House Price Beliefs and Mortgage Leverage Choice*

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Abstract

We study the effects of homebuyers' beliefs about future house price changes on their mortgage leverage choice. We show that, from a theoretical perspective, the relationship between homebuyers' beliefs and their leverage choice is ambiguous, and depends on the magnitude of a "collateral adjustment friction" that reduces homebuyers' willingness to adjust their house size in response to beliefs about house price changes. When households primarily maximize the levered return of their property investment and the collateral adjustment friction is small, more optimistic homebuyers take on more leverage to purchase larger houses and profit from the greater perceived price appreciation. On the other hand, when considerations such as family size pin down the desired property size and the collateral adjustment friction is large, more optimistic homebuyers take on less leverage to finance that property of fixed size, since they perceive a higher marginal cost of borrowing. To determine which scenario better describes the data, we empirically investigate the cross-sectional relationship between beliefs and leverage 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 documents 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 exploit these experiences as quasi-orthogonal shifters of individuals' house price beliefs. We show that more optimistic homebuyers choose lower leverage, consistent with a sizable collateral adjustment friction. As predicted by the model, the magnitude of the cross-sectional relationship between beliefs and leverage choice is stronger during periods when households expect prices to fall on average.

JEL Codes: E44, G12, D12, D84, R21

Keywords: Leverage, Mortgage Choice, Disagreement, Heterogeneous Beliefs

*This version: Monday 26^{th} June, 2017. We like to thank Jonathan Berk, Peter DeMarzo, Adam Guren, Sean Hundtofte, Kurt Mitman, Amit Seru, Alp Simsek, and Venky Venkateswaran, as well as numerous seminar and conference participants for helpful comments. Elizabeth Casano provided excellent research assistance. This project was supported through a grant of the Center for Global Economy and Business at NYU Stern.

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

We first develop a parsimonious model that characterizes the channels through which homebuyers' beliefs about future house price growth affect their choice of mortgage leverage. We show that the direction of the effect of optimism on leverage choice is ambiguous, and depends on homebuyers' willingness to live in substantially larger properties to benefit from bigger expected house price appreciation. We then empirically investigate the relationship between homebuyers' beliefs about future house price growth and their leverage choice. We use the recent house price experiences of individuals' geographically distant friends as quasi-exogenous shifters of those individuals' beliefs about future house price growth. Exploiting cross-sectional differences in the location of friends among individuals purchasing homes in the same place and at the same time, we find that more optimistic homebuyers take on lower leverage. We show how the cross-sectional patterns that we identify restrict the set of mechanisms through which changes in homebuyer beliefs can rationalize the aggregate behavior of prices and leverage during the recent housing boom.

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 house 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 house and their leverage. In our model, homebuyer beliefs affect leverage choice through two forces: (1) the expected return of the investment, and (2) the perceived marginal cost of borrowing. On the one hand, more optimistic agents want to buy larger houses, since they expect each unit of investment to earn a higher return. In order to afford the larger home, they need to further lever up their fixed resources. On the other hand, holding house size fixed, more optimistic agents choose lower leverage, because they expect to repay the loan in more states of the world, which increases their perceived marginal cost of borrowing.

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 size is not just determined by homebuyers' investment motives, but also by consumption-driven motives such as family size. This introduces a *"collateral adjustment friction"* that reduces homebuyers' willingness to adjust their property size in response to changes in house price beliefs.[1] Our main theoretical result is to show that

[1]We use the term friction to capture any force that reduces the willingness of individuals to adjust their exposure to the 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. As we

the strength of this friction is central to determining the relationship between beliefs and leverage in the housing market.

We highlight the key mechanisms in our model by considering two polar scenarios for which we can obtain explicit analytical results.[2] We first consider a *housing-as-investment* scenario in which there is no collateral adjustment friction and property size is determined purely by households' investment motive. This scenario recovers the predictions from the portfolio choice problem in Simsek (2013): more optimistic homebuyers take on more leverage because, under the appropriate definition of optimism, the "expected return" force dominates the "marginal cost of borrowing" 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 decide between spending their resources on consumption and making a downpayment to purchase the house. In this scenario, which corresponds to an infinite collateral adjustment friction, the "expected return" channel is inactive, but more optimistic agents continue to find borrowing more expensive at the margin. They will thus make a larger downpayment and reduce their leverage. Similarly, 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."

