related to the baseline environment studied by Simsek (2013). We show that the same theoretical framework can deliver new predictions when (i) an additional margin of adjustment — a consumption-savings decision — is introduced, and (ii) homebuyers' housing choices are not exclusively driven by the pecuniary investment return on housing. We operationalize the theory by developing implementable tests of how borrowers' beliefs affect their leverage choices. Our results provide support for theories in which investors' beliefs are an important determinant of individual and aggregate behavior, and are complementary to the findings of Koudijs and Voth (2016), who document the positive relation between lenders' optimism and high leverage.

Our theoretical observation that the relationship between borrowers' beliefs and leverage choices depends on the magnitude of the collateral adjustment friction is likely to be important across a number of other settings. In the housing market, the consumption aspect of housing reduces households' desire to adjust the size of their housing market investment based on their beliefs about future house price growth. In a similar way, firms borrowing against their machinery might not be able to sell any collateral that remains important in the current production process, even if the firms expect the collateral to lose value in the future. Even for pure investment assets, such as stock holdings, an investor's ability to dispose of those assets quickly might be affected by market liquidity, which could also introduce a collateral adjustment friction. In all of these settings, our model predicts that pessimistic agents would engage in significant (non-recourse) collateralized borrowing against any asset that they are unable to sell. To our knowledge, we are the first to *identify* the ability or willingness to adjust collateral positions as the key feature that determines the relation between borrowers' beliefs and leverage choices, although the primitive forces driving our model are important in many environments.[6]

[5] Other applications of collateral equilibrium include Araújo, Schommer and Woodford (2015), Cao (2017), Gottardi and Kubler (2015), Geanakoplos and Zame (2014), Geerolf (2015) and He and Xiong (2012).

[6] For example, the mechanism behind the downpayment protection force is also present in models of sovereign default, as those

On the empirical side, we provide evidence for the importance of beliefs in determining housing and leverage decisions. We also show that leverage choice in the housing market is best described by a housing-as-consumption paradigm with a sizable collateral adjustment friction. This potentially sets it apart from other markets, such as the stock market, where investment motives are the primary driving force determining the size of the investment. Our empirical findings also contribute to the growing literature that studies belief formation. Some recent work includes Malmendier and Nagel (2011, 2015), Greenwood and Shleifer (2014), and Kuchler and Zafar (2015). Much of this literature has focused on explaining how individuals' own experiences affect their expectations. We expand on the findings in Bailey et al. (2017*a*) to show that various moments of the experiences of individuals' friends also affect the corresponding moments of those individuals' belief distributions.

Our results speak to the active debate about the extent to which the joint movement in house prices and mortgage leverage during the 2002-2006 housing boom period was the result of homebuyer optimism or other forces in the economy, such as credit supply shocks (Adelino, Schoar and Severino, 2016; Burnside, Eichenbaum and Rebelo, 2016; Case, Shiller and Thompson, 2012; Cheng, Raina and Xiong, 2014; Di Maggio and Kermani, 2016; Foote, Loewenstein and Willen, 2016; Glaeser, Gottlieb and Gyourko, 2012; Landvoigt, Piazzesi and Schneider, 2015; Mian and Sufi, 2009; Nathanson and Zwick, 2014; Piazzesi and Schneider, 2009). Our findings suggest that, by itself, increased household optimism does not induce higher leverage, and that other forces, such as shifts in the credit supply function, also played an important role during the recent housing cycle.[7] This does not mean that homebuyer optimism was not important in explaining the boom-bust cycle in *house prices*. However, it does mean that a singular focus on homebuyer beliefs would have counterfactually predicted a decline in mortgage leverage during this period.[8] More broadly, our findings provide support for a literature that explores the role of beliefs as drivers of credit and business cycles (see Gennaioli, Shleifer and Vishny, 2012; Xiong, 2012; Angeletos and Lian, 2016; Gennaioli, Ma and Shleifer, 2016, for recent contributions).

1 A Model of Leverage Choice with Heterogeneous Beliefs

In this section, we develop a parsimonious model of leverage choice that allows us to characterize the various channels through which homebuyers' beliefs can affect their mortgage leverage choices.

1.1 Environment

We consider an economy with two dates, $t = \{0, 1\}$, populated by two types of agents: borrowers, indexed by i, and lenders, indexed by L.[9] There is a numeraire consumption good and a housing good.

described in Aguiar and Amador (2013) and Uribe and Schmitt-Grohé (2017). For instance, a sovereign with pessimistic expectations about the performance of the economy anticipates the possibility of defaulting, which generates an incentive to borrow more. As described in Section 2.2.1, this effect is modulated by the costs of default, which are endogenous in the sovereign context, as emphasized by Bulow and Rogoff (1989) and Gennaioli, Martin and Rossi (2014), among others.

[7] We show that, in both housing-as-consumption and housing-as-investment scenarios, lenders' optimism can generate an increase in leverage. Intuitively, access to cheaper credit makes borrowers more willing to borrow. This result establishes that shifts in the distribution of borrowers' and lenders' beliefs have an asymmetric impact on equilibrium leverage.

[8] This is consistent with the evidence in quantitative models of the housing market such as Kaplan, Mitman and Violante (2015), who show that more optimistic homebuyers can precipitate price increases, but that without a simultaneous relaxation in credit constraints, leverage will likely decrease. Such quantitative models incorporate general equilibrium effects of beliefs on house prices that our cross-sectional empirical strategy cannot speak to. For example, if more optimistic beliefs drive up house prices, this can provide an additional positive force on equilibrium leverage if the same downpayment to purchase the same house now involves taking on larger leverage. Quantitatively, the results in Kaplan, Mitman and Violante (2015) suggest that general equilibrium forces are not strong enough to overturn the negative correlation between homebuyer beliefs and leverage we uncovered in the cross section.

[9] For simplicity, we present our results in a principal-agent formulation in which borrowers and lenders have predetermined roles. A common theme in existing work is that optimists endogenously become asset buyers and borrowers while pessimists become asset sellers and lenders. This type of sorting is natural if belief disagreement is the single source of heterogeneity. However, in housing markets, additional dimensions of heterogeneity (e.g., life-cycle motives, wealth, risk preferences, access to credit markets, etc.) also determine which agents become buyers and borrowers in equilibrium.

Borrowers. Borrowers' preferences over initial consumption and future wealth are given by

$$u_i(c_{0i}) + \beta \mathbb{E}_i[w_{1i}],$$

where c_{0i} denotes borrowers' date-0 consumption and $\mathbb{E}_i[w_{1i}]$ corresponds to borrowers' date-1 expected wealth given their beliefs. We assume that the borrowers' discount factor satisfies $\beta < 1$ and that $u_i(\cdot)$ is an increasing and concave function that satisfies $u_i'(\cdot) > 0$, $u_i''(\cdot) < 0$, and $\lim_{c\to 0} u_i'(c) = \infty$. Our formulation preserves the linearity of borrowers' preferences with respect to future wealth, which allows us to derive sharp results while allowing for a meaningful date-0 consumption decision.[10]

Borrowers are endowed with $n_{0i} > 0$ and $n_{1i} > 0$ dollars at dates 0 and 1, respectively. At date 0, borrowers use their own resources or borrowed funds to either consume c_{0i} or to purchase a house of size h_{0i} at a price p_0. They can borrow through a non-contingent non-recourse loan (mortgage) that is collateralized exclusively by the value of the house they acquire. Formally, in exchange for receiving $p_0 h_{0i} \Lambda_i(\delta_i)$ dollars at date 0, borrowers promise to repay b_{0i} dollars at date 1. The function $\Lambda_i(\delta_i)$, which takes as an argument the normalized loan repayment $\delta_i = \frac{b_{0i}}{p_0 h_{0i}}$, denotes borrowers' loan-to-value (LTV) ratio and is determined by lenders as described below. Hence, borrowers' date-0 budget constraint corresponds to

$$c_{0i} + p_0 h_{0i}(1 - \Lambda_i(\delta_i)) = n_{0i}. \tag{1}$$

At date 1, borrowers have the option to default. In case of default, borrowers experience a private loss $\kappa_i h_{0i}$, which scales proportionally with the house size.[11] The default cost parameter $\kappa_i \geq 0$ captures both pecuniary and non-pecuniary losses associated with default and can be also interpreted as a simple form of allowing for heterogeneity across borrowers regarding future continuation values.

We denote house prices at dates 0 and 1 by p_0 and p_1, respectively, and define the growth rate of house prices by $g = \frac{p_1}{p_0}$. Borrowers hold heterogeneous beliefs about the growth rate of house prices. Borrower i's beliefs about the growth rate of house prices are described by a cdf $F_i(\cdot)$:

$$g = \frac{p_1}{p_0}, \text{ where } \quad g \sim_i F_i(\cdot),$$

where g has support in $\left[\underline{g}, \overline{g}\right]$, with $\underline{g} \geq 0$ and $\overline{g} \leq \infty$.[12] Borrowers solve the following optimization problem:

$$\max_{c_{0i}, b_{0i}, h_{0i}} u_i(c_{0i}) + \beta \mathbb{E}_i\left[\max\left\{w_{1i}^{\mathcal{N}}, w_{1i}^{\mathcal{D}}\right\}\right],$$

subject to Equation (1), where $w_{1i}^{\mathcal{N}}$ and $w_{1i}^{\mathcal{D}}$ denote borrowers' wealth in non-default and default states, given by

$$w_{1i}^{\mathcal{N}} = n_{1i} + p_1 h_{0i} - b_{0i}$$
$$w_{1i}^{\mathcal{D}} = n_{1i} - \kappa_i h_{0i}.$$

Finally, we incorporate the possibility of a "collateral adjustment friction" by assuming that borrowers have a

[10] We preserve the risk-neutrality assumption common in existing work on leverage cycles. In Appendix A.3, we study the implications of introducing curvature in borrowers' date-1 utility. Our theoretical results can be interpreted as a first-order approximation to the more general case.

[11] Formally, assuming that the default cost is proportional to the house size preserves the homogeneity of the borrowers' problem. This assumption can be relaxed without affecting our insights, though we believe that it is reasonable to assume that individual default costs are larger for homeowners with larger properties.

[12] An alternative interpretation of our framework involves thinking of individual beliefs as risk-neutral adjusted beliefs. Under this view, differences in $F_i(\cdot)$ across borrowers can partly capture differences in attitudes towards risk.

minimum desired house size. Formally, borrowers' housing choice h_{0i} must satisfy

$$h_{0i} \geq \underline{h_i}, \tag{2}$$

where $\underline{h_i} \geq 0$ is such that the borrowers' feasible set is non-empty. This specification tractably captures that borrowers' preferences for owner-occupied housing are also affected by the consumption aspect of housing.[13] When the home size constraint binds, homebuyers' housing investment decision is completely pinned down by consumption aspects of housing, such as the homebuyer's family size, the house quality or location, or the local amenities.[14] Considering this case allows us to study the relationship between beliefs and leverage with an infinite collateral adjustment friction. When the home size constraint does not bind, we can analyze the same relationship in the absence of collateral adjustment frictions. These two polar cases, which we study below, provide extreme characterizations that highlight how the relationship between beliefs and leverage choices varies as we adjust the magnitude of the collateral adjustment friction.

Lenders. Lenders are risk neutral and perfectly competitive. They require a predetermined rate of return $1 + r$, potentially different from β^{-1}, and, for simplicity, have the ability to offer borrower-specific loan-to-value schedules.[15] In bankruptcy, lenders recover only a fraction $\eta \in [0, 1]$ of the value of the collateral. The remaining fraction $1 - \eta$ corresponds to bankruptcy costs. Lenders' perceptions over house price growth, which may be different from those of borrowers, are given by a distribution with cdf $F_L(\cdot)$.

Equilibrium. An *equilibrium* is defined as consumption, borrowing, and housing choices c_{0i}, b_{0i}, h_{0i}, and default decisions by borrowers, such that borrowers maximize utility given the loan-to-value schedule offered by lenders to break even. Since our goal is to derive testable cross-sectional predictions for changes in borrowers' beliefs, we do not impose market clearing in the housing market. Fixing total housing supply and closing the housing market would not affect our cross-sectional predictions for leverage choices. We work under the presumption that homebuyers always find it optimal to borrow in equilibrium, and relegate a detailed discussion of regularity conditions to Appendix A.

1.2 Equilibrium characterization

We characterize the equilibrium of the model backwards. We first study borrowers' default decisions, then characterize the loan-to-value schedules offered by lenders, and, finally, study the ex-ante decisions made by borrowers.

[13] This constraint is a common feature of quantitative models of the housing market (e.g., Gervais, 2002; Cocco, 2004; Floetotto, Kirker and Stroebel, 2016). We adopt a hard constraint on h_{0i} for tractability. Imposing the constraint in Equation (2) is equivalent to assuming that borrowers' utility is augmented by an additive term $\alpha \cdot \mathbf{1}\left[h_{0i} \geq \underline{h_i}\right]$, where α is a sufficiently large positive scalar and $\mathbf{1}[\cdot]$ denotes the indicator function. We have explored alternative specifications for housing preferences, including preferences that feature linear and quadratic welfare losses around an optimum desired house size $h_i^\star$, that is, augmenting borrowers' utility by terms $-\psi_0 \left|h_{0i} - h_i^\star\right|$ or $-\psi_1 \left(h_{0i} - h_i^\star\right)^2$. When the positive scalars ψ_0 and ψ_1 are sufficiently large, borrowers find it optimal to choose $h_{0i} = h_i^\star$ in the linear case or $h_{0i} \approx h_i^\star$ in the quadratic case for a large set of model primitives, including borrowers' beliefs. The predictions under those assumptions are the same as the predictions when the housing constraint binds.

[14] While we model housing as an homogeneous good to maintain tractability, the collateral adjustment friction also proxies for households' willingness to adjust their housing choice in other dimensions. For example, it does not just capture households' willingness to buy a smaller house in the same neighborhood, but also their willingness to move to a cheaper neighborhood in other to reduce the fraction of their portfolio allocated to housing.

[15] Our results remain valid under weaker assumptions on the determination of credit supply. For instance, our results are unchanged if lenders are restricted to offering a single loan-to-value schedule to all borrowers. A correct interpretation of our empirical findings requires that potentially unobserved characteristics used by lenders' to offer loan-to-value schedules to borrowers must be orthogonal to the recent house price experiences of a borrower's geographically distant friends.

Default decision. At date 1, borrowers default according to the following threshold rule,

$$\text{if } \begin{cases} g \leq \delta_i - \chi_i, & \text{Default} \\ g > \delta_i - \chi_i & \text{No Default} \end{cases} \qquad \text{where} \quad \chi_i = \frac{\kappa_i}{p_0} \quad \text{and} \quad \delta_i = \frac{b_{0i}}{p_0 h_{0i}},$$

and where g denotes the actual realization of house price growth. Note that $\chi_i \geq 0$ is simply a rescaled version of the default cost, so that $\chi_i = 0$ when $\kappa_i = 0$. Intuitively, borrowers decide to default only when date-1 house prices are sufficiently low. For any realization of house price changes, the probability of default by borrower i increases with the borrower's promised repayment δ_i and decreases with the magnitude of default costs κ_i.

Remark. (Strategic default) There is a substantial literature that investigates the extent to which mortgage defaults represent strategic, ruthless defaults by households walking away from homes with negative equity ("underwater homes"), even though they have the resources to continue making mortgage payments (see Elul et al., 2010; Bhutta, Dokko and Shan, 2017; Gerardi et al., 2017). This literature concludes that default usually happens at levels of negative equity that are larger than what would be predicted by a frictionless default model. Our model incorporates these findings through the size of the parameter κ_i, which captures other, non-financial default costs (e.g., social stigma). As we discuss below, our theoretical and empirical findings do not depend on whether default is purely strategic or the result of also receiving negative income shocks. Indeed, our results only require that default is *more likely* when house prices decline; in other words, the results are robust as long as negative equity is a necessary condition for default, even if it is not sufficient.[16]

LTV schedules. Given borrowers' default decisions, competitive lenders offer loan-to-value (LTV) schedules to a type i borrower to break even. Equation (3) characterizes the loan-to-value schedule offered by lenders to a borrower of type i for any normalized promised repayment $\delta_i = \frac{b_{0i}}{p_0 h_{0i}}$:

$$\Lambda_i(\delta_i) = \frac{\eta \int_{\underline{g}}^{\delta_i - \chi_i} g dF_L(g) + \delta_i \int_{\delta_i - \chi_i}^{\overline{g}} dF_L(g)}{1 + r}. \tag{3}$$

The first term in the numerator corresponds to the payment received by lenders in default states net of default costs, normalized by the date-0 value of the house. The second term in the numerator corresponds to the normalized repayment in non-default states. Both terms are discounted at the lenders' risk-free rate, $1 + r$.

Although we formally let borrowers choose δ_i for tractability, this is identical to allow borrowers to choose loan-to-value ratios instead. Indeed, we establish in the Appendix that at any interior optimum for leverage there exists a positive relation between both variables, that is, $\Lambda_i'(\delta_i) > 0$. We also show that $\Lambda_i'(\delta_i) < 1$. Alternatively, we could have formulated homebuyers' choice in terms of the margin/haircut/downpayment, which is equal to $1 - \Lambda_i(\delta_i)$, or the leverage ratio, which is equal to $\frac{1}{1-\Lambda_i(\delta_i)}$.[17]

Borrowers' leverage choice. To determine borrowers' leverage choice, we reformulate their problem as a function of δ_i. Formally, borrowers choose c_{0i}, h_{0i}, and δ_i to maximize

$$\max_{c_{0i}, h_{0i}, \delta_i} u_i(c_{0i}) + \beta p_0 h_{0i} \left[-\chi_i \int_{\underline{g}}^{\delta_i - \chi_i} dF_i(g) + \int_{\delta_i - \chi_i}^{\overline{g}} (g - \delta_i) dF_i(g) \right], \tag{4}$$

[16] This requirement is fulfilled even in the "double trigger" theory, under which negative equity and income shocks are both required before households will default on their mortgage. Importantly, under this theory, when households receive a negative income shock and cannot continue making their mortgage payments, if house prices are high, households can just sell the home, repay the outstanding mortgage, and keep the difference. Only when they are underwater will the negative income shock precipitate mortgage default.

[17] There exists a one-to-one relation among these variables. For instance, if a borrower pays $\$100k$ dollars for a house, borrowing $\$75k$ and paying $\$25k$ in cash, the borrower's loan-to-value ratio is $\frac{75}{100} = 75\%$, his downpayment is 25%, and his leverage ratio is 4.

subject to a date-0 budget constraint and the housing constraint (collateral adjustment friction)

$$\begin{aligned} c_{0i} + p_0 h_{0i} \left(1 - \Lambda_i \left(\delta_i\right)\right) &= n_{0i} \qquad (\lambda_{0i}) \\ \underline{h_i} &\leq h_{0i} \qquad (\nu_{0i}) \,. \end{aligned}$$

Borrower i takes into account that $\Lambda_i \left(\delta_i\right)$ is given by Equation (3), and λ_{0i} and ν_{0i} respectively denote (non-negative) Lagrange multipliers. Note that the term in brackets in the objective function (4) corresponds to the net return per dollar invested in housing. Borrowers' optimality conditions for consumption, housing, and leverage, are given by the following equations:[18]

$$c_{0i}: \quad \underbrace{u_i'\left(c_{0i}\right)}_{\text{Mg. Benefit}} - \underbrace{\lambda_{0i}}_{\text{Mg. Cost}} = 0 \tag{5}$$

$$h_{0i}: \quad \underbrace{-\lambda_{0i} p_0 \left(1 - \Lambda_i \left(\delta_i\right)\right)}_{\text{Mg. Cost}} + \underbrace{\beta p_0 \left[-\chi_i \int_{\underline{g}}^{\delta_i - \chi_i} dF_i\left(g\right) + \int_{\delta_i - \chi_i}^{\overline{g}} \left(g - \delta_i\right) dF_i\left(g\right)\right]}_{\text{Mg. Benefit (Expected return channel)}} + \nu_{0i} = 0 \tag{6}$$

$$\delta_i: \quad \underbrace{\lambda_{0i} p_0 h_{0i} \Lambda_i'\left(\delta_i\right)}_{\text{Mg. Benefit}} - \underbrace{\beta p_0 h_{0i} \int_{\delta_i - \chi_i}^{\overline{g}} dF_i\left(g\right)}_{\substack{\text{Mg. Cost} \\ \text{(Downpayment protection} \\ \text{channel)}}} = 0, \tag{7}$$

The optimality condition for consumption simply equates the marginal benefit of consumption, given by $u_i'\left(c_{0i}\right)$, with the marginal cost of tightening the date-0 budget constraint, given by λ_{0i}.

The optimality condition for housing equates the marginal benefit of buying a larger house with the marginal cost of doing so. The marginal benefit of a housing investment is the net present value of the expected return received at date 1. This is the first channel through which borrower beliefs affect leverage choice, referred to above as the "expected return" force. The marginal cost of the investment corresponds to the reduction in available resources at date 0, valued by borrowers according to λ_{0i}. When the housing constraint binds, borrowers' housing corresponds to $h_{0i} = \underline{h_i}$ and Equation (6) simply defines ν_{0i}, the shadow value of relaxing the housing constraint.

The optimality condition for borrowing equates the marginal benefit of increasing the promised repayment, which corresponds to having more resources at date 0, valued by borrowers as λ_{0i}, with the marginal cost of doing so. The marginal cost corresponds to the net present value of the increased promised repayment in non-default states at date 1. This is the second channel through which borrower beliefs matter for leverage, referred to above as the "downpayment protection" force. Intuitively, a pessimistic borrower that needs a house of a certain size but thinks that house prices might decrease is more inclined to choose a lower downpayment (higher repayment and higher LTV ratio), since the perceived probability of repaying the mortgage is low. Equivalently, an optimistic borrower with a similar house size target who thinks that house prices are likely to increase, expects to repay her mortgage in more states of the world. This increase in the perceived marginal cost of borrowing leads more optimistic borrowers to invest more of their own funds by making a larger downpayment.

An alternative way of understanding borrowers' behavior is by considering the three possible uses for a dollar of own funds at date 0. When borrowers can adjust housing freely (no collateral adjustment friction), the following

[18] The derivation of Equation (7) uses the envelope theorem. Even though borrowers take into account that adjusting their leverage choice affects their probability of default ex-post — formally, varying δ_i modifies the limits of integration in Equation (4) — no additional terms appear in Equation (7) to account for this effect, since borrowers make default decisions optimally. Intuitively, because borrowers are indifferent between defaulting and repaying at the default threshold, a small change in the default threshold has no first-order effects on borrowers' welfare. The same logic applies to the derivation of Equation (6).

relation must hold at the optimum:

$$\underbrace{u_i'\left(c_{0i}\right)}_{\substack{\text{Marginal Benefit}\\ \text{of Consumption}}} = \underbrace{\frac{\beta \int_{\delta_i-\chi_i}^{\overline{g}} dF_i\left(g\right)}{\Lambda_i'\left(\delta_i\right)}}_{\substack{\text{Return on Larger}\\ \text{Downpayment}}} = \underbrace{\frac{\beta\left[-\chi_i \int_{\underline{g}}^{\delta_i-\chi_i} dF_i\left(g\right) + \int_{\delta_i-\chi_i}^{\overline{g}} \left(g-\delta_i\right) dF_i\left(g\right)\right]}{1-\Lambda_i\left(\delta_i\right)}}_{\text{Return on Leveraged House Purchase}}. \tag{8}$$

Intuitively, at an optimum in which the housing constraint is slack, a borrower is indifferent between (i) consuming a dollar, (ii) using a dollar to increasing today's downpayment, and (iii) leveraging the dollar to make a larger housing investment. The second and third terms in Equation (8) have an intuitive interpretation. A dollar of extra downpayment at date 0 allows borrowers to reduce their future per-dollar of housing repayment by $\frac{\partial \delta_i}{\partial \Lambda_i} = \frac{1}{\Lambda_i'(\delta_i)} > 1$ dollars. The per-dollar net present value of such a reduction corresponds to $\beta \int_{\delta_i-\chi_i}^{\overline{g}} dF_i\left(g\right)$, since borrowers only repay in states of the world in which they do not default. Said differently, pessimistic borrowers who think they are quite likely to default in the future perceive a very small benefit of reducing the promised payment tomorrow, and will therefore make small downpayments and take on larger leverage. Alternatively, a dollar invested in housing at date 0 can be levered $\frac{1}{1-\Lambda_i(\delta_i)}$ times, while the per-dollar net present value of a housing investment corresponds to $\beta\left[-\chi_i \int_{\underline{g}}^{\delta_i-\chi_i} dF_i\left(g\right) + \int_{\delta_i-\chi_i}^{\overline{g}} \left(g-\delta_i\right) dF_i\left(g\right)\right]$.

1.3 Two alternative scenarios

When borrowers have preferences for housing that are not purely driven by investment considerations and they can freely adjust their behavior along consumption, borrowing, and housing margins, it is not generally possible to provide clear analytic characterizations of the effect of changes in beliefs on leverage choices. However, by sequentially studying (i) a scenario with no collateral adjustment friction in which borrowers freely adjust their housing size, and (ii) a scenario in which borrowers' housing size is fixed due to non-investment-related forces such as family (infinite collateral adjustment friction), we can provide comparative statics on the effects of beliefs shifts.

We refer to the case in which borrowers freely adjust their housing choice as the *housing-as-investment* scenario. We adopt this terminology to capture that borrowers' housing decisions are mostly driven by investment considerations. In this case, borrowers make housing decisions purely based on its return as a levered investment and there is no collateral adjustment friction. We refer to the second case in which the housing decision is fixed as the *housing-as-consumption* scenario. We adopt this terminology to capture that idea that consumption considerations such as family Baileysize or locational preferences are mostly driving borrowers' housing decision. In practice, we expect borrowers' behavior to be a combination of the effects we identify under these polar scenarios. The purpose of our empirical exercise is to determine which scenario more closely captures the dominant forces driving leverage in the U.S. housing market.

Housing-as-Investment Scenario. In Appendix A, we show that the problem faced by borrowers in the housing-as-investment scenario can be solved sequentially. First, borrowers choose δ_i to maximize the levered return on a housing investment. Formally, they solve

$$\rho_i = \max_{\delta_i} \frac{-\chi_i \int_{\underline{g}}^{\delta_i-\chi_i} dF_i\left(g\right) + \int_{\delta_i-\chi_i}^{\overline{g}} \left(g-\delta_i\right) dF_i\left(g\right)}{1-\Lambda_i\left(\delta_i\right)}. \tag{9}$$

The solution to this problem yields borrowers' optimal LTV ratio, which is fully characterized by a single equation

$$\frac{\Lambda_i'\left(\delta_i\right)}{1-\Lambda_i\left(\delta_i\right)} = \frac{1}{-\chi_i \frac{F_i(\delta_i-\chi_i)}{1-F_i(\delta_i-\chi_i)} + \mathbb{E}_i\left[g \middle| g \geq \delta_i-\chi_i\right] - \delta_i}, \tag{10}$$

where the truncated expectation of house price growth corresponds to

$$\mathbb{E}_i\left[g|\, g \geq \delta_i - \chi_i\right] = \frac{\int_{\delta_i-\chi_i}^{\overline{g}} g dF_i\left(g\right)}{\int_{\delta_i-\chi_i}^{\overline{g}} dF_i\left(g\right)}. \tag{11}$$

Equation (10) can be derived directly from Equation (8) by combining borrowers' optimal borrowing and housing choices.[19] The numerator of Equation (11) captures the "expected return" channel described above, while its denominator captures the "downpayment protection" channel. Changes in the distribution of borrowers' beliefs affect leverage choices exclusively through the impact on the probability of default $F_i\left(\delta_i - \chi_i\right)$ and the truncated expectation $\mathbb{E}_i\left[g|\, g \geq \delta_i - \chi_i\right]$. Below, to derive unambiguous predictions, we will characterize conditions under which changes in beliefs shift the first two terms of the denominator of Equation (10) for any $\tilde{\delta}$ (point-wise).[20]

Equation (10) determines borrowers' optimal leverage choice independently of the choices of consumption and housing. This implies that the existence of a consumption-savings margin does not modify the predictions regarding the relationship between borrowers' optimism and leverage. Once δ_i is determined, borrowers choose initial consumption by equalizing the marginal benefit of investing in housing with the marginal utility of consumption:

$$u_i'\left(c_{0i}\right) = \rho_i,$$

where ρ_i, defined in (9), is the maximized levered return on a housing investment. Finally, given δ_i and c_{0i}, borrowers choose h_{0i} to satisfy

$$p_0 h_{0i} = \frac{n_{0i} - c_{0i}}{1 - \Lambda_i\left(\delta_i\right)}.$$

Housing-as-Consumption Scenario. In this scenario, borrowers choose δ_i to solve a consumption smoothing problem.[21] Formally, the optimal LTV ratio is fully characterized by the following equation

$$u_i'\left(n_{0i} - p_0 h_{0i}\left(1 - \Lambda_i\left(\delta_i\right)\right)\right)\Lambda_i'\left(\delta_i\right) = \beta\left(1 - F_i\left(\delta_i - \chi_i\right)\right). \tag{12}$$

Equation (12) can be derived directly from Equation (8) by combining borrowers' optimal consumption and borrowing choices. In this case, only the downpayment protection force is present, through the term $\int_{\delta_i-\chi_i}^{\overline{g}} dF_i\left(g\right) = 1 - F_i\left(\delta_i - \chi_i\right)$. Therefore, changes in the distribution of borrowers' beliefs only affect leverage choices through changes in the probability of repayment, $1 - F_i\left(\delta_i - \chi_i\right)$. In this scenario, as described below, unambiguous predictions can be found by comparing point-wise shifts in $F_i\left(\cdot\right)$. Once δ_i is determined, borrowers choose initial consumption to satisfy their budget constraint

$$c_{0i} = n_{0i} - p_0 h_{0i}\left(1 - \Lambda_i\left(\delta_i\right)\right), \tag{13}$$

where h_{0i} takes the value $\underline{h_i}$.

[19] Note that Equation (10) can be mapped to Equation (12) in Simsek (2013). The upshot of introducing a consumption margin in our formulation is that it highlights that borrowers' optimism only increases leverage indirectly – through Equation (6), not Equation (7) – through the fact that more optimistic borrowers need to lever up a given amount of resources to buy larger properties.

[20] Throughout the paper, we compare belief distributions along dimensions that allow us to guarantee that truncated expectations and default probabilities, when defined as functions of the default threshold, shift "point-wise." We could establish additional predictions from "local" changes in truncated expectations (starting from a given equilibrium). We do not pursue that route, because our empirical strategy only uses shifts in the distribution $F_i\left(\cdot\right)$ and does not use information on actual default thresholds.

[21] In a more general setup, borrowers will also be indifferent at the margin between consuming and investing in other assets. See Cocco (2004) and Chetty, Sándor and Szeidl (2017) for recent work on how housing affects optimal asset allocation problems.

2 Beliefs and Leverage Choice: Equilibrium Outcomes

We next study how changes in the distribution of borrowers' beliefs affect equilibrium outcomes in the model described above. In the body of the paper, we impose a parametric assumption on the distribution of beliefs and develop comparative statics for changes in the key moments of the belief distribution. In Appendix B, we derive and implement a non-parametric test of how beliefs affect leverage.

2.1 Parametric Predictions

Throughout this section, we assume that borrowers' beliefs about the expected growth rate of house prices follow a normal distribution with mean μ_i and standard deviation σ_i, that is,

$$g \sim_i N\left(\mu_i, \sigma_i^2\right).$$

We adopt the normal distribution for our parametric predictions based on the empirical evidence about the distribution of house price movements that we observe in our data. Appendix Figure A3 shows the distribution of annual house price changes since 1993 across U.S. counties, constructed using data from Zillow. The distribution is unimodal and approximately symmetric, which suggests that the normal distribution is a sensible parametric choice (see also Panel (c) of Figure 4). When needed, we truncate the normal distribution at $\underline{g} = 0$ in all calculations. As we show below, one desirable feature of the normal distribution is that shifts in the two moments, mean and variance, have unambiguous predictions for $\mathbb{E}_i\left[g | \, g \geq \delta_i - \chi_i\right]$ and $F_i\left(\delta_i - \chi_i\right)$, and therefore on the relationship between beliefs and leverage in both the housing-as-investment and housing-as-consumption scenarios.

Proposition 1. (Mean and variance shifts with normally distributed beliefs.)

a) [**Housing-as-investment predictions.**] *In the housing-as-investment scenario, holding all else constant, including the belief dispersion σ_i, borrowers with a higher average belief μ_i choose a higher LTV ratio and a larger house for any default cost. In the housing-as-investment scenario, holding all else constant, including the average belief μ_i, borrowers with a higher belief dispersion σ_i choose a higher LTV ratio and a larger house for moderate default costs. Formally, these predictions for equilibrium LTV ratios can be expressed as:*

$$\frac{\partial\left(-\chi_i \frac{F_i\left(\tilde{\delta}-\chi_i\right)}{1-F_i\left(\tilde{\delta}-\chi_i\right)} + \mathbb{E}_i\left[g | \, g \geq \tilde{\delta} - \chi_i\right]\right)}{\partial \mu_i} > 0, \; \forall \tilde{\delta} \quad \Rightarrow \quad \frac{\partial \delta_i}{\partial \mu_i} > 0,$$

$$\frac{\partial\left(-\chi_i \frac{F_i\left(\tilde{\delta}-\chi_i\right)}{1-F_i\left(\tilde{\delta}-\chi_i\right)} + \mathbb{E}_i\left[g | \, g \geq \tilde{\delta} - \chi_i\right]\right)}{\partial \sigma_i} > 0, \; \forall \tilde{\delta} \quad \Rightarrow \quad \frac{\partial \delta_i}{\partial \sigma_i} > 0, \quad \textit{when } \chi_i \textit{ is sufficiently low.}$$

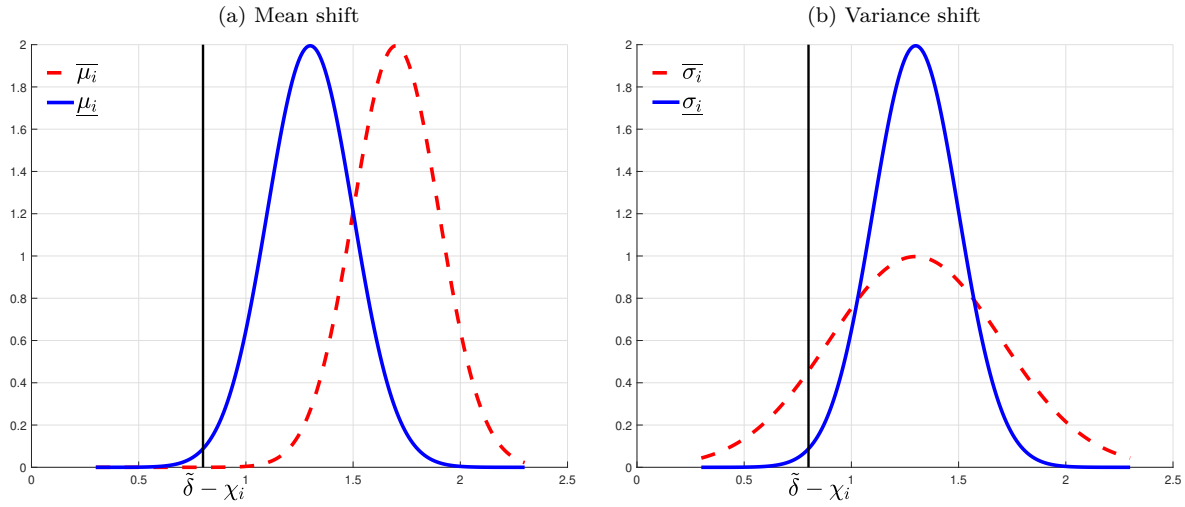
b) [**Housing-as-consumption predictions.**] *In the housing-as-consumption scenario, holding all else constant, including the belief dispersion σ_i, borrowers with a higher average belief μ_i choose a lower LTV ratio and lower consumption for any default cost. In the housing-as-consumption scenario, holding all else constant, including the average belief μ_i, borrowers with a higher belief dispersion σ_i choose a higher LTV ratio and higher consumption, as long as the default probability is less than 50% – the empirically appropriate case – for any default cost. Formally,*

these predictions for equilibrium LTV ratios can be expressed as:

$$\frac{\partial F_i\left(\tilde{\delta}-\chi_i\right)}{\partial \mu_i}<0,\ \forall \tilde{\delta} \quad \Rightarrow \quad \frac{\partial \delta_i}{\partial \mu_i}<0,$$
$$\frac{\partial F_i\left(\tilde{\delta}-\chi_i\right)}{\partial \sigma_i}>0,\ \forall \tilde{\delta} \quad \Rightarrow \quad \frac{\partial \delta_i}{\partial \sigma_i}>0, \qquad \text{if } \tilde{\delta}<\mu_i+\chi_i.$$

Our model shows that the relationship between beliefs and leverage depends crucially on the margins of adjustment that are active for a given borrower. Indeed, as highlighted by Equation (10), when borrowers perceive their housing choice to be an investment decision (the housing-as-investment scenario without a collateral adjustment friction), leverage increases when $-\chi_i \frac{F_i\left(\tilde{\delta}-\chi_i\right)}{1-F_i\left(\tilde{\delta}-\chi_i\right)}+\mathbb{E}_i\left[g|\, g \geq \tilde{\delta}-\chi_i\right]$ is higher for any leverage choice $\tilde{\delta}$. Figure 1 illustrates how $\mathbb{E}_i\left[g|\, g \geq \tilde{\delta}-\chi_i\right]$, which corresponds to the expected value of the house price change conditional on the value being to the right of the default threshold – given by the black line – and $F_i\left(\tilde{\delta}-\chi_i\right)$, which corresponds to the default probability, vary point-wise with changes in μ and σ. Panel (a) shows that an increase in the average belief increases the perceived net return on borrowers' housing investment by increasing $\mathbb{E}_i\left[g|\, g \geq \tilde{\delta}-\chi_i\right]$ and reducing $F_i\left(\tilde{\delta}-\chi_i\right)$ point-wise, which pushes them to choose higher leverage and invest more in housing. Panel (b) shows that an increase in σ_i raises the expected net return of a housing investment, which makes housing a more attractive investment for borrowers. This is because an increase in the probability of extremely good states of the world is valued by borrowers more than the increase in the probability of extremely bad states of the world, since they expect to default on those states.

Figure 1: Illustration of how shifts in μ_i and σ_i affect $\mathbb{E}_i\left[g|\, g \geq \tilde{\delta}-\chi_i\right]$ and $1-F_i\left(\tilde{\delta}-\chi_i\right)$



Note: Figure 1 illustrates how shifts in μ_i and σ_i modify $\mathbb{E}_i\left[g|\, g \geq \tilde{\delta}-\chi_i\right]$ and $1-F_i\left(\tilde{\delta}-\chi_i\right)$ for a given threshold $\tilde{\delta}-\chi_i$. The parameters used in Panel (a) are $\underline{\mu}=1.3$, $\overline{\mu}=1.7$, and $\sigma=0.2$. The parameters used in Panel (b) are $\mu=1.3$, $\underline{\sigma}=0.2$, and $\overline{\sigma}=0.4$. In both panels, we set $\tilde{\delta}-\chi_i=0.78$.

On the other hand, Equation (12) highlights that when a borrower finds it optimal not to adjust her housing choice, perhaps because it is determined primarily by family size (housing-as-consumption scenario with an infinite collateral adjustment friction), leverage is decreasing in the perceived probability that the mortgage will be repaid, $1-F_i\left(\tilde{\delta}-\chi_i\right)$, for a given default threshold $\tilde{\delta}-\chi_i$. In Figure 1, this is given by the probability-mass to the right of the default threshold. Panel (a) shows that a reduction in the average belief is perceived by borrowers as a reduction in the return to their downpayment, since now the resources put down as downpayment are more

likely to be lost in case of default. In that case, more pessimistic borrowers optimally decide to make smaller downpayments and borrow more. In this scenario, when the probability of default is less than 50%, a higher σ_i increases the probability of default (i.e., it reduces the probability mass to the right of the threshold), reducing the probability of repayment and reducing also the return on borrowers' downpayment. Higher variance of expected house price changes will thus induce borrowers to increase their leverage.

It is worth highlighting that borrowers' ability to default is crucial for our results. Had we assumed that borrowers are always forced to repay ($\kappa_i \to \infty$), the downpayment protection force would be inactive, and changes in borrowers' beliefs would have no impact on leverage choice in the housing-as-consumption scenario. As discussed above, our theoretical and empirical results do not depend on whether default is purely strategic (i.e., sizable negative equity is a sufficient condition for default), or whether households only default if negative income shocks make it impossible for them to continue making their mortgage payments. This is because even in response to income shocks, households will only default when they have negative equity, and the mortgage is worth more than their house – if they had positive equity, they could just sell the house, repay the mortgage, and keep the difference. This means that in either scenario, mortgage default is more likely when house prices decline (negative equity is either sufficient, when default is strategic, or necessary, when default is in response to negative income shocks), which is what we require for our results.

2.2 Additional Testable Predictions

The results in Proposition 1 establish that changes in beliefs can have differential implications for borrowers' leverage choices depending on the active margins of adjustment. In this section, we derive additional testable predictions from our theoretical framework. Specifically, we study how the relationship between beliefs and leverage choices characterized in Proposition 1 varies with the magnitude of the default cost. We also analyze how this relationship varies with the average optimism of homebuyers. As highlighted in the introduction, we find the empirical evidence to be more consistent with the housing-as-consumption scenario. In the interest of brevity, we therefore derive these additional predictions for the housing-as-consumption scenario in the body of the paper, and relegate the formal analysis of the empirically less-relevant housing-as-investment scenario to the Appendix.[22]

2.2.1 Interaction with Cost of Default

We first derive testable predictions for how the ability with which lenders can seize borrowers' collateral in case of default affects the strength of the relation between belief shifts and leverage choices

Proposition 2. (Interaction with cost of default.) *In the housing-as-consumption scenario, a given increase in the average belief, μ_i, generates a smaller decrease in leverage when borrowers' default cost κ_i is higher, as long as the default probability is less than* 50% *– the empirically appropriate case – for any default cost. A given increase in belief dispersion, σ_i, generates a smaller increase in leverage when borrowers' default cost κ_i is higher, as long as the default probability is less than* 16% *– the empirically appropriate case – for any default cost. Hence, high default costs dampen the effects of belief changes on leverage. Formally, the predictions for equilibrium LTV ratios*

[22] Note that when characterizing Propositions 2 and 3 below, we exclusively focus on the direct effects of changes in the default cost and average beliefs. As we describe in the Appendix, second-order comparative statics exercises are determined by both direct effects and curvature effects. Our focus is on the former set of effects.

can be expressed as:

$$\frac{\partial^2\left(1-F_i\left(\tilde{\delta}-\chi_i\right)\right)}{\partial\mu_i\partial\kappa_i}<0,\ \forall\tilde{\delta}\quad\Rightarrow\quad\frac{\partial^2\delta_i}{\partial\mu_i\partial\kappa_i}<0,\qquad \textit{if } \tilde{\delta}<\mu_i+\chi_i.$$
$$\frac{\partial^2\left(1-F_i\left(\tilde{\delta}-\chi_i\right)\right)}{\partial\sigma_i\partial\kappa_i}>0,\ \forall\tilde{\delta}\quad\Rightarrow\quad\frac{\partial^2\delta_i}{\partial\sigma_i\partial\kappa_i}<0,\qquad \textit{if } \left|\tilde{\delta}-\chi_i-\mu_i\right|<\sigma_i.$$

Proposition 2 shows that a high default cost dampens the strength of the downpayment protection force. Intuitively, when default costs are large, the probability of default is low, so a given change in μ_i and σ_i shifts only a small mass of the belief distribution from the default to no-default region or vice versa. Alternatively, when default costs are low, borrowers perceive that default is relatively more likely, so a given change in μ_i and σ_i shifts a larger mass of the belief distribution from the default to no-default region or vice versa. In the empirical implementation, we will use differences across states in lenders' recourse to borrowers' non-housing assets to provide variation in κ_i.

2.2.2 Interaction with Average Beliefs

We next use our framework to derive testable predictions regarding the relative importance of changes in beliefs on leverage choices across individuals or time periods with relatively higher or lower mean beliefs.

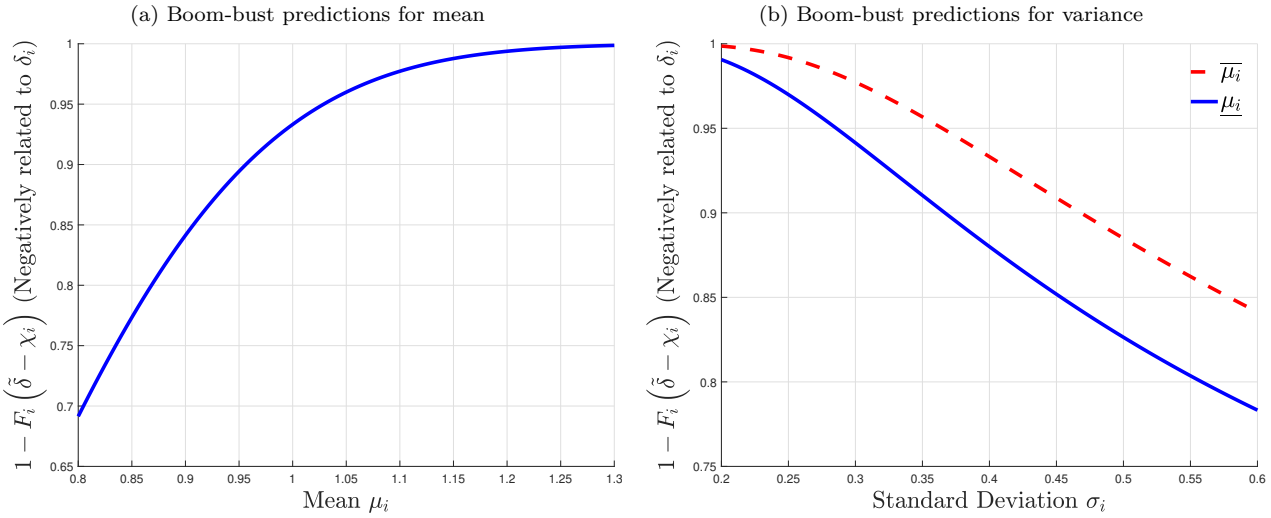
Proposition 3. (Interaction with average beliefs.) *In the housing-as-consumption scenario, a given increase in the average belief, μ_i, generates a smaller decrease in leverage when borrowers' average belief, μ_i, is higher to begin with, as long as the default probability is less than* 50% *– the empirically appropriate case – for any default cost. A given increase in belief dispersion, σ_i, generates a smaller increase in leverage when borrowers' average belief, μ_i, is higher to begin with, as long as the default probability is less than* 16% *– the empirically appropriate case – for any default cost. Hence, high average beliefs dampen the effects of belief changes on leverage. Formally, these predictions for equilibrium LTV ratios can be expressed as:*

$$\frac{\partial^2\left(1-F_i\left(\tilde{\delta}-\chi_i\right)\right)}{\partial\mu_i^2}<0,\ \forall\tilde{\delta}\quad\Rightarrow\quad\frac{\partial^2\delta_i}{\partial\mu_i^2}>0,\qquad \textit{if } \tilde{\delta}<\mu_i+\chi_i.$$
$$\frac{\partial^2\left(1-F_i\left(\tilde{\delta}-\chi_i\right)\right)}{\partial\sigma_i\partial\mu_i}>0,\ \forall\tilde{\delta}\quad\Rightarrow\quad\frac{\partial^2\delta_i}{\partial\sigma_i\partial\mu_i}<0,\qquad \textit{if } \left|\tilde{\delta}-\chi_i-\mu_i\right|<\sigma_i.$$

Proposition 3 shows that in the housing-as-consumption scenario, the effect of changes in μ_i and σ_i are smaller in magnitude when μ_i is higher to begin with. Panel (a) of Figure 2 shows that the probability of repayment, $1-F_i\left(\tilde{\delta}-\chi_i\right)$, is concave in μ_i. Intuitively, a given increase in optimism changes the probability of repayment by less when the average expectation is already high and default is unlikely. Panel (b) of Figure 2 shows that the dashed line, which corresponds to the repayment probability as a function of the variance of beliefs when expected house price growth is high, is flatter than the solid line, which corresponds to the repayment probability when expected high price growth is low. Intuitively, when μ_i is low to begin with, a larger mass of the belief distribution is around the default threshold, increasing the sensitivity of $1-F_i\left(\tilde{\delta}-\chi_i\right)$ to changes in the variance.

We will provide both cross-sectional and time-series evidence for Proposition 3. Cross-sectionally, we will show a stronger negative relation between beliefs and leverage for the most pessimistic individuals. In the time series, we document a stronger negative relation between beliefs and leverage during periods of declining house prices.

Figure 2: Interaction with average beliefs: Housing-as-consumption predictions



Note: The parameters used in Panel (a) are $\tilde{\delta} = 0.7$ and $\sigma = 2$. The parameters used in Panel (b) are $\tilde{\delta} = 0.7$, $\overline{\mu} = 1.3$, and $\underline{\mu} = 1.17$. In both figures, we set $\chi_i = 0$.