When we move away from these polar cases, whether more optimistic 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.[3] The empirical contribution of this paper is then 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 individuals' house price expectations, we rarely observe forces that induce heterogeneity in homebuyers' beliefs without also inducing variation in their economic resources or other variables that might independently affect their leverage choice.

Our empirical approach to overcome these challenges builds on Bailey et al. (2016), who document that the recent house price experiences in an individual's geographically distant social network affect

discuss below, in other settings where collateral adjustment frictions are potentially important, they could be the result of the production technology or the structure of the market.

[2] These predictions are 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.

[3] 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 how large a house to live in from the decision of the size of their housing market investment. However, in many cases, the set of properties 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, a force that is similar to the collateral adjustment friction we consider for the intensive margin adjustment.

her beliefs about the attractiveness of investments in the local housing market, as well as her actual investments in local real estate. 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 these house price experiences are unlikely to have an effect on leverage choice through channels other than beliefs. This then allows us to explore the empirical relationship between beliefs and leverage choice by analyzing the cross-sectional relationship between the leverage choice of individuals purchasing houses 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 active 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 Feed, elicited a distribution of respondents' expectations for future house price growth in their own zip code. Individuals whose friends experienced more recent house price increases expected 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. In addition, we find that individuals whose friends experienced more heterogeneous recent house price changes report a more dispersed distribution of expected future house price growth: a one-percentage-point increase in the across-friend standard deviation of house price experiences is associated with a 18 basis points increase in the standard deviation of the reported distribution of beliefs about future house price growth over the next year. 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 can affect the corresponding moments of the belief distribution.

In order to exploit these house price experiences as orthogonal shifters of individuals' beliefs, we match anonymized social network data on Los Angeles-based Facebook users to public record housing deeds data, which contain information on both transaction prices and mortgage choices. We observe information on homebuyers' leverage choice for about 250,000 housing transactions since 1994.

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 higher house price growth, and who are thus more optimistic about future house price growth, take on less leverage. Quantitatively, a one-percentage-point increase in the average house price experiences among an individual's friends is associated with a decline in the loan-to-value ratio of about 10 basis points. Combining this with the estimates from the survey, this suggests that a one-percentage-point increase in the expected house price appreciation over the next twelve months leads individuals to reduce their

[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.

loan-to-value ratio by 27 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 growth is associated with choosing higher leverage: holding the mean beliefs fixed, individuals who have a more dispersed belief distribution expect to default in more states of the world, and thus reduce the equity investment in their house.

We also test important predictions from our model regarding the relative strength of the relationship between beliefs and leverage across housing booms (periods when most people expect further house price growth) and housing busts (periods when most people expect house price declines). In the housing-as-consumption scenario that appears dominant in the data, differences in leverage choice are driven by differences in the perceived probability of repaying the mortgage. 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 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 during periods of declining house prices.

Throughout the analysis, we argue that the effect of the house price experiences of geographically distant friends on leverage comes only through influencing an individual's belief distribution about future house price growth. We conduct a number of tests to rule out other channels that might have also been able to explain this relationship. For example, we show that the results are not driven by wealth effects whereby higher house price appreciation in areas where an individual has friends increases their resources available for making downpayments. We also show that our results cannot be driven by correlated shocks to individuals and their friends that move aggregate house prices in those geographically distant regions where her friends live.

We also test the predictions of our model without imposing parametric restrictions on the distribution of borrowers' beliefs. The non-parametric approach is appealing, since it does not impose unnecessary restrictions on borrowers' belief distributions. Its downside is that it does not provide a complete order: not all belief distributions can be directly compared. We show that hazard rate dominance is the appropriate stochastic order that yields unambiguous predictions regarding the relation between homebuyers' beliefs and leverage for our two polar scenarios. Consistent with our parametric findings, we show that homebuyers whose friends have experienced higher house price growth according to the relevant hazard rate dominance criterion take on less leverage on average.

Finally, we show that, in both housing-as-consumption and housing-as-investment scenarios, lenders' optimism is necessary to generate an increase in leverage, all else constant.[5] 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.