2.3 Role of Lenders' Beliefs

Although our empirical findings build on cross-sectional variation on homebuyers' beliefs, it is valuable to separately characterize the effect of changes in lenders' beliefs on the equilibrium leverage choices of borrowers. This allows us to draw implications of our cross-sectional results for aggregate variables, as we discuss in the conclusion. We show that an increase in lenders' optimism can increase equilibrium leverage in both the housing-as-consumption and the housing-as-investment scenarios. We assume that lenders have normally distributed beliefs with mean μ_L.

Proposition 4. (Role of lenders' beliefs.) *In the housing-as-investment scenario and the housing-as-consumption scenario, higher optimism by lenders, in the form of a higher average belief μ_L, holding all else constant, including borrowers' beliefs, is necessary to generate an increase in leverage.*

In Appendix A, we formally show that a change in the average belief of lenders μ_L is associated with pointwise shifts in $\Lambda_i(\cdot)$ and $\Lambda_i'(\cdot)$. Intuitively, when lenders become more optimistic, borrowers have access to cheaper funding. In the housing-as-investment scenario, we show that access to cheaper credit increases the maximum levered return that a borrower can achieve, generating a substitution effect towards higher leverage in equilibrium. In the housing-as-consumption scenario, in addition to the substitution effect, there is an income effect that works in the opposite direction: lower interest rates make borrowers feel richer, which generates a force towards higher consumption and lower leverage. The findings of Propositions 1 and 4 thus show that shifts in the beliefs of borrowers and lenders, when considered in isolation, can have opposite predictions for equilibrium leverage.

3 Beliefs and Leverage Choice: Empirical Investigation

The previous sections showed that the effect of homebuyer beliefs on leverage choice is ambiguous. If households are able to substantially adjust the size of their property in response to changes in expected house price growth, then more pessimistic buyers will buy smaller houses with lower overall leverage. On the other hand, some homebuyers' property choices might be primarily determined by factors related to the consumption aspect of the house, such as family size. Such a collateral adjustment friction limits the ability of pessimistic homebuyers to reduce their home size, and the only way to minimize their financial exposure to the housing market is to reduce their downpayment.

In practice, individuals' behavior will be in between the extreme cases studied in Section 2.1. Indeed, whether collateral adjustment frictions are sufficiently large such that more optimistic individuals will choose lower leverage is an empirical question that is central to understanding the role of homebuyer beliefs in driving mortgage leverage.

In this section, we analyze the effects on equilibrium leverage of changes in homebuyer beliefs, holding lender beliefs fixed. Our tests use the recent house price experiences of geographically distant friends as shifters of individuals' beliefs about the distribution of future house price changes. Specifically, we compare the leverage choices of otherwise similar individuals purchasing houses at the same point in time and in the same neighborhood, where one individual's friends have experienced more positive, or more widely dispersed recent house price growth.

This empirical approach builds on recent evidence in Bailey et al. (2017*a*), who show that the recent house price changes experienced within an individual's social network affect that individual's beliefs about the attractiveness of local housing market investments. We expand on these findings, and analyze responses to a new survey that elicits individuals' distribution of beliefs about future house price changes. We document that the mean and standard deviation of the house price experiences across an individual's friends shift the corresponding moments of the distribution of individuals' house price beliefs. Bailey et al. (2017*a*) also show that there is no systematic relationship between the house price experiences of an individual's geographically distant friends and other characteristics of that individual that might also affect her housing market investment behavior. This means that the house price experiences of an individual's geographically distant friends are likely to only affect leverage choice through their effects on beliefs. Indeed, in our empirical analysis we will rule out a number of other initially plausible channels.

3.1 Data Description and Summary Statistics

Our empirical analysis is based on the combination of two key data sets. First, to measure different individuals' social networks, we use anonymized social network data from Facebook. Facebook was created in 2004 as a college-wide online social networking service for students to maintain a profile and communicate with their friends. It has since grown to become the world's largest online social networking service, with over 1.9 billion monthly active users globally and 234 million monthly active users in the U.S. and Canada (Facebook, 2017). Our baseline data include a de-identified snapshot of all U.S.-based active Facebook users from July 1, 2015. For these users, we observe the county of residence as well as the set of other Facebook users they are connected to. Using the language adopted by the Facebook community, we call these connections "friends." Indeed, in the U.S., Facebook serves primarily as a platform for real-world friends and acquaintances to interact online, and people usually only add connections to individuals on Facebook whom they know in the real world (Hampton et al., 2011; Jones et al., 2013; Bailey et al., 2017*b*).

To construct a measure of the house price experiences in different individuals' social networks, we combine the data on the county of residence of different individuals' friends with county-level house price indices from Zillow. As we describe below, this allows us to analyze the full distribution of recent house price experiences across any group of Facebook users. For example, we can calculate the standard deviation of house price experiences across every individuals' out-of-commuting zone friends.

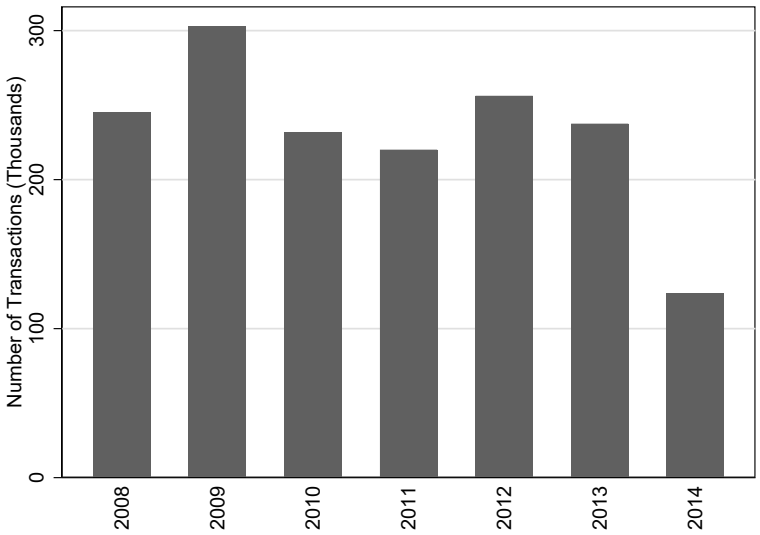
In order to measure homebuyers' leverage choice, we merge individuals on Facebook with three snapshots from Acxiom InfoBase for July 2010, July 2012, and July 2014.[23] These data are collected by Acxiom, a leading marketing services and analytics company, and contain a wide range of individual-level demographic information

[23]This merge involves a scrambled merge-key based on common characteristics. 53% of merges relied on email address. Other characteristics were full date of birth (51%) or year-month of date of birth (28%), last name (45%) and first name (84%), location at the level of zip code (44%), county (37%), Core Based Statistical Area (8%), and telephone number (2%). Most matches are based on multiple characteristics.

compiled from a large number of sources (e.g., public records, surveys, and warranty registrations). We observe information on age, marital status, education, occupation, income, household size, and homeownership status. For current homeowners, the data also include information on housing transactions after 1993 that led to the ongoing homeownership spell, compiled from public records deeds recordings. These data include the transaction date, the transaction price, and details on any mortgage used to finance the home purchase.[24]

Since we can only analyze origination mortgages that have not been refinanced by the time we observe the transaction in an Acxiom snapshot, we focus our analysis on home purchases between 2008 and 2014. There are at most two years between these transaction and the closest Acxiom snapshot, allowing us to observe virtually all of the initial mortgages. We want to study the mortgage choices for home purchases across a dispersed set of geographies, in order to provide us with cross-sectional heterogeneity in the cost of default created by differences in the legal environment across states. To achieve this, we first define a set of eligible geographies as those with good Acxiom coverage and complete reporting of house prices and mortgage amounts; this excludes, for example, property transactions from non-disclosure states such as Texas, where housing transaction prices are not reported in the public record. We select all transactions in our data since January 2008 from a random sample of 2,900 zip codes from these eligible geographies. This provides us with about 1.35 million housing transactions for which we can match the buyer to Facebook.[25] These transactions come from 33 different states, with the most prominently represented states being California (24.6%), Florida (12.4%), and Arizona (9.5%), with Ohio, Washington, Nevada and North Carolina each contributing approximately 5% of all transactions. Figure 3 shows how these transactions are distributed over time.

Figure 3: Number of Transactions



Note: Figure shows the number of transactions by purchase year in our matched transaction-Facebook sample.

Table 1 shows summary statistics for our sample.[26] The average combined loan-to-value (CLTV) ratio across

[24]While the original deeds data contain the precise information on mortgage amount and purchase price, the Acxiom data include these in ranges of $50,000. We take the mid-point of the range as the transaction price and mortgage amount. While the resulting measurement error in LTV ratios does not affect our ability to obtain unbiased estimates in regressions where LTV ratio is the dependent variable, it complicates the interpretation of the R^2 from these regressions.

[25]This only includes transactions with a buyer that has more than 10 geographically distant (i.e., out-of-commuting zone) friends. Having such friends is a requirement to construct the belief shifters for these individuals.

[26]For some of the transactions, the property is purchased by more than one individual, and we can match both individuals to their Facebook accounts. In these cases, we use the characteristics and friends' house price experiences of the head of household, as reported in the Acxiom data. Pooling the sets of friends of both buyers yields very similar results.

Table 1: Summary Statistics

	Mean	Standard Deviation	P10	P50	P90
Purchase Characteristics					
Transaction price (k$)	302.3	237.8	125	225	550
Combined Loan-to-Value (CLTV) Ratio	88.5%	16.9%	69.2%	94.7%	100.0%
Network Statistics					
Number of Friends	353.9	408.3	63	241	733
Number of Out-of-Commuting Zone Friends	194.3	272.6	27	114	427
Number of Out-of-State Friends	155.7	241.3	19	83	351
Number of Counties with Friends	74.7	65.5	19	59	144
Neighborhood Statistics					
Homeownership Rate	74.3%	11.7%	58.7%	76.7%	87.2%
Recourse	0.54	0	0	1	1
Δ Friends' House Prices (24m)					
Mean - All Friends	-6.4%	13.3%	-22.6%	-7.7%	12.1%
Mean - Out-of-Commuting Zone Friends	-5.3%	10.3%	-16.3%	-7.4%	10.2%
St.Dev. - All Friends	8.0%	3.3%	4.2%	7.5%	12.5%
St.Dev. - Out-of-Commuting Zone Friends	9.0%	3.1%	5.1%	8.8%	13.2%
Other Friend Experiences					
Δ Friends' County Income (24m) - Mean	3.1%	6.5%	-4.4%	1.7%	11.3%
Δ Friends' County Income (24m) - St.Dev.	5.7%	3.3%	2.8%	5.0%	9.3%
Friends' Foreclosure Rate (24m, Share of Units) - Mean	3.7%	2.3%	1.1%	3.2%	7.1%
Friends' Foreclosure Rate (24m, Share of Units) - St.Dev	2.0%	0.9%	0.9%	1.9%	3.2%
Property Characteristics					
Home Size (sqft)	2,032	12,766	1,056	1,730	3,077
Lot Size (sqft)	12,033	12,549	2,500	7,500	25,000
Property Age (years)	29.0	24.0	3.0	23.0	62.0
SFR	0.82	0	0	1	1
Has Pool	0.19	0	0	0	1
Buyer Characteristics					
Age at Transaction (years)	37.7	12.7	24	35	56
Has Max High School Degree in 2010	0.64	0.48	0	1	1
Has Max College Degree in 2010	0.26	0.44	0	0	1
Has Max Graduate Degree in 2010	0.10	0.30	0	0	0
Income in 2010 ($)	82,116	49,413	25,000	62,500	175,000
Married in 2010	0.41	0.49	0	0	1
Household Size in 2010	2.55	1.51	1	2	5

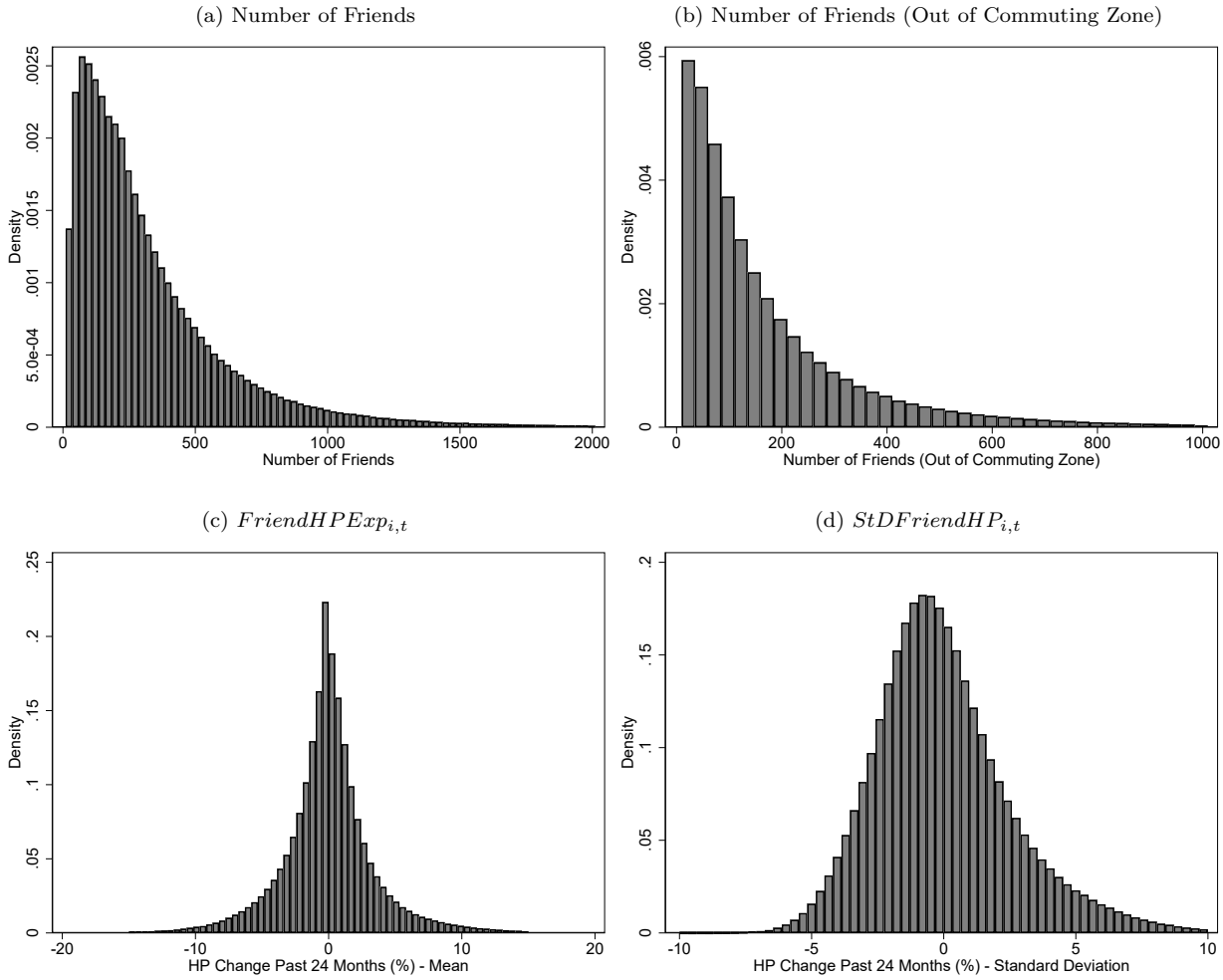
Note: Table shows summary statistics on our matched transaction-Facebook sample. It provides information on the sample mean and standard deviation, as well as the 10th, 50th, and 90th percentiles of the distribution.

all mortgages used to finance the transactions in our sample is 88.5%, but there is substantial heterogeneity in this number. The average purchase price is $302,300, while the median purchase price is $225,000. At the point of purchase, the average buyer was 38 years old, but this ranges from 24 years old at the 10th percentile to 56 years old at the 90th percentile of the distribution.

For the average homebuyer, we observe 354 friends, with a 10-90 percentile range of 63 to 733. The average homebuyer has 194 friends that live outside their own commuting zone, and 156 friends that live outside their own state. The top row of Figure 4 shows the full distribution of the number of friends and out-of-commuting zone friends across homebuyers in our sample. Most individuals are exposed to a sizable number of different housing markets through their friends: the average person has friends in over 74 different counties, with individuals at the 90th percentile having friends in 144 different counties.

There is significant heterogeneity across individuals purchasing homes in the same neighborhood in the geographic distribution of their friends. As an example, Figure 5 shows a heatmap of the distribution of the friendship networks of two individuals buying a house at the same time and in the same Los Angeles zip code. Both individuals have a substantial share of their friends who live locally. In addition, the individual in the left

Figure 4: Summary Statistics



Note: Figure shows summary statistics on our matched transaction-Facebook sample. Panel (a) shows the distribution of the number of friends, Panel (b) shows the distribution of the number of out-of-commuting zone friends. Panel (c) shows the distribution of residuals of a regression of $FriendHPExp_{i,t}$ on month-of-purchase fixed effects. Panel (d) shows the distribution of residuals from a regression of $StDFriendHP_{i,t}$ on month-of-purchase fixed effects.

panel has many friends in the area around Minneapolis, while the individual in the right panel has many friends in Pennsylvania and Florida.

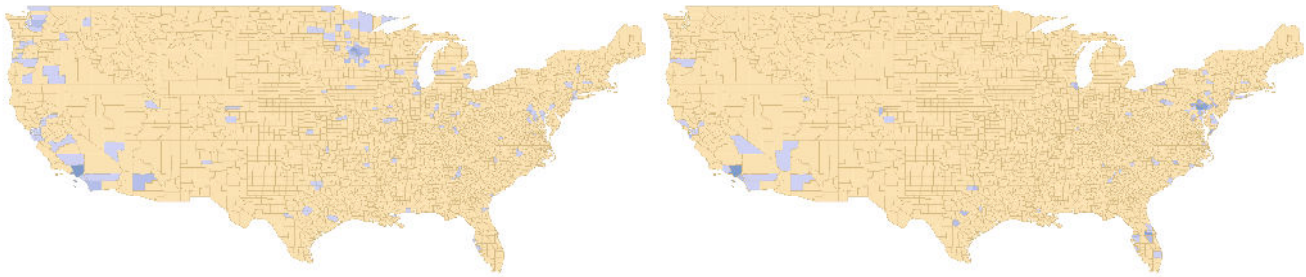
Such differences in the geographic distribution of friendship networks, combined with time-varying differences in regional house price movements, induce heterogeneity in the average house price movements in the social networks of different homebuyers purchasing similar properties at the same point in time. We define the average house price movements across homebuyer i's friends in the 24 month prior to purchasing a property at point t as:[27]

$$FriendHPExp_{i,t} = \sum_{c} ShareFriends_{i,c} \times \Delta HP_{c,t-24m,t},$$

where $ShareFriends_{i,c}$ measures the fraction of homebuyer i's friends that live in county c, and $\Delta HP_{c,t-24m,t}$ measures the house price changes in county c in the 24 months prior to time t using the Zillow house price indices. Panel (c) of Figure 4 shows the distribution of the residual when regressing $FriendHPExp_{i,t}$ on zip code by

[27]In all of the following analyses, we consider the house price experiences of the buyers' friends over the 24 months prior to the purchase. All results are robust to instead considering the experiences over the previous 12, 36, and 48 months.

Figure 5: Geographic Distribution of Friendship Links



Note: Figure shows heatmap of the friend distribution across two homebuyers in our matched transaction-Facebook sample. The individual in the left panel has a significant number of friends in Minnesota; the individual in the right panel has a significant number of friends in Pennsylvania and Florida.

purchase month fixed effects. The standard deviation of this residual is 3.7%, showing significant variation in friends' house price changes across individuals buying houses in the same place and at the same point in time.

In addition, most homebuyers have friends with relatively heterogeneous house price experiences: the same individuals can have some friends in regions where house prices did relatively well, and other friends in regions where house prices did relatively badly. We define the standard deviation of the house price experiences across homebuyer i's friends in the 24 months prior to time t as:

$$StDFriendHP_{i,t} = \sqrt{\sum_{c} \left(ShareFriends_{i,c} \times \Delta HP_{c,t-24m,t} - FriendHPExp_{i,t}\right)^2}$$

The average value of $StDFriendHP_{i,t}$ across the transactions in our sample is 8.0%, with a 10-90 percentile range of 4.2% to 12.5%. Panel (d) of Figure 4 shows the distribution of the residual when regressing $StDFriendHP_{i,t}$ on zip code by purchase month fixed effects. The standard deviation of this residual is 2.6%.

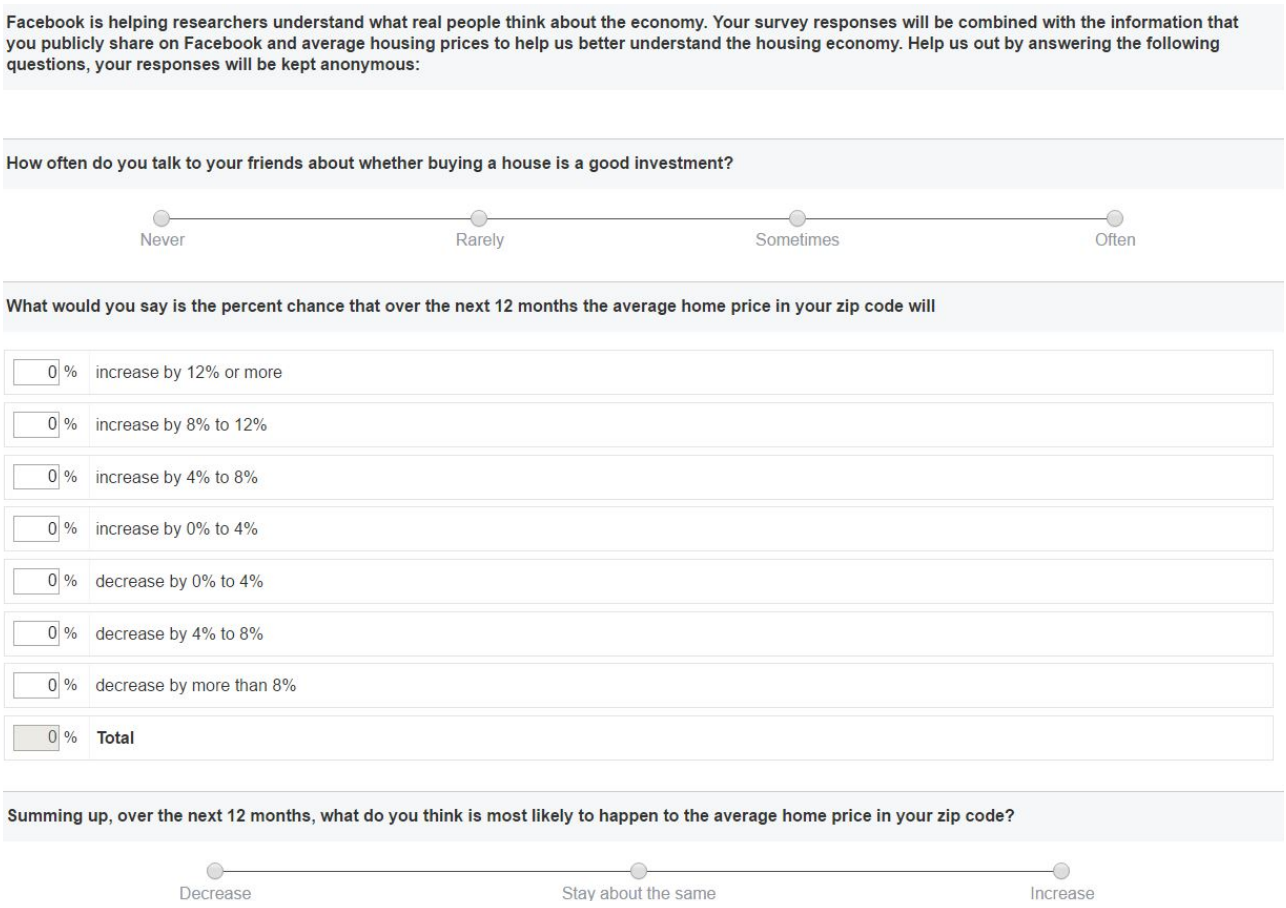
3.2 Expectation Survey: Evidence for Belief Shifters

The first step of our empirical analysis is to verify that the moments of the distribution of house price experiences across an individual's friends affect that individual's distribution of beliefs about future house price changes in their own zip code. To do this, we analyze responses to a short survey conducted by Facebook in April 2017. The survey targeted Facebook users living in Los Angeles through a post on their News Feed. Figure 6 shows the survey interface. We observe 504 survey responses. The respondents' average age was 38 years, with a 10-90 percentile range of 23 to 58 years. 62% of respondents are male.

The first survey question elicits how often individuals talk to their friends about whether buying a house is a good investment. Regular conversations with friends about housing investments are important in order for there to be a channel through which the house price experiences of friends can influence an individual's own house price beliefs. Panel (a) of Figure 7 shows the distribution of responses to this question. About 43% of respondents gave the modal answer, "sometimes." The other possible responses were "never" (16% of responses), "rarely" (21% of responses) and "often" (20% of responses).

To measure an individual's beliefs about future house price changes, we use responses to the second question, which asked individuals to assign probabilities to various scenarios of house price growth in their zip codes over the following 12 months. The survey enforced the assigned probabilities to add up to 100%. We use the responses

Figure 6: Survey Interface



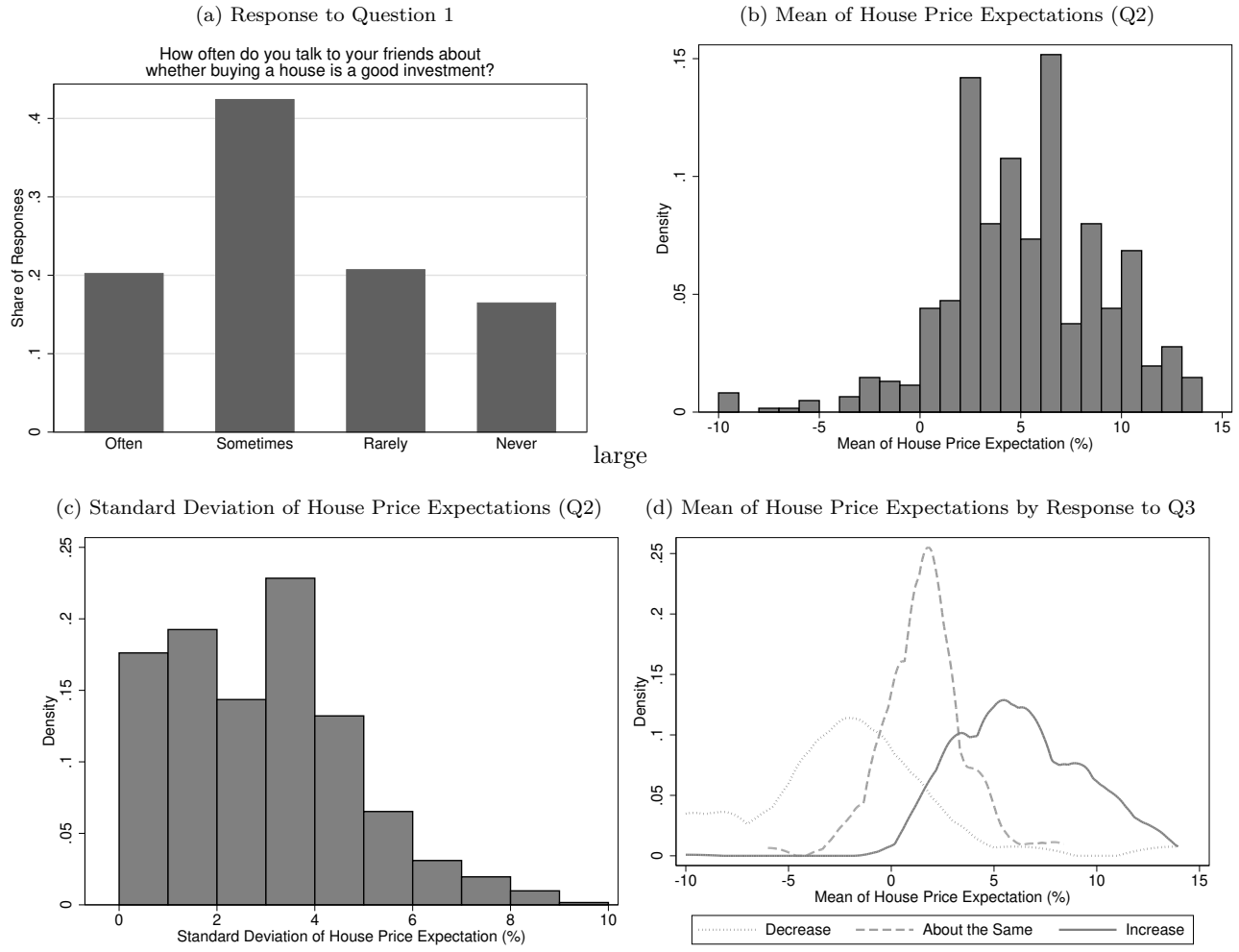
Note: Figure shows the interface on a user's News Feed of the expectation survey conducted by Facebook on April 2017.

to determine the mean and standard deviation of the distribution of individuals' house price beliefs.[28] Panels (b) and (c) of Figure 7 show the distribution of these moments across the survey respondents. There is substantial disagreement about expected house price growth among individuals living in the same local housing markets: while the median person expects house prices to increase by 5.3% over the next year, the 10-90 percentile range for this estimate is 0.8% to 10.0%, and the standard deviation is 3.8%.

As a first test for whether individuals provide sensible and consistent responses to the expectation survey, Panel (d) of Figure 7 shows the distribution of the means of the belief distributions for individuals separately by their responses to Question 3, which asks if the respondents expect the average home price in their zip code to increase, stay the same, or decrease over the next 12 months. As a response to that question, 79.8% of individuals said they expected house prices in their zip code to increase over the next 12 months, 14.6% said they would expect them to stay about the same, and 5.6% expected them to decline. As a reference point, in the 12 months running up to the survey, Los Angeles house prices increased by 7.4%. Individuals that thought it was most likely that house prices in their zip code would increase over the next twelve months have a median belief about house price growth of 6.0%; the median expected house price growth of respondents who said house prices would stay about the same (decline) was 2.0% (-2.4%). While there are a small number of individuals who indicate they expect house price

[28] To do this, we take the mid-point of each bucket, as well as the probabilities that individual agents assign to that bucket. For the open-ended buckets "Increase by more than 12%" and "Decrease by more than 8%", we use point-estimates of 14% and -10%, respectively, but our results are robust to using different values assigned to these buckets. The roughly 15% of respondents who only assign probabilities to one bucket are assigned a standard deviation of beliefs of 0%.

Figure 7: Summary Statistics - Survey Responses



large

Note: Figure shows summary statistics on the responses to the housing expectation survey. Panel (a) shows the responses to Question 1. Panels (b) and (c) show the distribution of the mean and standard deviation of the belief distribution derived from individuals' answers to Question 2. Panel (d) shows the distribution of the mean of the belief separately by individuals' answer to Question 3.

to fall, yet assign probabilities that imply increasing house prices, the combined evidence documents a substantial degree of consistency across individuals' answers within the same survey.

We next analyze how moments of the distribution of house price changes across individual i's social network in the 24 months prior to answering the survey affect the corresponding moments of the distribution of beliefs about future house price changes. There is significant variation across respondents in both the mean and the standard deviation of the experiences of their friends: indeed, $FriendHPExp_{i,April2017}$ has a mean of 15.1% and a standard deviation of 1.7% across survey respondents. When only measured among out-of-commuting zone friends, it has a mean of 16.3% and a standard deviation of 2.6%. Similarly, $StDFriendHP_{i,April2017}$ has a mean of 5.0% and a standard deviation of 1.7% across all friends of the survey respondents; among all out-of-commuting zone friends, the mean and standard deviation of $StDFriendHP_{i,April2017}$ are 6.9% and 1.7%, respectively.

Table 2 shows results from regressions of moments of the belief distribution on moments of the experience distribution among respondents' friends. All specifications control for zip code fixed effects to ensure that we are comparing individuals' assessments of the same local housing markets; it also includes flexible controls for the age, gender, and the number of friends of the respondent. In columns 1 to 3, the dependent variable is the

Table 2: Regression Results - House Price Expectations

	Dep. Var.: Mean of the Belief Distribution			Dep. Var.: Standard Deviation of the Belief Distribution		
	(1)	(2)	(3)	(4)	(5)	(6)
Δ House Prices - Past 24 Months						
Out-of-CZ Friends - Mean	0.186**					
	(0.082)					
Out-of-CZ Friends - St. D				0.121**		
				(0.058)		
All Friends - Mean		0.326**	0.322**			-0.024
		(0.144)	(0.148)			(0.055)
All Friends - St. D			0.027		0.182**	0.184**
			(0.145)		(0.089)	(0.090)
Zip Code Fixed Effects	Y	Y	Y	Y	Y	Y
Demographic Controls	Y	Y	Y	Y	Y	Y
Specification Note	OLS	IV	IV	OLS	IV	IV
N	426	426	426	426	426	426

Note: Table analyzes the determinants of individuals' expectations about house price changes in their own zip codes over the next 12 months. In columns 1 to 3, the dependent variable is the mean of individuals' belief distributions, based on their responses to Question 2 of the expectation survey (see Figure 6); in columns 4 to 6, the dependent variable is the standard deviation of these belief distributions. All specifications include fixed effects for the zip code of the survey respondents; we also control for age, gender, and the number of friends. Columns 1 and 4 present OLS specifications, while columns 2, 3, 5, and 6 present instrumental variables regressions, where the moments of the house price experiences across an individual's friends are instrumented for by the corresponding moments of the distribution of experiences across their out-of-commuting zone friends. Standard errors are in parentheses. Significance Levels: * (p<0.10), ** (p<0.05), *** (p<0.01).

mean of the belief distribution. Since all friends in Los Angeles experience the same recent house price changes, across-individual variation in friends' house price experiences is driven by differences in the experiences of their out-of-commuting zone friends as well as differences in the share of friends that live locally. As we discuss below, we want to isolate variation in friends' experiences coming from the experiences of their out-of-commuting zone friends, since this allows us to address a number of potential alternative interpretations of our findings. Column 1 of Table 2 shows that a one-percentage-point (0.38 standard deviation) increase in the house price appreciation across an individuals out-of-commuting zone friends, $FriendHPExp^{Out-CZ}_{i,April2017}$, is associated with a 0.19 percentage point (0.05 standard deviation) increase in the expected house price increase over the next twelve months.[29]

In column 2, the main explanatory variable is the average house price experience of all friends, $FriendHPExp_{i,April2017}$, instrumented for by the average house price experiences of the individuals' out-of-commuting zone friends, $FriendHPExp^{Out-CZ}_{i,April2017}$. This specification mirrors our baseline regressions in Sections 3.3 and 3.4 below, and will allow us to compare estimates across specifications with different outcome variables. A one-percentage-point increase in the house price experiences of all friends is associated with a 0.33 percentage

[29]The effect of $FriendHPExp^{Out-CZ}_{i,April2017}$ on the R-squared is relatively modest: conditional on the control variables, the house price experiences of an individual's out-of-commuting zone friends explain an additional 1.1% - 1.6% of the observed variation in the mean of house price beliefs. Specifically, the OLS regression without controlling for out-of-commuting zone friends' average house price experiences, but including all the other control variables, has an R-squared of 0.362; the within-zip code R-squared is 0.074. When we include the out-of-commuting zone friends' house price experiences as an additional control variable, the R-squared increases to 0.373, and the within-zip code R-squared increases to 0.090. However, given the large sample sizes in the leverage choice regressions in Sections 3.3 and 3.4, the belief shifter has sufficient power to identify statistically significant effects of beliefs on leverage. The number of observations in Table 2 is lower than the total number of responses we observe. This is because 78 responses are from individuals who are the only respondents from their own zip code. Their responses are thus fully explained by the zip code fixed effects.

point increase in individuals' mean belief about house price growth over the coming twelve months.[30] In column 3, we also include the (instrumented) standard deviation of house price experiences across individuals' friends, $StDFriendHP_{i,April2017}$, as an additional control variable; it has no statistically significant effect on individuals' average house price expectations.

The dependent variable in columns 4 to 6 of Table 2 is the standard deviation of the distribution of individuals' beliefs about future house price changes. Column 4 shows that a one-percentage-point (0.38 standard deviation) increase in $StDFriendHP^{Out-CZ}_{i,April2017}$ is associated with a 0.12 percentage point (0.08 standard deviation) increase in the standard deviation of the belief distribution. In column 5, the main explanatory variable of interest is the standard deviation of house price experiences across all friends, $StDFriendHP_{i,April2017}$, instrumented for by its counterpart among out-of-commuting zone friends, $StDFriendHP^{Out-CZ}_{i,April2017}$. The estimated effect of a one-percentage-point increase in $StDFriendHP_{i,April2017}$ on the standard deviation of the belief distribution is 0.18 percentage points. In column 6, we also include $FriendHPExp_{i,April2017}$ as a control variable, but it has no statistically significant effect on the standard deviation of the belief distribution.

Overall, these findings confirm that the mean and variance of the house price experiences across an individual's friends can shift the corresponding moments of the distribution of these individuals' house price beliefs. In the following section we will use this insight to analyze the effect of house price beliefs on leverage choice.

3.3 Main Results

In this section, we test how moments of the distribution of house price experiences across a homebuyer's friends affect that homebuyer's leverage choice in the sample of transactions described in Section 3.1. Based on the evidence in Section 3.2 and in Bailey et al. (2017*a*), we argue that these house price experiences provide shifters of individuals' distributions of beliefs about future house price changes that are orthogonal to other factors that might influence leverage choice.

In our baseline regression specification R1, the unit of observation is a housing transaction. We run regressions of the combined loan-to-value (CLTV) ratio for transaction i at time t in county c and financed by mortgage lender l on moments of the distribution of the house price experiences of the friends of the homebuyer. This combined loan-to-value ratio includes all mortgages originated to finance the home purchase.[31] We also control for a rich set of homebuyer characteristics,[32] and include county by purchase month by lender fixed effects, $\psi_{t,c,l}$.[33] This allows us to compare the leverage choices across individuals who borrow from the same lender in the same county and at the same point in time, and who therefore faced the same schedule of loan-to-value ratios and interest rates to choose from.

$$CLTV_{i,t,c,l} = \alpha + \beta_1 MeanFriendHP_{i,t} + \beta_2 StDFriendHP_{i,t} + \beta_3 X_{i,t} + \psi_{t,c,l} + \epsilon_{i,t,z}, \tag{R1}$$

In order to use estimates of β_1 and β_2 to differentiate between the housing-as-consumption scenario and the

[30] One can provide a structural interpretation of this estimate as a Kalman gain in the context of standard linear-gaussian bayesian updating.

[31] For example, many homebuyers that choose to borrow more than 80% of the value of the house split their borrowing into a first mortgage with an LTV of 80%, for which they do not have to pay private mortgage insurance (PMI), and a higher-interest piggy-back loan for the remaining amount.

[32] With the exception of age, which can be observed at the point of the transaction, other homebuyer characteristics are observed as of the points of the Acxiom snapshots. We assign the value from the most proximate snapshot. We flexibly control for homebuyer income, age, household size, family status, occupation, and education level. We also control for the number of friends, the number of out-of-commuting zone friends, and the number of counties in which an individual has friends.

[33] Even though Hurst et al. (2016) have shown that most lenders do not vary their mortgage pricing geographically, this choice of fixed effects is conservative, and ensures that we are comparing the leverage choices of individuals facing the same trade-offs between making a smaller downpayment and paying higher interest rates. In the rare cases where the first and second mortgages are by different lenders, we use the identity of the lender of the first mortgage to determine the lender fixed effect.

housing-as-investment scenario, we need to ensure that our key explanatory variables, $MeanFriendHP$ and $StDFriendHP$, only affect leverage choice through their effect on homebuyers' beliefs about the distribution of future house price changes. A first concern is that individuals who have more local friends, and for whom higher local house prices would thus lead to a higher $MeanFriendHP$, might also be more affected by this local house price growth through channels other than the effect on their house price expectations. For example, if individuals with more local friends were more likely to own local property, then they would be more likely to benefit from higher capital gains, allowing them to make a larger downpayment on any subsequent property purchase. To rule out confounding effects through such alternative channels, we estimate regression R1 using an instrumental variables (IV) strategy, where we instrument for the mean and standard deviation of all friends' house price experiences with the mean and standard deviation of the house price experiences of out-of-commuting zone friends.[34]

Table 3 shows the results of regression R1. The baseline estimate in column 1, which does not control for homebuyer demographics, suggests that individuals whose friends experienced a one-percentage-point higher house price appreciation over the past 24 months increase their downpayment (and reduce their CLTV ratio) by between 8 and 9 basis points. A one within-zip-code-month standard deviation increase in friends' house price experience is thus associated with a 31 basis points larger downpayment. Combining this with the estimates from the survey analyzed in Section 3.2 suggests that individuals that expect a one-percentage-point lower house price growth over the coming twelve months would choose a $\frac{0.084}{0.326} = 26$ basis points lower downpayment. This finding suggests that individuals behave more like in the housing-as-consumption scenario rather than in the housing-as-investment scenario.[35] Column 1 also shows that individuals whose friends had more dispersed house price experiences, and who thus expected more variance in future house price changes, chose higher leverage. A one-percentage-point increase in the across-friends standard deviation of house price experiences over the past 24 months is associated with a 35 basis points increase in the combined loan-to-value ratio. This result is also consistent with the predictions from the housing-as-consumption scenario: individuals that expect future house price growth to be more dispersed perceive large house price drops to be more likely. This increases the benefits of not putting all their savings into the house, and therefore increases their optimal leverage choice.

In column 2 of Table 3, we also control flexibly for a large number of borrower characteristics. The estimated effects of the house price experiences of a person's friends is remarkably stable with respect to the addition of these observable controls. This provides additional evidence consistent with Bailey et al. (2017*a*) that the house price experiences of a person's friends in a given year are uncorrelated with that person's observable characteristics, and reduces concerns that the results are driven by selection on unobservable buyer characteristics (see Altonji, Elder and Taber, 2005). In column 3, we interact the buyer demographics with year fixed effects. This allows, for example, the effect of having a different education or a different profession on leverage choice to vary by year. This specification provides a first test of whether our findings could be explained by correlated shocks to homebuyers and their friends. For example, one might have worried that less-educated Los Angeles residents have more friends in regions with a relatively less-educated population. In that case, a positive shock to the income prospects of less-educated individuals in a given year might both raise house prices where less-educated buyers have friends, and would increase the ability of these less-educated buyers to make larger downpayments. Our results are essentially

[34]The instrument has an F-Statistic above 1,500 across all specifications, largely driven by the fact that the set of out-of-commuting zone friends, which is used to construct the instruments, is a subset of the set of all friends, which is used to construct the instrumented variables, $MeanFriendHP_{i,t}$ and $StDFriendHP_{i,t}$.

[35]This does not mean that more pessimistic individuals did not also reduce their housing market investments, as in the extreme case with infinite collateral adjustment friction studied above. Indeed, Bailey et al. (2017*a*) document that individuals whose friends experienced lower recent house price growth did buy smaller houses: a one-percentage-point smaller friends' house price experience was associated with purchasing a 0.3 percentage points smaller property. Instead, the estimate in column 1 of Table 3 suggests that as individuals got more pessimistic, their desire to reduce their financial exposure to potential house price declines increased faster than the reduction in that exposure that was possible to achieve by buying a smaller house. As a result, they ended up buying (slightly) smaller houses with larger overall leverage.

Table 3: Main Results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Δ Friends' House Prices (24m)							
Mean	-0.084***	-0.087***	-0.107***	-0.136***	-0.060***	-0.144***	-0.027*
	(0.005)	(0.005)	(0.006)	(0.008)	(0.012)	(0.008)	(0.012)
St. D.	0.349***	0.318***	0.319***	0.546***	0.276***	0.439***	-0.027
	(0.013)	(0.013)	(0.014)	(0.021)	(0.015)	(0.019)	(0.023)
Mean X Recourse				0.063***			
				(0.011)			
St. D. X Recourse				-0.451***			
				(0.031)			
Mean X Mean					0.0005*		
					(0.0002)		
St. D. X Mean					-0.004***		
					(0.00)		
Mean X Recovery						0.046***	
						(0.012)	
St. D. X Recovery						-0.268***	
						(0.027)	
Mean X HO-Rate							-0.103***
							(0.014)
St. D. X HO-Rate							0.463***
							(0.025)
Month x County x Lender FE	Y	Y	Y	Y	Y	Y	Y
Demographic Controls	N	Y	Y, x Year	Y, x Year	Y, x Year	Y, x Year	Y, x Year
N	1,350,606	1,350,606	1,350,600	1,350,600	1,350,600	1,350,600	1,350,600
R-Squared	0.242	0.267	0.269	0.269	0.269	0.269	0.270
Mean Dep. Var.	88.38	88.38	88.38	88.38	88.38	88.38	88.38

Note: Table shows results from regression R1. The unit of observation is a housing transaction, the dependent variable is the combined loan-to-value ratio of the mortgages financing the home purchase. All specifications are instrumental variables regressions where we instrument for the moments of the distribution of house price experiences across an individual's friends with the corresponding moments of the distribution of house price experiences across her out-of-commuting zone friends. All specifications control for county × transaction month × lender fixed effects. Columns 2-7 also control for homebuyer characteristics (dummy variables for income groups, household size, marriage status, occupation, education levels, age, the number of friends, the number of out-of-commuting zone friends, and the number of unique counties with friends. In Columns 3 to 7 we interact all borrower controls with year fixed effects. Column 4 interacts the measures of friends' house price experiences with a dummy variable of whether the transaction was in a recourse state. Column 5 interacts the measures of friends' house price experiences with the mean of friends' house price experiences. Column 6 interacts the measures of friends' house price experiences with a dummy variable capturing zip code - months where the average house price experiences of all buyers' friends were above the sample median, loosely corresponding to a recovery period in the housing market. Column 7 interacts the measures of friends' house price experiences with the homeownership rate in the zip code of the transaction. Standard errors are clustered at the zip code × transaction-month level. Significance Levels: * ($p<0.10$), ** ($p<0.05$), *** ($p<0.01$).

unchanged from our baseline specification, suggesting that correlated shocks are not a key driver of our results. We provide additional robustness checks in Section 3.4.

Column 4 of Table 3 tests the predictions from Section 2.2.1, which show that the downpayment protection force at the heart of the housing-as-consumption scenario is particularly strong when the cost of mortgage default is low. We proxy for the cost of default by whether or not the transaction occurred in a recourse state. In recourse states, lenders can collect on debt not covered by the sale of a foreclosed property by going after other assets of the defaulting borrowers. This substantially increases the cost of default for borrowers in recourse states.[36] Table 1 shows that about half of our transactions come from recourse states. Consistent with the predictions from Section 2.2.1 for the housing-as-consumption scenario, we find that the effect of friends' average house price experiences on individuals' leverage choice is about twice as large for transactions in non-recourse states. Similarly, the effect of a higher standard deviation of friends' house price experiences on mortgage leverage choice is over five times as large in non-recourse states as it is in recourse states. This provides strong evidence that the downpayment protection force, which is central to the housing-as-consumption scenario, is indeed stronger in legal environments that feature relatively low costs of default.

Columns 5 and 6 of Table 3 test the predictions from Section 2.2.2, which highlight that in the housing-as-consumption scenario, the effects of changes in house price beliefs on optimal leverage choice should be smaller if the baseline house price belief is more optimistic. When comparing the beliefs of relatively optimistic borrowers, either in the time-series, or the cross-section, all borrowers expect to repay their mortgage most of the time, and there is little disagreement about the probability of default that is central to leverage choices in the housing-as-consumption scenario. Column 5 interacts our measures of friends' house price experiences with the mean of friends' house price experiences. The estimates show that changes in both the mean and the variance of friends' house price experiences have smaller effects for individuals' already starting from an already higher mean house price expectation. This concavity in the effect of mean house price experiences is a central prediction of the housing-as-consumption scenario.

In column 6, we interact the mean and the standard deviation of friends' house price experiences with a dummy variable that captures whether or not the average house price experiences of all buyers in the purchase zip code-month were above the sample median value. These transactions usually occur during the later years of our sample, when the housing market had started to enter a recovery period, and when homebuyers were generally expecting future house price increases (see Case, Shiller and Thompson, 2012, and Kuchler and Zafar, 2015, for evidence on such extrapolative house price expectations). Consistent with the predictions from the housing-as-consumption framework, the effects of both the mean and standard deviation of friends' house price experiences on the leverage choice are significantly larger in absolute terms during the housing bust period than they are during the recovery period.[37] This is consistent with the downpayment protection force being particularly strong during periods when there is a comparatively large disagreement between optimists and pessimists about the probability of default.