When combined together, our results speak to the active debate about the extent to which the joint

[5] We focus on the effect of a shift in lenders' beliefs to highlight the differences with a shift in borrowers' beliefs. Any credit supply shifter, such as a "global savings glut" or agency frictions in mortgage securitization, would yield identical implications.

movement in house prices and mortgage leverage during the 2002-2006 housing boom period were the result of homebuyer optimism or other forces in the economy, such as credit supply shocks (Mian and Sufi, 2009; Case, Shiller and Thompson, 2012; Glaeser, Gottlieb and Gyourko, 2012; Landvoigt, Piazzesi and Schneider, 2015; Adelino, Schoar and Severino, 2016; Burnside, Eichenbaum and Rebelo, 2016; Di Maggio and Kermani, 2016; Foote, Loewenstein and Willen, 2016). Our findings suggest that, by itself, increased household optimism does not induce higher credit demand and leverage, and that other forces, such as shifts in the credit supply function, also played an important role during the recent housing cycle. This does not mean that homebuyer optimism was not important in explaining the boom-bust cycle in *house prices*. Indeed, Bailey et al. (2016) use a similar cross-sectional identification strategy as we do to suggest that more optimistic households purchase larger houses at higher prices. However, it does mean that a singular focus on homebuyer beliefs would have counterfactually predicted a decline in mortgage leverage during this period. 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.[6] Such a relaxation of credit constraints could arise, for example, from increased lender optimism, a "global savings glut," or due to agency problems in the securitization process (e.g., Keys et al., 2010; Taylor, 2013).

Our theoretical observation that the relationship between borrowers' beliefs and leverage choice 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' ability to adjust the size of their housing 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 we might expect pessimistic agents to 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 that the inability or unwillingness to adjust individuals' collateral positions is the key feature that determines the relation between borrowers' beliefs and leverage choices, although the primitive forces present in this paper are at play in many environments.[7]

On the theoretical side, our paper builds on and contributes to the the literature on collateralized credit with heterogeneous beliefs developed by Geanakoplos (1997, 2003, 2010), and Fostel and

[6] Such quantitative models can also 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.

[7] Our results also relate to a vast body of work in contract theory and corporate finance that explores the implications of non-linear payoffs for individual decisions (e.g., risk-shifting/asset substitution).

Geanakoplos (2008, 2012, 2015, 2016).[8] Our model is most closely related to the baseline environment studied by Simsek (2013), which features standard debt contracts. This literature has focused on environments in which investors exclusively make a leveraged purchase in a risky asset. We show that the same theoretical framework can be used to 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. Our paper operationalizes the theory by developing implementable tests of how borrowers' beliefs affect leverage. Our results are thus consistent with and complementary to the findings of Koudijs and Voth (2016), who document the positive relation between lenders' optimism and high leverage in a similar framework.

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 the implications of own experiences and other's experiences for investors beliefs. 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. (2016) to show that various moments of the experiences of individuals' friends also affect the corresponding moments of those individuals' belief distributions. Indeed, unlike extrapolation from own experiences, extrapolation from friends' experiences can induce belief disagreement across individuals in the same local housing market.

We also relate to a recent literature that has focused on the important role of homebuyer beliefs during the housing boom period (e.g., Piazzesi and Schneider, 2009; Nathanson and Zwick, 2014; Glaeser and Nathanson, 2015; Burnside, Eichenbaum and Rebelo, 2016; Landvoigt, 2016). Our findings suggest that more optimistic homebuyers by themselves would have likely led to counterfactually declining leverage ratios over the housing boom period, and suggest that an equally important role during this period comes from the credit supply side. 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; 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 leverage choice.

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

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 consumption good (dollar) in this economy, which serves as numeraire, and a housing good.

Borrowers. Borrowers' preferences 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 an Inada condition, that is, $u_i'(\cdot) > 0$, $u_i''(\cdot) < 0$, 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] As described below, we will enrich borrowers' preferences by assuming that borrowers' housing decisions must be within a target region.

Borrowers are endowed with $n_{0i} > 0$ and $n_{1i} > 0$ dollars at dates 0 and 1, respectively. They have access to a non-contingent non-recourse loan (mortgage) that is collateralized exclusively by the value of the house they acquire. Borrowers promise to repay b_{0i} dollars at date 1 in exchange for receiving $q_{0i}(\cdot) b_{0i}$ dollars at date 0. Borrowers use their funds to either consume c_{0i} or to purchase a house of size h_{0i}. Borrowers have the option to default. In case of default, borrowers experience a private loss that corresponds to a fraction of date-1 house value in dollar terms, $\phi_i p_1 h_{0i}$, where $\phi_i \geq 0$. This term captures both pecuniary and non-pecuniary losses for borrowers associated with default. The parameter ϕ_i can be alternatively interpreted as a simple form of capturing unmodeled heterogeneity across borrowers regarding future continuation values.[11]

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 $F_i(\cdot)$:

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

[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.