In column 7, we interact the mean and variance of the house price experiences of a homebuyers' friends with the homeownership rate in the zip code of the transaction. The homeownership rate is one proxy for the extent of

[36] Ghent and Kudlyak (2011) analyze mortgage default behavior across U.S. states, and find strong evidence that the recourse/non-recourse environment does indeed have significant effects on the default behavior of borrowers, as would be predicted if it induced significant differences in the costs of default. Specifically, the authors find that at the average value of negative equity, the monthly probability of default is 1.3 times higher in non-recourse states than it is in recourse states. All else equal, this means that it takes 8.6% more negative equity to make the probability of default in a recourse state the same as the probability of default in a non-recourse state. See also the discussion in Kuchler and Stroebel (2009).

[37] A potential concern when interpreting these differential effects across time comes from the fact that we only observe the friendship network at one point in time, July 2015. This networks becomes a noisier measure of individuals' contemporaneous network the further back we go, which could induce increased attenuation bias for measuring friends' house price experiences for buyers in earlier transactions. However, given that the housing bust period preceded the housing recovery period, such an attenuation bias would reduce the measured effect during the housing bust period, and therefore work against producing the effect that we uncover.

the collateral adjustment frictions faced by pessimists who want to reduce their exposure to the housing market. In markets with a low homeownership rate, individuals wanting to live in a certain zip code (for example, because of proximity to work or good schools) are more likely to find a suitable rental property than individuals wanting to live in zip codes with extremely high homeownership rates. The estimates show that the effects of house price beliefs on leverage choices are of the same direction across the entire support of the distribution of homeownership rates. However, in regions with high homeownership rates, the effects of increased perceptions of the possibility of default on leverage choice are larger, because, in those regions, reducing the downpayment is a comparatively easier way for households to reduce their exposure to the housing market.

Taken together, the behavior of the homebuyers in our sample corresponds to the predictions from the housing-as-consumption scenario, with a sizable collateral adjustment friction preventing relatively pessimistic homebuyers from purchasing a substantially smaller home to live in.[38] These pessimistic homebuyers therefore make smaller downpayments in order to reduce their housing market exposures, in particular in states where the cost of default is comparatively smaller, and in particular during time periods when there are concerns about substantial price drops in the housing market.

3.4 Robustness Checks and Ruling Out Alternative Explanations

Our interpretation of the results in Section 3.3 is that the relationship between friends' house price experiences and leverage was driven by the effects of friends' experiences on an individual's belief about future house price growth. In this section, we rule out a number of alternative interpretations of the correlation between friends' house price experiences and individuals' mortgage leverage choice. As we address these alternative interpretations, we note that most of these stories could have potentially explained the effect of friends' average house price experiences on leverage. However, the effect of the dispersion of friends' house price experiences on leverage choices are much harder to rationalize with alternative mechanisms, as are the differential effects across recourse/non-recourse states, across periods with relatively high/low average beliefs, and across regions with different homeownership rates.

A first concern we address is that the instruments in our baseline regression, the moments of the house price experiences of out-of-commuting zone friends, might still be correlated with the individuals' own house price experiences, and therefore potentially with their own capital gains, in particular for individuals who have more friends in close-by commuting zones that have house price movements similar to those in their own commuting zone. In column 1 of Table 4, we therefore use moments of the house price experiences of out-of-state friends as instruments. Reassuringly, the magnitudes of the effects in this specification are, if anything, slightly larger than in our baseline specifications.

In column 2 of Table 4, we restrict the sample to purchases by individuals who have more than 50 out-of-commuting zone friends; in column 3, we restrict the sample to transactions by individuals with friends in at least 35 counties. These specifications address concerns that the effects of the dispersion of friends' experiences on leverage could be driven by individuals without sufficiently many geographically distant friends to construct powerful shifters of the belief distribution. Reassuringly, the magnitude of the estimates are very similar to those in the baseline specification.

A further possible concern is that unobserved shocks to an individual's *ability* to make a downpayment in a given year might be correlated with her friends' house price experiences in that year. Such an alternative interpretation requires a shock to an individual's wealth or income that contemporaneously moves house prices

[38] One caveat regarding the generalizability of these findings is that our sample is restricted to purchases by owner-occupiers, since we cannot match buyers making investment purchases to their respective Facebook accounts. While we do not have the data to analyze the leverage choices of these investment buyers, our theoretical framework suggests that those individuals should face a much smaller collateral adjustment friction. They might therefore respond to increasing optimism by buying more houses with higher leverage.

Table 4: Robustness Checks I

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Δ Friends' House Prices (24m)							
Mean	-0.112***	-0.094***	-0.093***	-0.080***	-0.090***	-0.084***	-0.114***
	(0.007)	(0.006)	(0.007)	(0.007)	(0.025)	(0.006)	(0.008)
St. D.	0.456***	0.283***	0.278***	0.319***	0.256***	0.273***	0.370***
	(0.019)	(0.016)	(0.017)	(0.014)	(0.065)	(0.014)	(0.023)
Δ Friends' County Income (24m)							
Mean				-8.015***			
				(0.962)			
St. D.				-13.33***			
				(0.910)			
Friends' Foreclosure Rate (24m)							
Mean						40.83***	
						(1.773)	
St. D.						-32.37***	
						(3.479)	
Month x County x Lender FE	Y	Y	Y	Y	Y	Y	Y
Demographic Controls	Y, x Year	Y, x Year	Y, x Year	Y, x Year	Y, x Year	Y, x Year	Y, x Year
Specification Notes	Out-of-State Friends' Exp. As Instrument	> 50 Out-Of-Commuting Zone Friends	> 35 Unique Counties		Geographically Non-Clustered Profession		Only Friends in Recourse States
N	1,350,348	996,864	937,075	1,253,013	1,308,731	1,347,592	1,349,396
R-Squared	0.268	0.271	0.280	0.269	0.277	0.270	0.269
Mean Dep. Var.	88.38	88.65	88.86	88.39	88.37	88.38	88.38

Note: Table shows results from regression R1, and provides robustness checks to the baseline results presented in Table 3. The unit of observation is a home transaction, the dependent variable is the combined loan-to-value ratio in the transaction. All specifications include controls and fixed effects as in column 2 of Table 3. In columns 1, we instrument for moments of the house price experiences of the buyers total friends with the corresponding moments of the distribution of house price experiences of the buyers' out-of-state friends. In column 2, we restrict the sample to purchases by individuals with at least 50 out-of-commuting zone friends, in column 3 to purchases by individuals with friends in at least 35 unique counties. Column 4 also controls for the average income changes in the counties where an individual has friends. In column 5, we focus on purchases by individuals working in geographically non-clustered professions (e.g., teachers and lawyers). Column 6 also controls for the average foreclosure share in the counties where an individual has friends. Column 7 only uses the house price experiences of out-of-commuting zone friends in recourse states to instrument for the house price experiences of all friends. Standard errors are clustered at the zip code × transaction-month level. Significance Levels: * ($p<0.10$), ** ($p<0.05$), *** ($p<0.01$).

in geographically distant regions where she has friends. As discussed above, our baseline regressions already minimize the scope for such potentially confounding effects, by including year-specific controls for a large number of observable characteristics of homebuyers. We next address the one additional potential confounder that we were able to identify. In particular, many people have friends that work in the same sector of the economy. If economic activity in that sector features significant geographic clustering (e.g., tech in Silicon Valley), positive shocks to that sector in a given year might both enable an individual to make a larger downpayment and drive up aggregate house prices in those sector-exposed regions where the individual has friends.

To rule out this explanation of our findings, column 4 includes the average income change in the county where the person has friends as a control, in addition to the average house price change. We measure income annually at the county level using data from the Tax Statistics of Income (SOI). In addition, in column 5 we restrict the sample of transactions to those in which the homebuyer works in geographically non-clustered professions (e.g., lawyers and teachers). Any positive shocks to such professions, which might increase those individuals' ability to make a larger downpayment, should not affect house prices in regions where they have friends. This is because there are no parts of the country where there are so many teachers or lawyers that positive shocks to those professions can shift aggregate house prices. In both specifications the estimates are similar to our baseline estimates, confirming that common shocks to individuals and their friends that shift house prices in areas where their friends live cannot explain our findings.

Lastly, a potential alternative interpretation of our findings is that when house prices decline in counties where

an individual has friends, and there are subsequently more foreclosures in those counties, individuals might update both their own house price beliefs as well as their expectations about the cost of default or the benefits of the foreclosure process, both of which might also directly affect their leverage choice. To address such concerns, column 6 also includes measures of the share of all properties in friends' counties that experienced a foreclosure over the previous 24 months, based on data provided by Zillow. While a higher foreclosure rate in friends' locations is associated with larger leverage and a smaller downpayment, the inclusion of this additional control variable does not significantly affect the estimated effect of friends' house price experiences on mortgage leverage choice.[39] In column 7, we only use the house price experiences of friends in recourse states to instrument for the house price experiences of all friends. If most of the effect came through individuals learning about the cost of default when house prices fall where their friends live, then the estimated effect should be smaller when only using variation in house prices in recourse states where house price changes translate less into foreclosures. However, the estimated coefficients are, in fact, almost identical in size.

Table 5: Robustness Checks II

	Same Employer		Same College		Family		All Friends
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Δ Friends' House Prices (24m)							
Mean	-0.126***	-0.191***	-0.121***	-0.133***	-0.089***	-0.086**	-0.362***
	(0.014)	(0.030)	(0.012)	(0.018)	(0.017)	(0.033)	(0.027)
St. D.	0.366***	0.629***	0.254***	0.333***	0.222***	0.118	0.776***
	(0.035)	(0.119)	(0.029)	(0.074)	(0.039)	(0.091)	(0.051)
Month x County x Lender FE	Y	Y	Y	Y	Y	Y	Y
Demographic Controls	Y, x Year	Y, x Year	Y, x Year	Y, x Year	Y, x Year	Y, x Year	Y, x Year
Specification Notes	All Friends	Same Employer	All Friends	Same College	All Friends	Family	Purchase in Home State, Out-of-State Friends for Instrument
N	257,450	257,450	368,612	368,612	167,587	167,587	485,031
R-Squared	0.323	0.324	0.297	0.298	0.343	0.340	0.300
Mean Dep. Var.	89.719	89.702	88.221	88.200	91.112	91.096	88.957

Note: Table shows results from regression R1, and provides robustness checks to the baseline results presented in Table 3. The unit of observation is a home transaction, the dependent variable is the combined loan-to-value ratio in the transaction. All specifications include controls and fixed effects as in column 2 of Table 3. In columns 1 and 2, we focus on purchases by people for whom we can identify at least ten work friends, in columns 3 and 4 on purchases by people for whom we can identify at least ten college friends, and in columns 5 and 6 on purchases by people for whom we can identify at least ten family members. In columns 1, 3, and 5, we repeat our baseline specification on the restricted sample for comparability. In columns 2, 4, and 6, we use the house price experiences of an individual's geographically distant work friends, college friends, and family members, respectively, to instrument the corresponding moments of the house price experiences among all friends. In column 7, we only include transactions of individuals who report a hometown, and who purchase a property in their home state. We use these buyers' out-of-state friends' house price experiences to instrument for the house price experiences of all friends. Standard errors are clustered at the zip code × transaction-month level. Significance Levels: * (p<0.10), ** (p<0.05), *** (p<0.01).

An additional challenge to our interpretation is the potential for wealth effects: if an individual has family in those areas where she has friends, and if those family members own real estate, then house price increases in those areas might increase her expected bequest. This wealth channel could then provide an alternative explanation for why individuals make larger downpayments when their geographically distant friends have experienced higher house price increases. We rule out such an explanation in a number of ways. First, columns 1 to 6 of Table 5

[39] While the house price experiences and foreclosure rate across friends' counties are naturally correlated, they are far from collinear. Specifically, the extent to which declining house prices translate into more foreclosures depends both on the legal environment across states as well as on the initial level of equity that individuals have in their homes, which, in turn, depends on the entire house price history in the county. In addition, there is a substantial time-lag between the initial house price decline and default/foreclosure activity.

separately explore the house price experiences across an individual's social network of work friends, family friends, and college friends. Since not all individuals report their family member, their employer, or their college on Facebook, these regressions have fewer observations than our baseline estimates. In columns 1, 3, and 5, we run our baseline regression (corresponding to column 2 of Table 3), but only on the set of individuals for whom we can identify at least ten work friends, family friends, and college friends. In columns 2, 4, and 6, we then run the same regression, but only use the house price experiences among out-of-commuting zone work friends, family friends, and college friends, respectively, to instrument for all friends' house price experiences.[40] While one might expect to inherit a house from a family member, this is much less likely for a work friend or college friend. Yet, our results are very similar when exploiting variation in house price experiences across these three networks, suggesting that wealth effects are not a key driver of our findings. Finally, in column 7 we restrict our sample to individuals who report their hometown on Facebook, and who purchase a property in their home state. We use the house price experiences of their out-of-state friends as an instrument. For those individuals, the exposure of their expected bequest to out-of-state house price movements is more limited, since most of the properties they might inherit are likely to be located in their home state, yet we find, if anything, a larger correlation between the house price experiences of their geographically distant friends and their leverage choice.

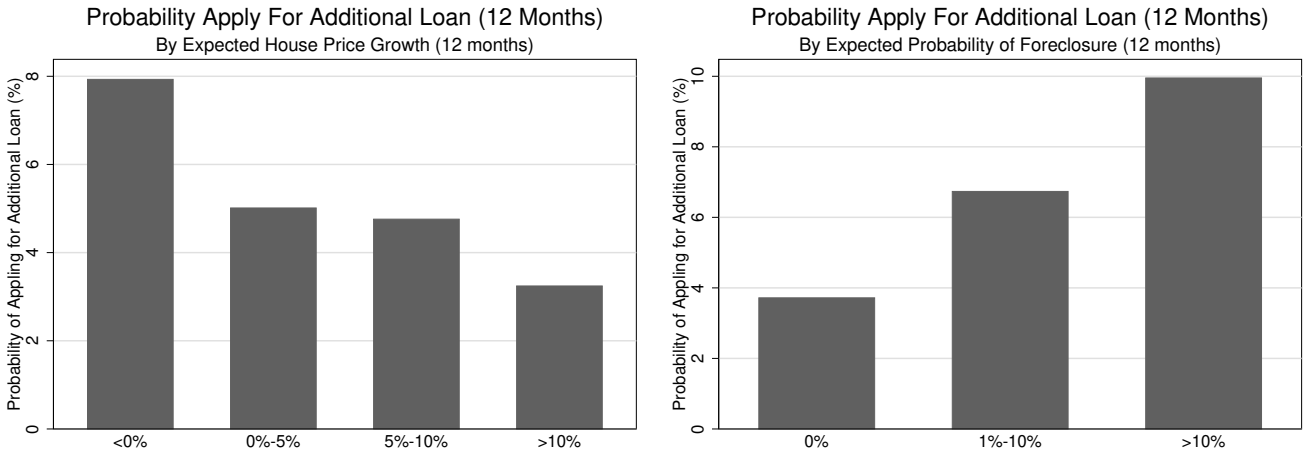
4 House Price Beliefs and Leverage Choice: Ancillary Evidence

The previous section documented that more optimistic individuals make larger downpayments, consistent with the directional predictions from the housing-as-consumption scenario. In this section, we show that this relationship between house price beliefs and mortgage leverage choice is consistent with various additional survey data. We also provide evidence for the importance of the key mechanism underlying the housing-as-consumption scenario.

First, we consider data from the New York Fed Survey of Consumer Expectations to corroborate that, in these data, respondents' anticipated leverage choice is also decreasing in their expectations about future house price growth, and increasing in their expected default probabilities. Second, we use SurveyMonkey to conduct a Downpayment Motivation Survey (DMS) that allows us to explore individuals' leverage choices under various scenarios for future house price growth. In the survey, individuals select smaller downpayments when the probability of large house price declines increases. We also explore the thought-process behind individuals' leverage choices. In particular, the DMS elicits a "free text" response asking individuals to describe why they adjusted their downpayment choice across different house price beliefs. Many individuals report to reduce their downpayments in response to a larger probability of house price declines for reasons that are aligned with the key mechanism in the housing-as-consumption scenario, namely that lower downpayments minimize the financial exposure to adverse house price movements. We also show that financial advice websites and blogs regularly highlight the tradeoffs behind the housing-as-consumption scenario when discussing how large a downpayment to make. Lastly, we explore survey evidence on households' perceived cost of mortgage default, to highlight that these perceived default costs are often small enough to not make defaulting on a mortgage prohibitively expensive, consistent with an important assumption behind the housing-as-consumption scenario.

[40] Bailey et al. (2017*a*) documented that the average house price experiences across these three separate out-of-commuting zone networks are relatively uncorrelated. This suggests that homebuyers' family friends do not, in general, live in the same parts of the country as their work or college friends.

Figure 8: Expectation of Applying for Additional Loan



Note: Figure shows summary statistics based on data from the FRBNY Survey of Consumer Expectations. The left panel shows the average probability that survey respondents assign to applying for an additional loan on their property over the next 12 months, in percent, separately by groups of expected house price growth over the next 12 months. The right panel shows the average probability of applying for an additional loan separately by the probability that individuals assign to having their house foreclosed over the next 12 months.

4.1 NY Fed Survey of Consumer Expectations.

We first analyze survey data from the 2014 Real Estate and Housing Module of the New York Fed Survey of Consumer Expectations (SCE).[41] Within these data, we consider the determinants of individuals' (anticipated) leverage choice. Our key outcome variable is the answer to the following question asked of current homeowners: "What is the percent chance that over the next 12 months you will apply for an additional loan on your primary residence?" In Figure 8, we explore how the answer to this question differs with respondents' expectations. In the left panel, we sort respondents by their beliefs about house price growth in their neighborhood over the coming 12 months, which was also elicited in the survey. In the right panel, we sort respondents by their answer to the following question: "What is the percent chance that over the next 12 months you will enter foreclosure or lose your home through a repossession?"

In both panels, there is evidence that individuals who are more pessimistic are more likely to want to increase leverage going forward, thereby reducing their financial exposure to the housing market. However, while these results are highly consistent with the key mechanism in the housing-as-consumption scenario, there are other possible explanations for the observed correlations. For example, in regions where the economy is doing badly, individuals might expect house prices to decline and might also fear they have to tap into home equity to smooth out income shocks. Such possibly confounding stories highlight the value of the quasi-orthogonal belief shifters in our main empirical analysis for identifying causal relationships between beliefs and leverage choice.

[41] The Survey of Consumer Expectations is a monthly online survey of a rotating panel of household heads launched by the Federal Reserve Bank of New York in 2013. A household head is defined as the person in the household who owns, is buying, or rents the home. It is nationally representative. New respondents are drawn monthly to match demographic targets from the American Community Survey (ACS), and stay on the panel for up to twelve months before rotating out. The Housing Module is an annual 30-minute add-on to the SCE conducted in February; the set of questions varies by year. In the 2014 implementation, 85% of SCE household heads completed the module, for a sample size of 1,213.

4.2 Downpayment Motivation Survey

To provide direct evidence on the motivations behind individuals' mortgage choices, we designed a short Downpayment Motivation Survey (DMS) to elicit how and why individuals' mortgage choices depend on their beliefs about future house price changes. The most important purpose of this survey is to provide direct evidence that the mechanism behind the housing-as-consumption scenario features regularly in the narratives that individuals have about their own mortgage choice process.

The DMS was administered to current homeowners via SurveyMonkey in September 2017. The demographics of the survey respondents are described in Appendix C.3. The survey presented individuals with different scenarios about future house price growth, and asked them to recommend one of three possible downpayment choices to a friend. Specifically, the first wave of the survey, administered to 826 respondents, was designed as follows:[42]

> Your friend is buying a house, and is asking you for advice on what downpayment to choose. The house costs $100,000, and your friend has a total of $30,000 in savings.
>
> [**OPTIMISTIC SCENARIO.**] Your friend believes that over the next few years there is an equal 50% chance that house prices will either *stay the same* or *increase* by 25%. If the bank offers him the following three 30-year mortgages, which mortgage would you advise your friend to take?
>
> (i) Downpayment of $20,000, interest rate of 3%
>
> (ii) Downpayment of $10,000, interest rate of 4%
>
> (iii) Downpayment of $3,000, interest rate of 5%
>
> [**PESSIMISTIC SCENARIO.**] If your friend instead believes that over the next few years there is an equal 50% chance that house prices will either *stay the same* or *decrease* by 25%, which of the following 30-year mortgages would you advise him to take?
>
> (i) Downpayment of $20,000, interest rate of 3%
>
> (ii) Downpayment of $10,000, interest rate of 4%
>
> (iii) Downpayment of $3,000, interest rate of 5%

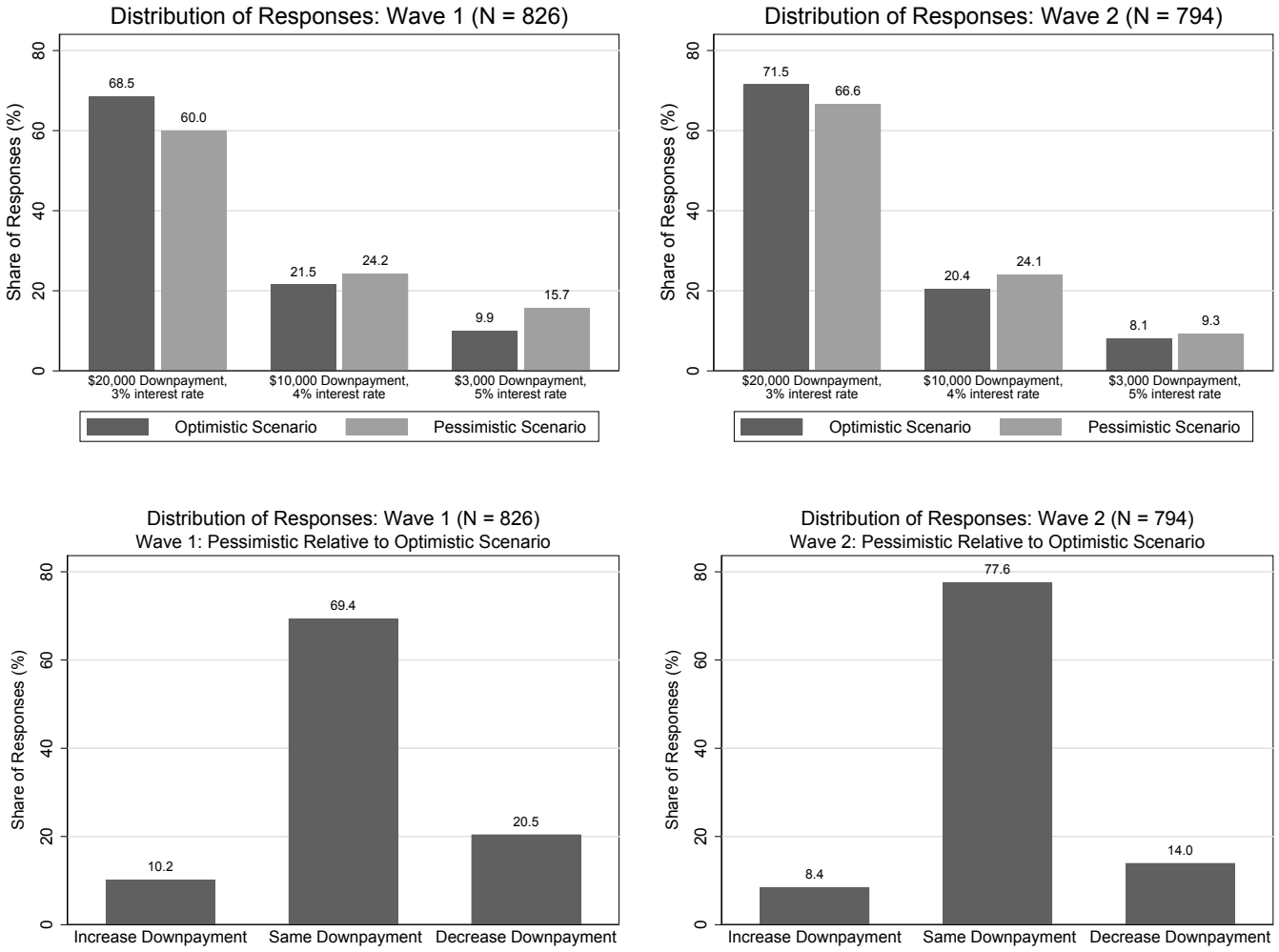
The order of the mortgage options and the order of the optimistic and pessimistic scenarios were randomized across respondents. If the respondent did not change the downpayment recommendation across the two house price scenarios, we asked the following free-text question: "Why did you decide not to change the mortgage recommendation for your friend?"; if the respondent did change the downpayment recommendation, we asked: "Why did you change the mortgage recommendation for your friend?"

The second wave of the survey, which had 794 respondents, presented different house price scenarios. In that wave, the optimistic scenario was house prices that stayed flat with certainty, while the pessimistic scenario involved an equal probability each of a 25% increase and a 25% decrease in house prices. We call this second scenario, which involves a mean-preserving increase in the spread, more pessimistic, because it entails a higher probability of substantial house price declines.

For each of the two survey waves, we begin by exploring if and how individuals changed their leverage choices across the two house price scenarios. The left column of Figure 9 analyzes responses to the first survey wave, the right column to the second wave. The top row of Figure 9 shows the share of respondents that make each of the three downpayment recommendations, both in the optimistic and the pessimistic house price scenarios. The

[42] The actual survey design did not include the terms in square brackets ("Optimistic Scenario" and "Pessimistic Scenario").

Figure 9: Downpayment Motivation Survey – Responses



Note: Figure shows summary statistics on the responses to the Downpayment Motivation Survey. In the left panels, we show responses from survey wave 1, where the optimistic scenario was a 50% probability of constant house prices and a 50% probability of a 25% increase in house prices, and the pessimistic scenario was a 50% probability of constant house prices and a 50% probability of a 25% house price decrease. In the right panels, we show responses from survey wave 2, where the optimistic scenario was house prices that stayed flat, while the pessimistic scenario was a 50% chance each of a 25% house price increase and a 25% house price decrease. In the top row we show the share of respondents that make each downpayment recommendation in both the optimistic and the pessimistic scenario. In the bottom row, we show the share of respondents that either increase, do not change, or decrease their recommended downpayment in the pessimistic relative to the optimistic scenario.

bottom row shows the share of individuals that either increase, do not change, or decrease their recommended downpayment in the pessimistic relative to the optimistic scenario.

Consistent with the findings in Sections 3.3 and 4.1, and consistent with the predictions from the housing-as-consumption scenario, there is a noticeable shift in the distribution of recommendations towards lower downpayments in the more pessimistic house price scenarios.[43] The bottom row confirms this finding: across the two survey waves, there are twice as many people that recommend making a smaller downpayment in the relatively more pessimistic house price scenario than there are people that recommend making a larger downpayment.[44] In Appendix C.3, we explore how changes in downpayment recommendations across the two scenarios differ with demographic characteristics. We find that individuals across all gender, income, and location groups are more likely to recommend reduced downpayments in response to the more pessimistic house price scenario.

Table 6: Stated Reasons for Recommending Smaller Downpayment Under Pessimistic Scenario

	Wave 1	Wave 2
Optimistic First	• Less money at risk when the chance of a decline in value increases • Less money invested in potential loss • No need to put more for a down payment if the value will drop. • If he defaults and housing prices decrease so that he cannot sell to recoup his investment, he loses less deposit if he puts less down. • Because the house MAY be worth less I would rather have cash on hand than tied up in the house	• Put down less money in case house prices go down. • Risk of losing equity with house devaluation. • Because I am anticipating that the friend may need to file for a bankruptcy and would want to be sure to be able to shield his or her equity in the property. • If the value of the home decreases substantially, he wouldn't have as much invested in the asset which is losing value, yet will still have a better interest rate than the first option.
Pessimistic First	• Cheaper rate so total cost is lower and down payment is not in jeopardy • Could be a chance he defaults on the loan in the first case to get out from under a mortgage. • If the house is not going to appreciate in value I wouldn't put too much money in	• Because if they think they are going to lose money, they shouldn't risk much. • So he would put less money/savings down on a house that could quickly decrease in value. • As long as the housing market (and his investment in the house) stays stable, he should go for the smaller monthly payments he'd have with the smaller interest rate.

Note: Table shows comments from the free-text question in the Downpayment Motivation Survey among those individuals who recommended a smaller downpayment in the more pessimistic house price scenario. The free-text question asked respondents to explain their decision for changing the mortgage recommendation. In the left panels, we show responses from survey wave 1, where the optimistic scenario was a 50% probability of constant house prices, and a 50% probability of a 25% increase in house prices, and the pessimistic scenario was a 50% probability of constant house prices and a 50% probability of a 25% house price decrease. In the right panels, we show responses from survey wave 2, where the optimistic scenario was house prices that stayed flat, while the pessimistic scenario was a 50% chance each of a 25% house price increase and a 25% house price decrease. The top row shows responses from individuals who were first shown the optimistic scenario, and then recommended a smaller downpayment for the more pessimistic scenario. The bottom row shows responses from individuals who were first shown the pessimistic scenario, and then recommended a larger downpayment for the more optimistic scenario.

[43] Across all house price scenarios and survey waves, the most common recommendation is to make a downpayment of 20%. In addition, the majority of respondents did not change their downpayment recommendation in response to changes in house price expectations. This is consistent with other factors besides beliefs playing an important role in determining individuals' leverage choices. The "free text" responses of those individuals who did not change their recommendation provide some insights into what these reasons are. Very common explanations for keeping the downpayment recommendation fixed, usually at 20%, are a desire to reduce the interest rate as much as possible (e.g., "Choice is based on objective to reduce interest as much as possible"; "No matter what, better to have lower interest rate on smaller mortgage") or to borrow as little as possible (e.g., "Debt, even mortgage debt, makes me uncomfortable."; "Proverbs 22:7, Romans 13:8"; "Debt is a four-letter word. Don't borrow one penny more than you need to. Most people live in their homes for more than a few years, anyway."). Consistent with this last response, a second set of responses suggested that house price beliefs didn't matter so much for households that did not plan on selling/moving any time soon (e.g., "Because the interest rate makes the biggest difference to savings over time. Nothing indicated the friend might want to sell in the near future."; "Because it did not state whether or not he would be staying in the house long term.") Finally, a number of individuals explicitly recommend at least a 20% downpayment, if at all possible, in order to avoid having to pay private mortgage insurance ("By putting down 20% they eliminate the required mortgage insurance"; "with 20% down you do not have to have mortgage insurance, which is a great savings").

[44] Individuals are substantially more likely to report a lower downpayment recommendation in the pessimistic scenario if they first get presented with the more optimistic scenario than if they first get presented with the more pessimistic scenario.

While it is reassuring to find the same relationship between house price beliefs and mortgage leverage choice in the Downpayment Motivation Survey as in the detailed empirical analysis in Section 3.3, the primary benefit of the DMS is our ability to investigate the mechanism behind this relationship, by directly asking individuals to explain why they suggested a smaller downpayment in the more pessimistic house price scenario. Table 6 presents a number of representative explanations by the survey respondents. Importantly, many of the explanations reflect a desire to reduce the financial exposure to the housing asset in case of higher expected default probabilities, which maps directly into the mechanism behind the housing-as-consumption scenario.[45] Indeed, a number of individuals explicitly mention that through bankruptcy or default a smaller downpayment can allow individuals to avoid the potential capital loss coming from declining house prices.

4.3 Financial Advice Websites

Many homebuyers turn to the internet for help in the home purchase and mortgage choice process (see Piazzesi, Schneider and Stroebel, 2015). Indeed, financial advice websites and blogs regularly discuss the tradeoffs behind choosing the size of the downpayment, and therefore offer another window into how considerations about future house price changes affect leverage choices. In surveying these financial advice websites, we came across many instances of financial advisors highlighting the risk-shifting benefits of taking out smaller mortgages that are at the heart of the mechanism in the housing-as-consumption scenario. For example, Ric Edelman (2014), the number-one independent financial adviser as ranked by Barron's in 2009, 2010, and 2012, described the benefits of a large mortgage as follows:

> Have you noticed that your home is worth much more than it was 10 years ago? You might be worried that your home's value will fall. If you're afraid that your home's value might decline, you should sell the house before that happens. But you don't want to do that! It's your home, after all. You have roots in the community. Uproot the kids? And where would you move? No, selling is not a practical idea. Still, you fret that your home's equity is at risk. Can you protect it without having to sell? Yes! Simply get a new mortgage, and pull the equity out of the house. It's the same thing as selling, except that you don't have to sell!

In the language of our model: pessimistic homebuyers with a large collateral adjustment friction can reduce their exposure to house price changes by taking on higher leverage. Similarly, the following discussion on The Mortgage Reports (2017) highlights that making a 20% downpayment may not be the ideal choice, since "you're at risk when [your] home value drops. A down payment protects the bank, not the home buyer:"

> Home values are tied to the U.S. economy. Most of the time, the economy is making incremental gains, and home prices rise. But sometimes, the economy falters. This usually happens after extended periods of too-hot growth. That happened in the late 2000s. In this situation, consider two home buyers:
>
> - Buyer A: Puts 20% down on a $300,000 home
>
> - Buyer B: Uses FHA to put 3.5% down on a $300,000 home

[45] While respondents usually provided a reasonable explanation for why they did or did not change their mortgage recommendation, there is a fair amount of noise in the responses (e.g., respondents posting random YouTube links). In addition, some individuals responded with comments along the lines of "no clue," "not sure," and "just a feeling." The presence of such responses is unsurprising given the non-incentivized nature of the survey. Also, when asked why they changed their mortgage recommendation, a small number of individuals responded "I did not." Investigating these cases suggests that they were most likely responses from individuals who had picked the answer in the same "position" as their previous one, but which, due to the randomization of the downpayment choices presented to respondents, now corresponded to a different downpayment recommendation. The complete set of survey responses is available from the authors on request.

> Buyer A, thinking he is being "conservative" puts $60,000 down on a home. Buyer B puts down just $10,500. If home values fall 20% neither Buyer A nor Buyer B have any equity in their homes. However, Buyer A lost a much bigger amount. Plus, Buyer B carries less risk of being foreclosed on if she can no longer make her payments. This is because banks know they will take a bigger loss repossessing a home with a larger outstanding loan balance. So, really, which home buyer is more conservative? The one who puts the least amount down.

Appendix C.1 shows additional examples of financial advice websites and blogs highlighting that one benefit of small downpayments is the limited exposure to potential house price declines. This evidence, combined with the responses to the Downpayment Motivation Survey analyzed in Section 4.2, provides evidence for the channel through which concerns about falling house prices can motivate individuals to make smaller downpayments. Importantly, we do not want to suggest that house beliefs are the only, or even the most important determinant of mortgage leverage choice. However, to the extent that beliefs do affect households' downpayment decision, there appears to be strong support for the mechanism through which more pessimistic individuals choose lower downpayments in the housing-as-consumption scenario.

4.4 Beliefs about Default Costs

One important reason why more pessimistic individuals make smaller downpayments in the housing-as-consumption scenario is their perception that walking away from an underwater mortgage is not overly costly, either financially or socially. This is very consistent with some of the responses from the Downpayment Motivation Survey presented in Table 6. In this final section, we explore additional data to investigate households' beliefs about the cost of mortgage default.

We first analyze responses to the following question from the SCE described in Section 4.1: "If somebody with a mortgage like yours and living in your state went through foreclosure, do you think their lender could legally go after some of their other assets (e.g. bank accounts, cars, other property, etc.) to cover the remaining amount they owe?" 55% or respondents said that the bank could legally go after other assets, 45% responded that the bank could not. (As discussed above, the true legal authority of the bank depends on state-level recourse laws. Unfortunately, the public release data from the SCE do not contain state identifiers that would allow us to explore whether individual perceptions of banks' legal authority are correlated with banks' true legal authority). However, only 77% of those respondents who said that the bank could go after their other assets (which corresponds to 42% of all respondents) believed that the bank *would* actually do this.[46] This suggests that the majority of survey respondents believe that walking away from an underwater mortgage would allow them to discard any negative equity without putting other assets at risk.

We also review the evidence reported in Guiso, Sapienza and Zingales (2013), who conducted a quarterly survey on the mortgage default beliefs and attitudes of a representative sample of U.S. households between December 2008 and September 2010. Consistent with the evidence from the SCE, respondents reported an average probability of 53.4% that lenders would go after other assets of defaulters.[47] In addition, 23% of respondents said that they would walk away from their house (default on their mortgage) if they had more than $100,000 negative equity in the house, even if they were able to repay their loans; this is despite the fact that 82% of respondents argued

[46] The precise question from the SCE is: "If somebody with a mortgage like yours and living in your state went through foreclosure, do you think their lender actually would go after some of their other assets (e.g. bank accounts, cars, other property, etc.) to cover the remaining amount they owe?"

[47] The exact question was: "When people default on their mortgage, the lender repossesses the house. Sometimes the mortgage is more than the value of the house. On a scale from 0 to 100, where 0 equals "absolutely no chance" and 100 equals "absolutely certain" what do you expect are the chances that the lenders will go after people who default on their mortgage for the full amount of the mortgage?"

that it was morally wrong to default on a mortgage if it were possible to keep making mortgage payments. While this survey suggests that default costs appear low enough that a substantial proportion of the population would consider defaulting strategically, recall that strategic default is not a necessary condition for our mechanism to work (see Section 1.2).

4.5 Collateral Adjustment Friction

The behavior of households documented in Section 3 implies the presence of a significant collateral adjustment friction. As discussed above, this friction captures that individuals' decisions about what house to buy are not just determined by their investment motives, but also by their consumption motives. A high collateral adjustment friction means that more pessimistic homebuyers could not reduce their exposure to house price movements by buying a smaller property or moving to a different neighborhood without a substantial decline in their utility from living in their house. Instead, these pessimistic households chose to reduce their downpayment to minimize their housing market exposure. In this section, we analyze data from Zillow's "Consumer Housing Trends Report 2017" to provide direct evidence for the presence of a sizable collateral adjustment friction.

In the survey, a sample of about 3,000 representative homebuyers were asked about the requirements in the selection of their property. With respect to location, 71% of buyers required the home to be in a safe neighborhood, 40% required off-street parking, 39% required that the house was in their preferred neighborhood, and 29% required that the house was in their preferred school district. Other neighborhood requirements were proximity to shopping (29% of respondents), proximity to work (28%), proximity to family and friends (26%) and proximity to public transportation (18%). With respect to the actual property, 67% of respondents required the home to be within their initial price range, 62% required that the property had air conditioning, 62% required that it had their preferred number of bedrooms, and 53% that it had the preferred number of bathrooms. Other requirements were that the property had private outdoor space (48% of respondents), that it had the preferred square footage (47%), that it had a layout that fit the buyers' preferences (47%), that it had ample storage (41%), and that it had the buyers' preferred utilities (40%). Only 40% of respondents required that the property had good potential to increase in value. This suggests that, consistent with a sizable collateral adjustment frictions, homebuyers regularly perceive the consumption aspect of the property to be more important than the investment aspect.

5 Conclusion

We develop a parsimonious model of mortgage leverage determination in the presence of heterogeneous beliefs to show that the relationship between homebuyers' optimism and leverage crucially depends on the degree of collateral adjustment frictions faced by homebuyers. When households primarily maximize the levered return of their property investment (small collateral adjustment friction), more pessimistic homebuyers reduce their leverage to purchase smaller houses (housing-as-investment scenario). However, when the collateral adjustment friction is large and considerations such as family size pin down the desired property size, the only way for pessimistic homebuyers to reduce the size of their exposure to the housing market is by reducing their downpayment and increasing their leverage (housing-as-consumption scenario). Our empirical findings show that borrowers' beliefs indeed play an important role in determining borrowers' leverage decisions. We show that more pessimistic individuals take on more leverage, in particular during periods of declining house prices, and in particular in states with a relatively low cost of default. These findings are consistent with a large collateral adjustment friction, and map most closely to the housing-as-consumption scenario.

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Appendix

A Theoretical Derivations

A.1 Proofs

Properties of $\Lambda_i(\delta_i)$

The loan-to-value ratio offered to borrower i for a given promised repayment δ_i corresponds to

$$\Lambda_i(\delta_i) = \frac{\eta \int_{\underline{g}}^{\delta_i - \chi_i} g dF_L(g) + \delta_i \int_{\delta_i - \chi_i}^{\overline{g}} dF_L(g)}{1+r},$$

which can be alternatively written in terms of default and non-default probabilities and truncated expectations as $\Lambda_i(\delta_i) = \frac{\eta F_L(\delta_i - \chi_i)\mathbb{E}[g|g \leq \delta_i - \chi_i] + (1 - F_L(\delta_i - \chi_i))\delta_i}{1+r}$. Note that $\Lambda_i(\delta_i)$ is strictly positive and that $\Lambda_i'(\delta_i)$ can be expressed as

$$\Lambda_i'(\delta_i) = \left(1 - \left(\eta\chi_i + (1-\eta)\delta_i\right)\lambda_L(\delta_i - \chi_i)\right)\frac{1 - F_L(\delta_i - \chi_i)}{1+r},$$

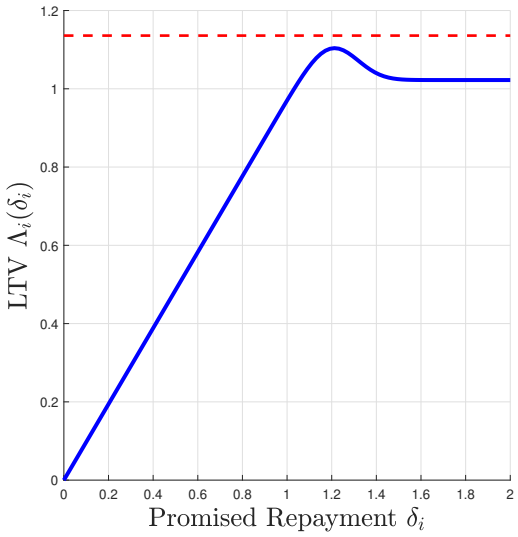
where $\lambda_L(\delta_i - \chi_i) = \frac{f_L(\delta_i - \chi_i)}{1 - F_L(\delta_i - \chi_i)}$. In general, $\Lambda_i'(\delta_i)$ can take positive or negative values, depending on the sign of $1 - (\eta\chi_i + (1-\eta)\delta_i)\lambda_L(\delta_i - \chi_i)$. When $\eta < 1$ or $\chi_i > 0$, the function $\Lambda_i(\delta_i)$ has a well-defined maximum. Note that, whenever $\delta_i > 0$, it is the case that $\Lambda_i'(\delta_i) < 1$.

Note that the limits of the LTV schedule offered by lenders correspond to

$$\lim_{\delta_i \to \infty} \Lambda_i(\delta_i) = \frac{\eta \int_{\underline{g}}^{\overline{g}} g dF_L(g)}{1+r} = \frac{\eta \mathbb{E}_L[g]}{1+r} \quad \text{and} \quad \lim_{\delta_i \to 0} \Lambda_i(\delta_i) = 0.$$

Figure A1 illustrates the behavior of $\Lambda_i(\delta_i)$ when lenders' beliefs are normally distributed.

Figure A1: LTV schedule $\Lambda_i(\delta_i)$



Note: Figure shows the LTV schedule $\Lambda_i(\delta_i)$ offered by lenders with normally distributed beliefs with mean $\mu_L = 1.17$ and standard deviation $\sigma_L = 0.1$, for a recovery rate after default of $\eta = 0.9$ and a default cost that corresponds to $\chi_i = 0.1$. The red dashed line corresponds to the maximum LTV ratio with full recovery, which corresponds to $\frac{\mu_L}{1+r}$.

Borrowers' problem

The specification of the housing constraint in Equation (2) guarantees equilibrium existence provided that $n_{0i} > p_0 \underline{h_i}$, which guarantees that the feasible choice set is non-empty. Exploiting homogeneity, the problem solved by borrowers can

be expressed in terms of the following Lagrangian:

$$\max_{c_{0i},\delta_i,h_{0i}} u_i(c_{0i}) + \beta p_0 h_{0i}\left[-\chi_i \int_{\underline{g}}^{\delta_i-\chi_i} dF_i(g) + \int_{\delta_i-\chi_i}^{\overline{g}} (g-\delta_i)\, dF_i(g)\right] - \lambda_{0i}\left(c_{0i} + p_0 h_{0i}(1-\Lambda_i(\delta_i)) - n_{0i}\right) + \nu_{0i}\left(h_{0i} - \underline{h_i}\right).$$

The optimality conditions of this problem regarding consumption, promised repayment, and housing choice, correspond to Equations (5) to (7) in the text.

In the housing-as-investment scenario, the borrowers' problem in the housing-as-investment scenario simplifies to

$$\max_{c_{0i}} J(c_{0i}), \quad \text{where} \quad J(c_{0i}) = u_i(c_{0i}) + (n_{0i} - c_{0i})\,\beta\rho_i,$$

and

$$\rho_i = \max_{\delta_i} \frac{-\chi_i \int_{\underline{g}}^{\delta_i-\chi_i} dF_i(g) + \int_{\delta_i-\chi_i}^{\overline{g}} (g-\delta_i)\, dF_i(g)}{1-\Lambda_i(\delta_i)}.$$

We derive all regularity conditions for the leading case $\kappa_i = \chi_i = 0$. Similar conditions apply to the general case. Given c_{0i} and δ_i, borrowers' housing choice satisfies $h_{0i} = \frac{1}{p_0}\frac{n_{0i}-c_{0i}}{1-\Lambda_i(\delta_i)}$. Note that the problem solved by borrowers can be decoupled into two problems. First, borrowers maximize the levered return on a housing investment. Second, borrowers solve a consumption savings problem. Therefore, introducing a consumption margin per se does not affect borrowers' leverage choice. If $\kappa_i = \chi_i = 0$ and $\eta = 1$, then the borrowers' leverage choice has a unique optimum if borrowers' beliefs dominate lenders' beliefs in a hazard rate sense, as in Simsek (2013). That condition is not necessary when $\eta < 1$ or $\chi_i > 0$, which we assume throughout. In that case, the problem that maximizes the levered return on a housing investment always has a well defined interior solution, since $\Lambda_i'(\delta_i)$ has to be strictly positive at the optimum, implying that an optimum is reached before the maximum feasible LTV level. The consumption-savings problem is equally well defined, since $\frac{\partial J}{\partial c_{0i}} = u_i'(c_{0i}) - \beta\rho_i = 0$ and $\frac{\partial^2 J}{\partial c_{0i}^2} = u_i''(c_{0i}) < 0$.

In the housing-as-consumption scenario, the problem solved by borrowers can be expressed as

$$\max_{\delta_i} J(\delta_i), \quad \text{where} \quad J(\delta_i) = u_i(n_{0i} - p_0 h_{0i}(1-\Lambda_i(\delta_i))) + \beta p_0 h_{0i}\left[-\chi_i \int_{\underline{g}}^{\delta_i-\chi_i} dF_i(g) + \int_{\delta_i-\chi_i}^{\overline{g}} (g-\delta_i)\, dF_i(g)\right],$$

where $h_{0i} = \underline{h_i}$. Borrowers' first order condition corresponds to

$$\frac{\partial J}{\partial \delta_i} = p_0 h_{0i}\left(u_i'(n_{0i} - p_0 h_{0i}(1-\Lambda_i(\delta_i)))\,\Lambda_i'(\delta_i) - \beta(1-F_i(\delta_i-\chi_i))\right).$$

Borrowers' second order condition satisfies

$$\begin{aligned}
\frac{\partial^2 J}{\partial \delta_i^2} &= p_0 h_{0i}\left(u_i''(c_{0i})\left(\Lambda_i'(\delta_i)\right)^2 p_0 h_{0i} + u_i'(c_{0i})\,\Lambda_i''(\delta_i) + \beta f_i(\delta_i-\chi_i)\right) \\
&= p_0 h_{0i}\left(u_i''(c_{0i})\left(\Lambda_i'(\delta_i)\right)^2 p_0 h_{0i} + \beta\int_{\delta_i-\chi_i}^{\overline{g}} dF_i(g)\left(\frac{\Lambda_i''(\delta_i)}{\Lambda_i'(\delta_i)} + \frac{f_i(\delta_i-\chi_i)}{1-F_i(\delta_i-\chi_i)}\right)\right) \\
&= p_0 h_{0i}\left(u_i''(c_{0i})\left(\Lambda_i'(\delta_i)\right)^2 p_0 h_{0i} + \beta\int_{\delta_i-\chi_i}^{\overline{g}} dF_i(g)\left(M - \frac{f_L(\delta_i-\chi_i)}{1-F_L(\delta_i-\chi_i)} + \frac{f_i(\delta_i-\chi_i)}{1-F_i(\delta_i-\chi_i)}\right)\right),
\end{aligned}$$

where the second line is valid at an optimum and $M \equiv \frac{-\left((1-\eta)\lambda_L(\delta_i-\chi_i)+(\eta\chi_i+(1-\eta)\delta_i)\lambda_L'(\delta_i-\chi_i)\right)}{(1-(\eta\chi_i+(1-\eta)\delta_i)\lambda_L(\delta_i-\chi_i))} < 0$. Hence, sufficient conditions that guarantee that borrowers' first order condition corresponds to an optimum are a) a non-decreasing lenders' hazard rate, and b) that borrowers' beliefs dominate lenders' beliefs in a hazard rate sense.