[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 remain valid up to a first-order in that case.

[11] We assume that the total private default loss is proportional to the house value $p_1 h_{0i}$ to preserve the homogeneity of the borrowers' problem. This assumption can be relaxed without affecting our insights. It is reasonable to argue that individual default costs are larger for homeowners with larger properties.

where g has support in $\left[\underline{g}, \overline{g}\right]$, $\underline{g} \geq 0$, and $\overline{g}$ could be infinite.[12] Formally, borrowers solve the following optimization problem:

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

$$\text{s.t.} \quad c_{0i} + p_0 h_{0i} = n_{0i} + q_{0i}\left(\cdot\right) b_{0i},$$

where their future wealth corresponds to $w_{1i} = \max\left\{w_{1i}^{\mathcal{N}}, w_{1i}^{\mathcal{D}}\right\}$, and where $w_{1i}^{\mathcal{N}}$ and $w_{1i}^{\mathcal{D}}$ denote borrowers' wealth in no default and default states, respectively given by

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

Finally, we incorporate the possibility of a "collateral adjustment friction" by assuming that borrowers have a desired *target region* for housing. Formally, borrowers' housing choice h_{0i} must satisfy

$$\underline{h_i} \leq h_{0i} \leq \overline{h_i}, \tag{1}$$

where the values of $\underline{h_i}$, and $\overline{h_i}$ are such that the borrowers' feasible choice set is non-empty. This specification provides a tractable approach to capture that borrowers' preferences for owner-occupied housing are also affected by the consumption aspect of housing. We adopt hard constraints on h_{0i} for tractability.[13] In cases when the housing target constraint binds, the borrowers' house size decision is completely pinned down by consumption aspects of housing, such as the homebuyer's family size. Considering this case allows us to study the relationship between beliefs and leverage with an infinite collateral adjustment friction. In the case when h_{0i} is not at the constraint, 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. Indeed, we demonstrate that an identical shift in the distribution of borrowers' beliefs has opposite predictions for equilibrium leverage depending on whether or not borrowers can freely adjust their housing investment.

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

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

[13] Imposing the constraint in Equation (1) is equivalent to assuming that borrowers' utility is augmented by an additive term $\alpha \cdot \mathbf{1}\left[\underline{h_i} \leq h_{0i} \leq \overline{h_i}\right]$, where α is a sufficiently large positive scalar and $\mathbf{1}\left[\cdot\right]$ 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 target constraint binds.

schedules conditional on loan-to-value ratios.[14] In bankruptcy, lenders recover only a fraction $\kappa \in [0,1]$ of the value of the collateral. The remaining fraction $1-\kappa$ corresponds to bankruptcy costs. Lenders are endowed with some beliefs about house prices, which follow a distribution with cdf $F_L(\cdot)$. Lenders' perceptions over house price changes may be different from those of borrowers.

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 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.

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

$$\text{if} \begin{cases} g \leq \chi_i \delta_i, & \text{Default} \\ g > \chi_i \delta_i & \text{No Default} \end{cases} \qquad \text{where} \quad \chi_i = \frac{1}{1+\phi_i} \quad \text{and} \quad \delta_i = \frac{b_{0i}}{p_0 h_{0i}},$$

and where g denotes the actual realization of house price growth. Note that $\chi_i \in [0,1]$ is decreasing in the default cost. In particular, $\chi_i \to 1$ when $\phi_i \to 0$.

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 relative magnitude of default costs ϕ_i.