Proof of Proposition 1. (Parametric predictions)

In the housing-as-investment scenario, given Equation (10) and the sustained regularity conditions, it is sufficient to establish the behavior of

$$\Psi_{HAI}\left(\tilde{\delta}\right) \equiv -\chi_i \frac{F_i\left(\tilde{\delta}-\chi_i\right)}{1-F_i\left(\tilde{\delta}-\chi_i\right)} + \mathbb{E}_i\left[g \middle| g \geq \tilde{\delta}-\chi_i\right]$$

to characterize the effect of beliefs on leverage. Any change in parameters associated with an upwards point-wise shift in $\Psi_{HAI}(\cdot)$ for a range of $\tilde{\delta}$ implies a higher equilibrium level of δ_i. Under the assumption that $g \sim N\left(\mu_i, \sigma_i^2\right)$, we can express $\mathbb{E}_i\left[g | g \geq \tilde{\delta} - \chi_i\right]$ and $F_i\left(\tilde{\delta} - \chi_i\right)$ as follows

$$\begin{aligned}\mathbb{E}_i\left[g | g \geq \tilde{\delta} - \chi_i\right] &= \mu_i + \sigma_i \lambda\left(\alpha_i\right) \\ F_i\left(\tilde{\delta} - \chi_i\right) &= \Phi\left(\alpha_i\right),\end{aligned}$$

where $\lambda\left(\alpha_i\right) = \frac{\phi(\alpha_i)}{1-\Phi(\alpha_i)}$ and $\alpha_i = \frac{\tilde{\delta}-\chi_i-\mu_i}{\sigma_i}$, which allows us to express $\Psi_{HAI}\left(\tilde{\delta}\right)$ as

$$\Psi_{HAI}\left(\tilde{\delta}\right) = -\chi_i \frac{\Phi\left(\alpha_i\right)}{1-\Phi\left(\alpha_i\right)} + \mu_i + \sigma_i \lambda\left(\alpha_i\right).$$

The relevant comparative statics in μ_i and σ_i are given by[48]

$$\begin{aligned}\frac{\partial \Psi_{HAI}\left(\tilde{\delta}\right)}{\partial \mu_i} &= \chi_i \frac{\phi\left(\alpha_i\right) \frac{1}{\sigma_i}}{\left(1-\Phi\left(\alpha_i\right)\right)^2} + 1 - \lambda'\left(\alpha_i\right) > 0 \\ \frac{\partial \Psi_{HAI}\left(\tilde{\delta}\right)}{\partial \sigma_i} &= \chi_i \frac{\phi\left(\alpha_i\right) \frac{1}{\sigma_i} \alpha_i}{\left(1-\Phi\left(\alpha_i\right)\right)^2} + \lambda\left(\alpha_i\right) - \lambda'\left(\alpha_i\right)\alpha_i = \underbrace{\chi_i \frac{\lambda\left(\alpha_i\right)}{1-\Phi\left(\alpha_i\right)} \frac{\alpha_i}{\sigma_i}}_{\gtrless 0} + \underbrace{\lambda\left(\alpha_i\right)\left(1 - \left(\lambda\left(\alpha_i\right) - \alpha_i\right)\alpha_i\right)}_{>0},\end{aligned}$$

where we have used the properties of the Normal hazard rate from Fact 2. Note that the sign of the comparative statics on σ_i is strictly positive for low or moderate values of χ_i, since $\lim_{\chi_i \to 0} \chi_i \frac{\lambda(\alpha_i)}{1-\Phi(\alpha_i)} \frac{\alpha_i}{\sigma_i} = 0$. Importantly, the qualifier for sufficiently low default costs is only a sufficient condition, not a necessary one. These results establish the conclusions for the housing-as-investment scenario.

In the housing-as-consumption scenario, given Equation (13) and the sustained regularity conditions, it is sufficient to establish the behavior of

$$\Psi_{HAC}\left(\tilde{\delta}\right) \equiv 1 - F_i\left(\tilde{\delta} - \chi_i\right) = 1 - \Phi\left(\alpha_i\right), \tag{A1}$$

where $\alpha_i = \frac{\tilde{\delta}-\chi_i-\mu_i}{\sigma_i}$, to characterize the effect of beliefs on leverage. Any change in parameters associated with an upwards point-wise shift in $\Psi_{HAC}(\cdot)$ for a range of $\tilde{\delta}$ implies a lower equilibrium level of δ_i.

The relevant comparative statics in μ_i and σ_i are given by

$$\begin{aligned}\frac{\partial \Psi_{HAC}\left(\tilde{\delta}\right)}{\partial \mu_i} &= \frac{1}{\sigma_i}\phi\left(\alpha_i\right) > 0 \\ \frac{\partial \Psi_{HAC}\left(\tilde{\delta}\right)}{\partial \sigma_i} &= \phi\left(\alpha_i\right)\frac{\alpha_i}{\sigma_i} = -\frac{\phi'\left(\alpha_i\right)}{\sigma_i},\end{aligned}$$

which is negative when the probability of default is less than 50%, that is, when $\alpha_i < 0$ or, equivalently, when $\tilde{\delta} < \mu_i + \chi_i$.

Proof of Proposition 2. (Interaction with cost of default)

As described in the text, we exclusively focus on the direct effects of how changes in χ_i affect the sensitivity of leverage choices to beliefs. Abstractly, in an optimization problem in which agents choose x to solve $\max_x F(x;\theta,\alpha)$, where θ are parameters and where an interior optimum $x^\star$ is characterized by $F_x(x^\star;\theta,\alpha) = 0$ and $F_{xx} \leq 0$, we can characterize first-order comparative statics by $\frac{dx^\star}{d\theta} = \frac{F_{x\theta}}{-F_{xx}}$ and second-order comparative statics by $\frac{d\left(\frac{dx^\star}{d\theta}\right)}{d\alpha} = \frac{d^2x^\star}{d\theta d\alpha} = \frac{F_{xxx}\frac{dx^\star}{d\alpha}\frac{dx^\star}{d\theta} + F_{xx\alpha}\frac{dx^\star}{d\theta} + F_{x\theta x}\frac{dx^\star}{d\alpha} + F_{x\theta\alpha}}{-F_{xx}}$. When we state that we characterize the direct effect of recourse non-recourse, we refer to the term of the form $F_{x\theta\alpha}$, which does not rely directly on assumptions about the curvature of the model, as F_{xxx} and $F_{xx\alpha}$ do.

[48] At times, we use the fact that $\phi'(\alpha_i) = -\alpha_i\phi(\alpha_i)$. The following results are also relevant for our derivations:

$$\frac{\partial\left(\frac{\Phi(\alpha_i)}{1-\Phi(\alpha_i)}\right)}{\partial \mu_i} = \frac{-\phi\left(\alpha_i\right)\frac{1}{\sigma_i}}{\left(1-\Phi\left(\alpha_i\right)\right)^2} \quad \text{and} \quad \frac{\partial\left(\frac{\Phi(\alpha_i)}{1-\Phi(\alpha_i)}\right)}{\partial \sigma_i} = \frac{-\phi\left(\alpha_i\right)\frac{\alpha_i}{\sigma_i}}{\left(1-\Phi\left(\alpha_i\right)\right)^2},$$

as well as

$$\frac{\partial \alpha_i}{\partial \mu_i} = \frac{\partial \alpha_i}{\partial \chi_i} = -\frac{1}{\sigma_i} \quad \text{and} \quad \frac{\partial \alpha_i}{\partial \sigma_i} = -\frac{\alpha_i}{\sigma_i}.$$

In the housing-as-consumption scenario, where Ψ_{HAC} is defined in Equation A1,

$$\frac{\partial^2 \Psi_{HAC}\left(\tilde{\delta}\right)}{\partial \mu_i \partial \chi_i} = -\frac{1}{\sigma_i^2}\phi'\left(\alpha_i\right),$$

which is negative when the probability of default is less than 50%. The marginal cost of borrowing goes up by less when the cost of default is higher.

$$\frac{\partial^2 \Psi_{HAC}\left(\tilde{\delta}\right)}{\partial \sigma_i \partial \chi_i} = \frac{1}{\sigma_i^2}\phi''\left(\alpha_i\right),$$

which is positive as long as $\left|\tilde{\delta} - \mu_i - \chi_i\right| > \sigma_i$. Hence, it is needed that $\tilde{\delta} < \mu_i + \chi_i - \sigma_i$, which is valid whenever the probability of default is less than 16%.

In the housing-as-investment scenario, to be able to derive unambiguous predictions, we focus for simplicity on the case in which $\chi_i \to 0$. In that case,

$$\begin{aligned}
\frac{\partial^2 \Psi_{HAI}\left(\tilde{\delta}\right)}{\partial \mu_i \partial \chi_i} &= \frac{1}{\sigma_i}\lambda''\left(\alpha_i\right) + \frac{\phi\left(\alpha_i\right)\frac{1}{\sigma_i}}{\left(1-\Phi\left(\alpha_i\right)\right)^2} > 0 \\
\frac{\partial^2 \Psi_{HAI}\left(\tilde{\delta}\right)}{\partial \sigma_i \partial \chi_i} &= -\frac{1}{\sigma_i}\lambda'\left(\alpha_i\right) + \frac{\alpha_i}{\sigma_i}\lambda''\left(\alpha_i\right) + \frac{1}{\sigma_i}\lambda'\left(\alpha_i\right) + \frac{\phi\left(\alpha_i\right)\frac{\alpha_i}{\sigma_i}}{\left(1-\Phi\left(\alpha_i\right)\right)^2} = \frac{\alpha_i}{\sigma_i}\lambda''\left(\alpha_i\right) + \frac{\phi\left(\alpha_i\right)\frac{\alpha_i}{\sigma_i}}{\left(1-\Phi\left(\alpha_i\right)\right)^2},
\end{aligned}$$

which is negative when the probability of default is less than 50%, that is, when $\alpha_i < 0$ or, equivalently, when $\tilde{\delta} < \mu_i + \chi_i$.

Proof of Proposition 3. (Interaction with average belief) In the housing-as-consumption scenario, where Ψ_{HAC} is defined in Equation A1,

$$\frac{\partial^2 \Psi_{HAC}\left(\tilde{\delta}\right)}{\partial \mu_i^2} = -\frac{1}{\sigma_i^2}\phi'\left(\alpha_i\right),$$

which is negative when the probability of default is less than 50%, that is, when $\tilde{\delta} < \mu_i$. We also find that

$$\begin{aligned}
\frac{\partial^2 \Psi_{HAC}\left(\tilde{\delta}\right)}{\partial \sigma_i \partial \mu_i} &= \frac{1}{\sigma_i}\left[-\frac{1}{\sigma_i}\phi'\left(\alpha_i\right)\alpha_i - \phi\left(\alpha_i\right)\frac{1}{\sigma_i}\right] \\
&= \frac{\phi\left(\alpha_i\right)}{\sigma_i^2}\left[\alpha_i^2 - 1\right] \\
&= \frac{\phi\left(\alpha_i\right)}{\sigma_i^2}\left[\left(\frac{\tilde{\delta} - \chi_i - \mu_i}{\sigma_i}\right)^2 - 1\right],
\end{aligned}$$

which is positive as long as $\left|\tilde{\delta} - \chi_i - \mu_i\right| > \sigma_i$. Hence, it is needed that $\tilde{\delta} < \mu_i + \chi_i - \sigma_i$, which is valid whenever the probability of default is less than 16%.

In the housing-as-investment scenario, to be able to derive unambiguous predictions, we focus for simplicity in the case in which $\chi_i \to 0$. In that case,

$$\begin{aligned}
\frac{\partial^2 \mathbb{E}_i\left[g \middle| g \geq \tilde{\delta}\right]}{\partial \mu_i^2} &= \lambda''\left(\alpha_i\right)\frac{1}{\sigma_i} > 0,\ \forall \tilde{\delta} \\
\frac{\partial^2 \mathbb{E}_i\left[g \middle| g \geq \tilde{\delta}\right]}{\partial \sigma_i \partial \mu_i} &= -\lambda'\left(\alpha_i\right)\frac{1}{\sigma_i} + \frac{1}{\sigma_i}\lambda''\left(\alpha_i\right)\alpha_i + \frac{1}{\sigma_i}\lambda'\left(\alpha_i\right) = \frac{\alpha_i}{\sigma_i}\lambda''\left(\alpha_i\right),
\end{aligned}$$

which is negative when the probability of default is less than 50%, that is, when $\tilde{\delta} < \mu_i$.

Proof of Proposition 4. (Parametric predictions for lenders' beliefs)

To provide comparative statics in the case of lenders' beliefs, we must characterize the behavior of $\frac{\partial \Lambda_i(\delta_i)}{\partial \mu_L}$ and $\frac{\partial \Lambda_i'(\delta_i)}{\partial \mu_L}$.[49] Formally, we find that both the LTV schedule offered by lenders and its derivative with respect to δ_i shift pointwise with changes in μ_L:

$$\begin{aligned}
\frac{\partial \Lambda_i(\delta_i)}{\partial \mu_L} &= \frac{\eta \Phi_L\left(\frac{\delta_i-\chi_i-\mu_L}{\sigma_L}\right) - \frac{(\eta\mu_L-\delta_i)}{\sigma_L}\phi_L\left(\frac{\delta_i-\chi_i-\mu_L}{\sigma_L}\right) + \eta\phi_L'\left(\frac{\delta_i-\chi_i-\mu_L}{\sigma_L}\right)}{1+r} > 0, \\
\frac{\partial \Lambda_i'(\delta_i)}{\partial \mu_L} &= (\eta\chi_i + (1-\eta)\delta_i)\left(\lambda\left(\frac{\delta_i-\chi_i-\mu_L}{\sigma_L}\right) - \frac{\delta_i-\chi_i-\mu_L}{\sigma_L}\right)\frac{1}{\sigma_L}\frac{\phi\left(\frac{\delta_i-\chi_i-\mu_L}{\sigma_L}\right)}{1+r} \\
&\quad + \left[1 - (\eta\chi_i + (1-\eta)\delta_i)\lambda\left(\frac{\delta_i-\chi_i-\mu_L}{\sigma_L}\right)\right]\frac{1}{\sigma_L}\frac{\phi\left(\frac{\delta_i-\chi_i-\mu_L}{\sigma_L}\right)}{1+r} > 0,
\end{aligned}$$

where we use the fact that the pdf of the Normal distribution satisfies $\phi'(x) = -x\phi(x)$ and that $1 > (\eta\chi_i + (1-\eta)\delta_i)\lambda\left(\frac{\delta_i-\chi_i-\mu_L}{\sigma_L}\right)$ at any interior solution. Both results, when combined, imply that

$$\frac{d\left(\frac{\Lambda_i'(\delta_i)}{1-\Lambda_i(\delta_i)}\right)}{d\mu_L} > 0.$$

In the housing-as-investment scenario, Equation (10) directly implies that upward point-wise shifts on $\frac{\Lambda_i'(\delta_i)}{1-\Lambda_i(\delta_i)}$ are associated with a higher equilibrium leverage choice δ_i. Hence, a higher μ_L is associated with a higher equilibrium leverage choice δ_i.

In the housing-as-consumption scenario, Equation (12) directly implies that upward point-wise shifts on $u_i'(n_{0i} - p_0 h_{0i}(1-\Lambda_i(\delta_i)))\Lambda_i'(\delta_i)$ are associated with a higher equilibrium leverage choice δ_i. Note that

$$\frac{\partial\left(u_i'(\cdot)\Lambda_i'(\delta_i)\right)}{\partial \mu_L} = u_i'(n_{0i} - p_0 h_{0i}(1-\Lambda_i(\delta_i)))\frac{\partial \Lambda_i'(\delta_i)}{\partial \mu_L} + p_0 h_{0i} u_i''(n_{0i} - p_0 h_{0i}(1-\Lambda_i(\delta_i)))\frac{\partial \Lambda_i(\delta_i)}{\partial \mu_L}\Lambda_i'(\delta_i),$$

whose sign is ambiguous. An increase in μ_L generates both a substitution and an income effect. More optimistic lenders offer more attractive LTV schedules at the margin, so borrowers substitute towards higher leverage. More optimistic lenders offer more attractive schedule, which makes borrowers effectively richer at date 0, reducing their need to borrow, which reduces their equilibrium leverage. The results in both scenarios, when combined, establish the result in Proposition 4.

A.2 Auxiliary results

Facts 1 and 2 follow from Greene (2003). Fact 3 follows from Krishna (2010). When needed, we respectively denote the pdf and cdf of the standard normal distribution by $\phi(\cdot)$ and $\Phi(\cdot)$.

Fact 1. (Truncated expectation of a normal distribution) *If* $X \sim N\left(\mu, \sigma^2\right)$, *then*

$$\begin{aligned}
\mathbb{E}[X|X>a] &= \mu + \sigma\lambda(\alpha), \quad \textit{where} \quad \lambda(\alpha) = \frac{\phi(\alpha)}{1-\Phi(\alpha)} \quad \textit{and} \quad \alpha = \frac{a-\mu}{\sigma} \\
\mathbb{E}[X|X<b] &= \mu - \sigma\frac{\phi(\beta)}{\Phi(\beta)}, \quad \textit{where} \quad \beta = \frac{b-\mu}{\sigma}.
\end{aligned}$$

More generally, $\mathbb{E}[X|a<X<b] = \mu + \sigma\frac{\phi(\alpha)-\phi(\beta)}{\Phi(\beta)-\Phi(a)}$, *where* α *and* β *are defined above.*

Fact 2. (Properties of normal hazard function) *The function* $\lambda(\cdot)$, *which corresponds to the hazard rate of the normal distribution, is also known as the Inverse Mills Ratio. It satisfies the following properties:*

1. $\lambda(0) = \sqrt{\frac{2}{\pi}}$, $\lambda(\alpha) \geq 0$, $\lambda(\alpha) > \alpha$, $\lambda'(\alpha) > 0$, and $\lambda''(\alpha) > 0$.

[49] Note that we can express LTV schedules as

$$\begin{aligned}
\Lambda_i(\delta_i) &= \frac{\eta\Phi_L\left(\frac{\delta_i-\chi_i-\mu_L}{\sigma_L}\right)\left(\mu_L - \sigma_L\frac{\phi_L\left(\frac{\delta_i-\chi_i-\mu_L}{\sigma_L}\right)}{\Phi_L\left(\frac{\delta_i-\chi_i-\mu_L}{\sigma_L}\right)}\right) + \left(1-\Phi_L\left(\frac{\delta_i-\chi_i-\mu_L}{\sigma_L}\right)\right)\delta_i}{1+r} \\
&= \frac{\delta_i + (\eta\mu_L - \delta_i)\Phi_L\left(\frac{\delta_i-\chi_i-\mu_L}{\sigma_L}\right) - \eta\sigma_L\phi_L\left(\frac{\delta_i-\chi_i-\mu_L}{\sigma_L}\right)}{1+r}
\end{aligned}$$

2. $\lim_{\alpha\to-\infty}\lambda(\alpha)=\lim_{\alpha\to-\infty}\lambda'(\alpha)=0$, and $\lim_{\alpha\to\infty}\lambda'(\alpha)=1$.

3. $\lambda(\alpha)<\frac{1}{\alpha}+\alpha$, $\lambda'(\alpha)=\frac{\phi'(\alpha_i)}{1-\Phi(\alpha_i)}+(\lambda(\alpha_i))^2=\lambda(\alpha)(\lambda(\alpha)-\alpha)>0$, $\lambda'(\alpha)<1$, and $\lambda''(\alpha)\geq 0$.

Fact 3. (Hazard rate dominance implies first-order stochastic dominance) *The hazard rate of a distribution with cdf $F(\cdot)$ is defined by $\lambda(x)=\frac{f(x)}{1-F(x)}=-\frac{d\ln(1-F(x))}{dx}$, so $F(x)=1-e^{-\int_0^x\lambda(t)dt}$. If $\lambda_j(g)>\lambda_j(g)$, $\forall g$, then it trivially follows that $F_i(\cdot)>F_j(\cdot)$.*

A.3 Generalized environment

Two assumptions crucially allow us to derive tractable analytical results: the risk neutrality of borrowers and our formulation for housing preferences. Here, we show how our framework can be extended to incorporate borrowers' risk aversion and smooth preferences for housing.

It is conceptually easy to make borrowers in our model risk averse. We assume that, at date 1, borrowers derive a continuation utility of wealth $v_i(\cdot)$. We also assume that their date 0 flow utility corresponds to $u_i(c_{0i},h_{0i})$, which satisfies appropriate regularity conditions,

$$\max_{\delta_i,h_{0i}} u_i\left(n_{0i}-p_0h_{0i}\left(1-\Lambda_i(\delta_i)\right),h_{0i}\right)+\beta\left[\int_{\underline{g}}^{\delta_i-\chi_i}v_i\left(w_{1i}^{\mathcal{D}}\right)dF_i(g)+\int_{\delta_i-\chi_i}^{\overline{g}}v_i\left(w_{1i}^{\mathcal{N}}\right)dF_i(g)\right],$$

where $w_{1i}^{\mathcal{N}}=n_{1i}+p_1h_{0i}-b_{0i}=n_{1i}+p_0h_{0i}(g-\delta_i)$ and $w_{1i}^{\mathcal{D}}=n_{1i}-\kappa_ih_{0i}=n_{1i}-\chi_ip_0h_{0i}$.

Borrowers' optimality conditions in this case correspond to

$$\frac{\partial u_i}{\partial c_{0i}}\left(1-\Lambda_i(\delta_i)\right)=\frac{\frac{\partial u_i}{\partial h_{0i}}}{p_0}\underbrace{-\chi_i\beta\int_{\underline{g}}^{\delta_i-\chi_i}v_i'\left(w_{1i}^{\mathcal{D}}\right)dF_i(g)+\beta\int_{\delta_i-\chi_i}^{\overline{g}}(g-\delta_i)\,v_i'\left(w_{1i}^{\mathcal{N}}\right)dF_i(g)}_{\text{Expected Return}},$$

$$\frac{\partial u_i}{\partial c_{0i}}\Lambda_i'(\delta_i)=\underbrace{\beta\int_{\delta_i-\chi_i}^{\overline{g}}v_i'\left(w_{1i}^{\mathcal{N}}\right)dF_i(g)}_{\text{Mg. Cost of Borrowing}},$$

which are the counterparts of Equations (6) and (7) in the main text. We highlight the terms through which the expected return and downpayment protection channels materialize. Equation (8) corresponds in this case to

$$\frac{\partial u_i}{\partial c_{0i}}=\beta\frac{\int_{\delta_i-\chi_i}^{\overline{g}}v_i'\left(w_{1i}^{\mathcal{N}}\right)dF_i(g)}{\Lambda_i'(\delta_i)}=\frac{\frac{\partial u_i}{\partial h_{0i}}}{p_0\left(1-\Lambda_i(\delta_i)\right)}+\beta\frac{\left(-\chi_i\int_{\underline{g}}^{\delta_i-\chi_i}v_i'\left(w_{1i}^{\mathcal{D}}\right)dF_i(g)+\int_{\delta_i-\chi_i}^{\overline{g}}(g-\delta_i)\,v_i'\left(w_{1i}^{\mathcal{N}}\right)dF_i(g)\right)}{1-\Lambda_i(\delta_i)}.$$

In this more general scenario, changes in borrowers' beliefs only affect borrowers' decisions insofar as they affect the expected return and downpayment protection terms, which now include marginal utilities. We now study several alternative modeling assumptions.

Risk aversion

We now assume that housing does not enter borrowers' utility directly. In that case, we can combine borrowers' optimality conditions for housing and leverage to find a condition that generalizes (10). In particular, assuming $\kappa_i=0$ for simplicity,

$$\frac{\Lambda_i'(\delta_i)}{1-\Lambda_i(\delta_i)}=\frac{1}{\frac{\mathbb{E}_i\left[(g-\delta_i)v_i'\left(w_{1i}^{\mathcal{N}}\right)\middle|g\geq\delta_i\right]}{\mathbb{E}_i\left[v_i'\left(w_{1i}^{\mathcal{N}}\right)\middle|g\geq\delta_i\right]}},$$

where

$$\frac{\mathbb{E}_i\left[(g-\delta_i)\,v_i'\left(w_{1i}^{\mathcal{N}}\right)\middle|\,g\geq\delta_i\right]}{\mathbb{E}_i\left[v_i'\left(w_{1i}^{\mathcal{N}}\right)\middle|\,g\geq\delta_i\right]}=\mathbb{E}_i\left[g-\delta_i\middle|\,g\geq\delta_i\right]+\frac{\mathbb{C}ov_i\left[g-\delta_i,v_i'\left(w_{1i}^{\mathcal{N}}\right)|g\geq\delta_i\right]}{\mathbb{E}_i\left[v_i'\left(w_{1i}^{\mathcal{N}}\right)\middle|\,g\geq\delta_i\right]}.$$

This more general expression includes a new term that separately affects borrowers' leverage choices. Unfortunately, it is not possible to analytically characterize how a change on borrowers' beliefs affects the new term. In numerical simulations, we find that the directional theoretical predictions that we find in Proposition 1 remain valid for a wide range of plausible parameter combinations. This is not surprising, since the effects characterized in Proposition 1 remain active.

In the housing-as-consumption scenario, a simple result can be found when borrowers are prevented from defaulting. In that case, the first-order condition for borrowing corresponds to

$$\frac{\partial u_i}{\partial c_{0i}}\Lambda_i'(\delta_i) = \beta\int_{\underline{g}}^{\overline{g}} v_i'(n_{1i} + p_0 h_{0i}(g-\delta_i))\,dF_i(g).$$

In this case, it is easy to show that more optimistic borrowers, in a first-order stochastic dominance sense, decide to borrow more. Intuitively, optimism is associated with a desire to transfer resources from the future and lower precautionary savings, both of which are associated with higher borrowing.

Smooth preferences for housing

In this case, we preserve borrowers' risk neutrality and focus on the case in which preferences for housing are separable, so $u_i(c_{0i}, h_{0i}) = v_i(c_0) + \frac{\alpha}{2}\left(h_{0i} - \bar{h}\right)^2$ and $\frac{\frac{\partial u_i}{\partial h_{0i}}}{p_0} = \alpha\frac{h_{0i}-\bar{h}}{p_0}$. Setting again $\kappa_i = 0$ for simplicity, we can express borrowers' optimality condition for housing as

$$h_{0i} = \bar{h} + \frac{p_0}{\alpha}\left(\frac{\partial u_i}{\partial c_{0i}}(1-\Lambda_i(\delta_i)) - \beta\int_{\delta_i}^{\overline{g}}(g-\delta_i)\,dF_i(g)\right).$$

In the limit in which $\alpha \to \infty$, it must be that $h_{0i} \to \bar{h}$, so changes in borrowers' beliefs do not affect housing choices. In that case, borrowers' make leverage choices according to

$$\frac{\partial u_i}{\partial c_{0i}}\Lambda_i'(\delta_i) = \beta\int_{\delta_i}^{\overline{g}} dF_i(g),$$

as in the housing-as-consumption scenario.

Alternative savings opportunities

Finally, although we have introduced consumption at date 0 as homebuyers' alternative use of funds, they could be indifferent at the margin between their investment return on housing and an alternative investment opportunity. In particular, if we assume that households have access to a savings opportunity with a constant gross returns R_s, their date 0 budget constraint becomes

$$n_{0i} = p_0 h_{0i}(1-\Lambda_i(\delta_i)) + s, \tag{A2}$$

where s denotes savings. Therefore, at the optimum, the counterpart of Equation (8) corresponds to

$$R_s = \frac{\beta\int_{\delta_i-\chi_i}^{\overline{g}} dF_i(g)}{\Lambda_i'(\delta_i)} = \frac{\beta\left[-\chi_i\int_{\underline{g}}^{\delta_i-\chi_i} dF_i(g) + \int_{\delta_i-\chi_i}^{\overline{g}}(g-\delta_i)\,dF_i(g)\right]}{1-\Lambda_i(\delta_i)}. \tag{A3}$$

Intuitively, homebuyers' housing and borrowing decisions must at the margin yield a return R_s, so every argument in the paper remains valid. We adopt the formulation with consumption in the paper because for this alternative formulation to be well-behaved in the housing-as-investment case, we would need to impose some curvature in the return R_s.[50]

B Non-Parametric Predictions

B.1 Theoretical results

While the parametric assumption underlying Propositions 1 through 3 are natural, given that the distribution of g is uni-modal and symmetric in the data, these results impose a priori unnecessary distributional restrictions. An alternative approach is to consider cross-sectional comparisons among borrowers that do not rely on parametric assumptions. This approach uses the ability to potentially observe shifts of the whole distribution of beliefs, which is a unique feature of our empirical setup.

In general, there are numerous ways in which one borrower may be "more optimistic" than another in a non-parametric sense. For example, two borrowers could disagree primarily about the probability of very large declines or very large

[50] By slightly changing the default formulation, one can allow for borrowers to save at date 0 to use some of those funds to avoid default at date 1. In that case, Equations A2 and A3 still determine the equilibrium after accounting for the different default behavior.

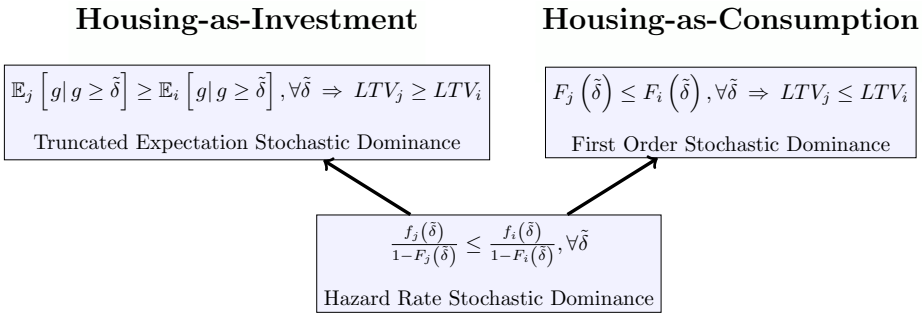
increases in house prices. In this section, we identify the appropriate definition of stochastic dominance that allows us to provide unambiguous directional predictions for borrowers' leverage choices across both the housing-as-consumption and housing-as-investment scenarios. Because of the inherent difficulties with establishing general comparisons between infinite-dimensional distributions, our non-parametric results only provide a partial order when comparing borrowers in the data — there are many pairwise comparisons of borrowers' distributions that cannot be ranked according to the appropriate dominance notion.

We use three different stochastic orders to define optimism. Given two distributions with cumulative distribution functions $F_j(\cdot)$ and $F_i(\cdot)$ with support $\left[\underline{g}, \overline{g}\right]$, we define truncated expectation stochastic dominance, first-order stochastic dominance and hazard rate dominance as follows:

1. **Truncated expectation stochastic dominance:** F_j stochastically dominates F_i (borrower j is more optimistic than i) in a truncated expectation sense if
$$\mathbb{E}_j\left[g | \, g \geq \delta\right] \geq \mathbb{E}_i\left[g | \, g \geq \delta\right], \quad \forall \delta \in \left[\underline{g}, \overline{g}\right].$$
2. **First-order stochastic dominance:** F_j stochastically dominates F_i (borrower j is more optimistic than i) in a first-order sense if
$$F_j(\delta) \leq F_i(\delta), \quad \forall \delta \in \left[\underline{g}, \overline{g}\right].$$
3. **Hazard rate stochastic dominance**: F_j stochastically dominates F_i (borrower j is more optimistic than i) in a hazard rate sense if
$$\frac{f_j(\delta)}{1 - F_j(\delta)} \leq \frac{f_i(\delta)}{1 - F_i(\delta)}, \quad \forall \delta \in \left[\underline{g}, \overline{g}\right].$$

All three definitions capture different notions of optimism. We show in Appendix A.2 that if $F_j(\cdot)$ dominates $F_i(\cdot)$ in a hazard rate sense, then $F_j(\cdot)$ also dominates $F_i(\cdot)$ in a first-order and a truncated expectation expectation sense. The converse is not true: first-order stochastic dominance and truncated expectation dominance do not imply hazard rate dominance. Figure A2 illustrates the relation between the different orders. Hazard rate dominance is equivalent to saying that $\frac{1-F_j(g)}{1-F_i(g)}$ is increasing on g. It captures the idea that optimists are increasingly optimistic about higher house price growth realizations.

Figure A2: Relation between stochastic orders when $\kappa_i = 0$



We have showed that in the housing-as-investment scenario, when $\kappa_i = 0$, there are clear predictions for the leverage choices across two borrowers whose belief distributions could be ranked according to truncated-expectation stochastic dominance. We also showed that in the housing-as-consumption scenario, clear predictions were obtained for belief distributions that could be ranked according to first-order stochastic dominance. However, neither of these dominance concepts implies the other, so it is unclear how to compare belief distributions if we are ex-ante agnostic about whether the housing-as-consumption or the housing-as-investment scenario applies, especially when $\kappa_i > 0$. Therefore, we adopt hazard rate dominance as the appropriate definition of optimism that allows to test non-parametrically for the effect of beliefs on leverage regardless of the underlying scenario, as formalized in Proposition 5.

Proposition 5. (Non-parametric predictions.) *Compare two borrowers i and j with different distributions $F_i(\cdot)$ and $F_j(\cdot)$ about the growth rate of house prices changes.*
a) In the housing-as-investment scenario, if $F_j(\cdot)$ dominates $F_i(\cdot)$ in a hazard rate sense (or in a truncated expectation sense when $\kappa_i = 0$), all else equal, borrower j chooses a higher LTV ratio and a larger house than borrower i.

b) In the housing-as-consumption scenario, if $F_j(\cdot)$ dominates $F_i(\cdot)$ in a hazard rate sense (or in a first-order sense), all else equal, borrower j chooses a lower LTV ratio and lower consumption than borrower i.

Proposition 5 shows that borrowers' optimism, measured as hazard rate dominance, has opposite predictions in the polar scenarios we consider for any value of κ_i. More optimistic borrowers take on more leverage in the housing-as-investment scenario, but they take on less leverage in the housing-as-consumption scenario. These results generalize the insights from the case with normally distributed beliefs, but they are not exactly identical. We show in the Appendix that, when beliefs are normally distributed, a distribution with a higher mean dominates in a hazard rate sense a distribution with a lower mean (holding its variance constant). Hence, when comparing means in the normal case, the results of Proposition 1 are implied by those of Proposition 5. However, we also show that, in the normal context, a distribution with a higher variance does not dominate in a hazard rate sense a distribution with a lower variance (holding its mean constant). This illustrates that hazard rate dominance is only a sufficient (not a necessary) condition to derive unambiguous predictions for the relationships between beliefs and leverage choice.

Proof of Proposition 5. (Non-parametric predictions)

In the housing-as-consumption scenario, it follows that an upward pointwise shift in $1-F_i\left(\tilde{\delta}\right)$, $\forall\tilde{\delta}$, is associated with a lower equilibrium value of δ_i. If the beliefs of borrower j first-order stochastically dominate the beliefs of borrower i (borrower j is more optimistic), then $F_j\left(\tilde{\delta}\right) < F_i\left(\tilde{\delta}\right)$ and $1-F_j\left(\tilde{\delta}\right) > 1-F_i\left(\tilde{\delta}\right)$, which implies that borrower j takes on more leverage on equilibrium.

In the housing-as-investment scenario, from Equation (10), it follows that an upward pointwise shift in $-\chi_i \frac{F_i\left(\tilde{\delta}-\chi_i\right)}{1-F_i\left(\tilde{\delta}-\chi_i\right)} + \mathbb{E}_i\left[g|\, g \geq \tilde{\delta}-\chi_i\right]$, $\forall\tilde{\delta}$ is associated with a higher equilibrium value of δ_i. To compare the leverage choices of two different borrowers i and j, it is thus sufficient to show that $F_j \succ_{HRD} F_i$ implies that

$$\mathbb{E}_j\left[g|\, g \geq \tilde{\delta}\right] - \mathbb{E}_i\left[g|\, g \geq \tilde{\delta}\right] > 0, \quad \forall\tilde{\delta},$$

to conclude that the more optimistic borrower j takes on more leverage, since hazard-rate dominance implies first order stochastic dominance, which trivially implies that $\frac{F_j\left(\tilde{\delta}-\chi_i\right)}{1-F_j\left(\tilde{\delta}-\chi_i\right)} < \frac{F_i\left(\tilde{\delta}-\chi_i\right)}{1-F_i\left(\tilde{\delta}-\chi_i\right)}$. To this purpose, we can define $h(\delta)$ as

$$h\left(\tilde{\delta}\right) = \mathbb{E}_j\left[g|\, g \geq \tilde{\delta}\right] - \mathbb{E}_i\left[g|\, g \geq \tilde{\delta}\right].$$

We can express the derivative of $h\left(\tilde{\delta}\right)$ as

$$\begin{aligned} h'\left(\tilde{\delta}\right) &= \frac{\partial \mathbb{E}_j\left[g|\, g \geq \tilde{\delta}\right]}{\partial\delta} - \frac{\partial \mathbb{E}_i\left[g|\, g \geq \tilde{\delta}\right]}{\partial\delta} \\ &= \frac{f_j\left(\tilde{\delta}\right)}{1-F_j\left(\tilde{\delta}\right)}\left[\mathbb{E}_j\left[g|\, g \geq \tilde{\delta}\right] - \tilde{\delta}\right] - \frac{f_i\left(\tilde{\delta}\right)}{1-F_i\left(\tilde{\delta}\right)}\left[\mathbb{E}_i\left[g|\, g \geq \tilde{\delta}\right] - \tilde{\delta}\right] \\ &= \underbrace{\left(\frac{f_j\left(\tilde{\delta}\right)}{1-F_j\left(\tilde{\delta}\right)} - \frac{f\left(\tilde{\delta}\right)}{1-F\left(\tilde{\delta}\right)}\right)}_{>0}\mathbb{E}_j\left[g|\, g \geq \tilde{\delta}\right] + \frac{f_i\left(\tilde{\delta}\right)}{1-F_i\left(\tilde{\delta}\right)}h\left(\tilde{\delta}\right). \end{aligned} \tag{A4}$$

When $\tilde{\delta} \to 0$, it follows from hazard-rate dominance that $\mathbb{E}_j[g] - \mathbb{E}_i[g] > 0$. Note that all elements in A4 are strictly positive under hazard rate dominance, which implies that the solution to the ordinary differential equation for $h\left(\tilde{\delta}\right)$ must be weakly positive everywhere, implying that $h\left(\tilde{\delta}\right)$ is positive, which shows our claim.

B.2 Non-Parametric Test

The empirical results presented in Sections 3.3 and 3.4 test the predictions from our model under the assumption that individuals' beliefs about future house price changes are normally distributed. We argued that this is a realistic approximation, given the shape of the distribution of actual house price changes. In Section B.1, we also derived non-parametric predictions on the relative mortgage leverage choices of individuals with arbitrary belief distributions. In particular, we showed that an individual whose belief distribution dominated that of an otherwise identical individual in the sense of hazard rate dominance would choose higher leverage in the housing-as-investment scenario, but lower leverage in the housing-as-consumption scenario.

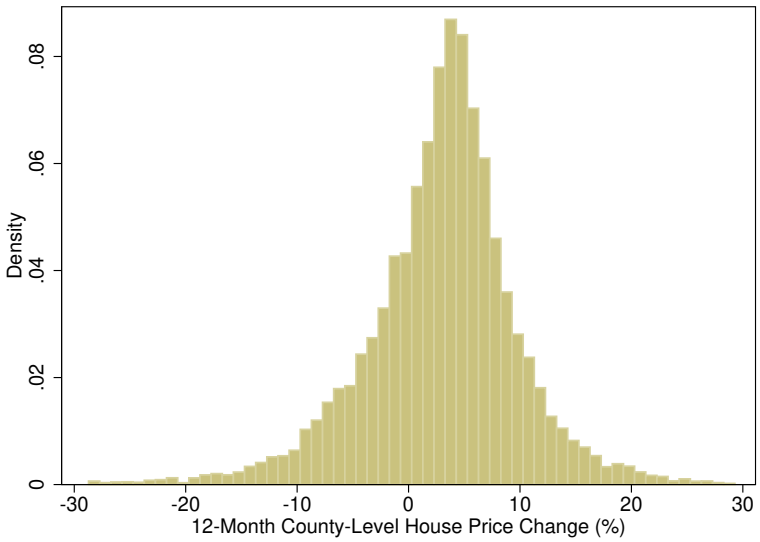
While we are not able to measure the full belief distribution of each individual, we can compare how the leverage choices of individuals vary with the full distribution of the house price experiences of their friends.[51] Specifically, we conduct pairwise comparisons of the distributions of the house price experiences of all friends (and all out-of-commuting zone friends) of individuals purchasing houses in the same county in the same month, and who borrow from the same lender. We then test whether one distribution dominates the other in a hazard rate dominance sense. We only focus on county-month-lender combinations with at least three mortgage originations: at the average (median) such combination, we have 9.8 (5) mortgage originations. Of all the pairwise comparisons across these originations, we can rank the distribution of all friends' house price experiences in a hazard rate sense for 3.5% of transaction pairs, and the distributions of out-of-commuting zone friends' house price experiences for 8.1% of transaction pairs. When comparing the mortgage leverage choices across the individuals with a clear ranking using the experience distribution of all friends, we find that individuals with an experience distribution that is hazard rate dominant will choose 90 basis points lower leverage; this difference is highly statistically significant. When comparing the experience distribution of individuals' out-of-commuting zone friends, those with a hazard rate dominant distribution choose a 68 basis points lower leverage. Both of these results provide additional evidence that the housing-as-consumption scenario with a sizable collateral adjustment friction is dominant in the data.

C Additional Evidence

C.1 House Price Changes

Figure A3 shows the distribution of county-year level annual house price changes in the United States since 1993, as measured by Zillow.

Figure A3: Distribution of house price changes (1993-)



Note: Figure shows the distribution of county-year level annual house price changes in the United States since 1993, as measured by Zillow.

C.2 Downpayments and Expected Default

As discussed in Section 4, many personal financial advice websites and blogs discuss the tradeoffs between making larger and smaller downpayments. Many of these highlight explicitly the tradeoffs that we formally model in Section 1. For example, the real estate brokerage website Home Point Real Estate describes one of the benefits of high leverage as follows:

[51] This test builds on the survey evidence in Section 3.2, which showed that, on average, the first and second moments of the house price experiences of an individual's friends affect the corresponding moments of her belief distribution about future house price changes. The assumption underlying the test in this section is that additional moments of the distribution of individuals' friends' house price experiences will also shift the corresponding moments of those individuals' belief distribution.

> This last reason for putting down a small down payment is kind of twisted, but sadly practical. I doubt we are going to have any down turn in the market soon, and I really doubt it will be like the one we just came through if it does come; but the less you put down the less you lose. Yet, if you are upside down on your home and have to walk away (or lose to foreclosure) the less down payment you put into it the less you lose.

Reuters (2011) outlines similar reasons for making a smaller downpayment:

> Even if you have the money for a bigger down payment, there can be good reasons to save your cash. Mortgage rates continue to skirt all-time lows: Why not put your money to work for yourself and borrow as much as you can reasonably afford, on a monthly basis, at today's rates? You can put the money you're not paying into a down payment to work elsewhere. If home values rise, you will have done your best to leverage a small down payment into bigger equity. If they fall, you'll have less skin in the game, and that could put more pressure on your banker to improve your loan terms lest you walk away.

US News (2017) described the benefits of a smaller downpayment as follows:

> The last major housing crash scared some people away from low down payments after many homeowners found themselves owing more than their homes were worth when values plummeted. But even a 20 percent down payment won't protect you against a 50 percent drop in home values. In fact, if you lost your home to foreclosure or did a short sale, you may have lost less money if you made a small down payment.

MK Real Estate (2016) describes why making smaller downpayments is the more conservative choice for home buyers worried about potential house price drops.

> The link between the economy and home prices is the third reason to consider a small down payment. In general, as the U.S. economy improves, home values rise. When the U.S. economy sags, home values sink. Buyers with large down payments find themselves over-exposed to economic downturns compared to buyers whose down payments are small.
>
> Consider the purchase of a $400,000 home and two home buyers, each with different ideas about how to buy a home. One buyer makes a 20% down payment to avoid Private Mortgage Insurance (PMI). The other buyer wants to stay as liquid as possible, and puts down just 3.5%. The first buyer takes $80,000 from the bank and converts it to illiquid home equity. The second buyer puts $14,000 into the home.
>
> Over the next few years, the economy falters. Our two buyers lose 20% of the value of each of their homes, bringing their values down to $320,000. Neither buyer has any equity left. Our first buyer lost all $80,000 of their money. That money is lost and cannot be recouped except through the housing market's recovery. The second buyer lost only $14,000. While the second buyer's home is "underwater," with more money owed on the home than the home is worth, the bank has the risk of loss and not the borrower.
>
> Let's say that both borrowers default and no longer make their payments. Which homeowner will the bank be more likely to foreclose upon? It's counter-intuitive, but the buyer who made a large down payment is less likely to get relief during a time of crisis and is more likely to face foreclosure. A bank's losses are limited to when the home is sold at foreclosure. The homeowner's twenty percent home equity is already gone, so the remaining losses (legal and home prep costs) are easily absorbed by the bank. Foreclosing on an underwater home will lead to great losses. All of the borrower's money is already lost. The bank will not only have legal and home prep costs, but will also have to write down $66,000 in lost value.
>
> Conservative borrowers recognize that risk increases with the size of the down payment. The smaller your down payment, the smaller your risk.

C.3 Downpayment Motivation Survey

In Section 4.2, we described results from our Downpayment Motivation Survey. In this Appendix, we provide additional information on the respondent demographics, and more details on how the responses vary with these demographics. For complete disclosure, the full data set is available from the authors upon request.

We ran two waves of the survey between September 19, 2017, and September 21, 2017. The survey was designed using the SurveyMonkey survey. Each wave was targeted at approximately 800 homeowners, and no additional filters for the target audience were selected. In each wave, respondents were presented with two different house price growth scenarios, and asked to select one of three different mortgage choices for each house price scenario. In Table A1, we show the changes in the downpayment recommendation between the optimistic and the pessimistic scenario ("Decreased Downpayment" represents individuals who suggested a smaller downpayment in the more pessimistic house price scenario).

Table A1: Downpayment Motivation Survey - Results by Demographics

	Wave 1				Wave 2			
	Total	Decreased DP	Same DP	Increased DP	Total	Decreased DP	Same DP	Increased DP
All	826	20.5%	69.4%	10.2%	794.0%	14.0%	77.6%	8.4%
Income								
$0 to $9,999	17	11.8%	82.3%	5.9%	12.0%	8.3%	91.7%	0.0%
$10,000 to $24,999	38	13.2%	63.2%	23.7%	37.0%	10.8%	62.2%	27.0%
$25,000 to $49,999	92	14.1%	76.1%	9.8%	84.0%	8.3%	88.1%	3.6%
$50,000 to $74,999	56	23.2%	73.2%	3.6%	46.0%	15.2%	60.9%	23.9%
$75,000 to $99,999	35	20.0%	71.4%	8.6%	40.0%	17.5%	80.0%	2.5%
$100,000 to $124,999	15	6.7%	86.7%	6.7%	18.0%	16.7%	83.3%	0.0%
$125,000 to $149,999	50	26.0%	66.0%	8.0%	51.0%	7.8%	84.3%	7.8%
$150,000 to $174,999	103	28.2%	59.2%	12.6%	88.0%	13.6%	77.3%	9.1%
$175,000 to $199,999	122	22.1%	68.0%	9.8%	122.0%	13.1%	80.3%	6.6%
$200,000 and up	117	18.0%	75.2%	6.8%	108.0%	16.7%	74.1%	9.3%
Prefer not to answer	125	16.0%	76.8%	7.2%	137.0%	16.8%	77.4%	5.8%
Age								
18-29	51	23.5%	62.8%	13.7%	42.0%	14.3%	78.6%	7.1%
30-44	168	18.5%	68.4%	13.1%	154.0%	11.7%	76.6%	11.7%
45-59	215	16.7%	76.3%	7.0%	216.0%	16.2%	76.4%	7.4%
60+	336	21.4%	70.5%	8.0%	331.0%	13.0%	79.2%	7.8%
Gender								
Male	324	19.4%	67.9%	12.6%	294.0%	14.3%	77.2%	8.5%
Female	446	21.5%	70.8%	7.7%	449.0%	9.2%	83.1%	7.7%
Region								
East North Central	130	21.5%	70.8%	7.7%	130.0%	9.2%	83.1%	7.7%
East South Central	46	15.2%	73.9%	10.9%	41.0%	9.8%	82.9%	7.3%
Middle Atlantic	94	18.1%	73.4%	8.5%	90.0%	16.7%	75.6%	7.8%
Mountain	58	13.8%	82.8%	3.5%	63.0%	14.3%	74.6%	11.1%
New England	44	13.6%	77.3%	9.1%	47.0%	12.8%	78.7%	8.5%
Pacific	133	23.3%	65.4%	11.3%	111.0%	10.8%	79.3%	9.9%
South Atlantic	131	22.1%	64.1%	13.7%	134.0%	18.7%	72.4%	9.0%
West North Central	59	17.0%	78.0%	5.1%	55.0%	18.2%	76.4%	5.4%
West South Central	74	20.3%	71.6%	8.1%	68.0%	11.8%	79.4%	8.8%

Note: This Table shows behavior in the Downpayment Motivation Survey separately by the reported demographic of the respondents. The results show how the downpayment changes in the pessimistic house price scenario relative to the optimistic house price scenario.