Remark. (Importance of 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. 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 ϕ_i, which captures other, non-financial default costs (e.g., social stigma). See Bhutta, Dokko and Shan (2016) for a recent summary of that debate. 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, all results are robust as long as default is

[14] 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.

more likely when house prices decline: in other words, as long as negative equity is a necessary condition for default, even if it is not a sufficient condition.[15]

Lenders' loan pricing. Given borrowers' default decisions, competitive lenders offer loan-to-value (LTV) ratio schedules to a type i borrower to break even. For a given normalized promised repayment $\delta_i = \frac{b_{0i}}{p_0 h_{0i}}$, the loan-to-value ratio of borrower i at date 0 corresponds to $\Lambda_i(\delta_i) \equiv \frac{q_{0i}(\cdot) b_{0i}}{p_0 h_{0i}}$. Formally, $\Lambda_i(\delta_i)$ is determined by the lenders' break-even condition, that is,

$$\Lambda_i(\delta_i) = \frac{\kappa \int_{\underline{g}}^{\chi_i \delta_i} g dF_L(g) + \delta_i \int_{\chi_i \delta_i}^{\overline{g}} dF_L(g)}{1+r}. \tag{2}$$

For any normalized promised repayment $\delta_i = \frac{b_{0i}}{p_0 h_{0i}}$, Equation (2) describes the loan-to-value ratio offered by lenders to a borrower of type i. The first term in the numerator corresponds to the repayment in default states net of default costs. The second term in the numerator corresponds to the repayment in non-default states. Both terms are discounted at the lenders' risk-free rate, $1+r$. Lenders' loan offers depend on the normalized promised repayment, δ_i, and the borrowers' default cost, ϕ_i. Importantly, offered loan-to-value ratios are independent of borrowers' beliefs. When ϕ_i is the same across borrowers, lenders offer the same schedule $\Lambda(\delta_i)$ to all borrowers.

Although we adopt δ_i as the borrowers' choice variable for analytical convenience, our formulation yields equivalent results if borrowers instead use loan-to-value ratios $\Lambda_i(\delta_i)$ as choice variables. We establish below 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 $\frac{1}{1-\Lambda(\delta_i)}$.[16]

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

$$\max_{c_{0i}, \delta_i, h_{0i}} u_i(c_{0i}) + \beta p_0 h_{0i} \left[-\phi_i \int_{\underline{g}}^{\chi_i \delta_i} g dF_i(g) + \int_{\chi_i \delta_i}^{\overline{g}} (g - \delta_i) dF_i(g) \right], \tag{3}$$

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

$$c_{0i} + p_0 h_{0i} (1 - \Lambda_i(\delta_i)) = n_{0i} \quad (\lambda_{0i})$$
$$\underline{h} \leq h_{0i} \leq \overline{h} \quad \left(\underline{\nu_{0i}}, \overline{\nu_{0i}}\right),$$

[15] This 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 (see Elul et al., 2010).

[16] 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 LTV ratio is $\frac{75}{100} = 75\%$, his margin/haircut/downpayment is 25%, and his leverage ratio is 4.

where borrower i takes into account that $\Lambda_i(\delta_i)$ is given by Equation (2). The (non-negative) Lagrange multipliers associated with each equation are respectively given by λ_{0i}, $\underline{\nu_{0i}}$, and $\overline{\nu_{0i}}$. Note that the term in brackets in the objective function described in (3) corresponds to the net return per dollar invested in housing. Borrowers' optimality conditions for consumption, housing, and leverage, are respectively given by:

$$c_{0i}: \quad \underbrace{u_i'(c_{0i})}_{\text{Mg. Benefit}} - \underbrace{\lambda_{0i}}_{\text{Mg. Cost}} = 0 \tag{4}$$

$$h_{0i}: \quad -\underbrace{\lambda_{0i} p_0 (1 - \Lambda_i(\delta_i))}_{\text{Mg. Cost}} + \underbrace{\beta p_0 \left[-\phi_i \int_{\underline{g}}^{\chi_i \delta_i} g dF_i(g) + \int_{\chi_i \delta_i}^{\overline{g}} (g - \delta_i) dF_i(g) \right]}_{\text{Mg. Benefit}} + \nu_{0i} = 0 \tag{5}$$

$$\delta_i: \quad \underbrace{\lambda_{0i} p_0 h_{0i} \Lambda_i'(\delta_i)}_{\text{Mg. Benefit}} - \underbrace{\beta p_0 h_{0i} \int_{\chi_i \delta_i}^{\overline{g}} dF_i(g)}_{\text{Mg. Cost}} = 0, \tag{6}$$

where we define $\nu_{0i} = \underline{\nu_{0i}} - \overline{\nu_{0i}}$.[17] The optimality condition for consumption simply equates the marginal benefit of consumption, given by $u_i'(c_{0i})$, 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 the 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" channel. The marginal cost of extra investment corresponds to the reduction in available resources at date 0, which are valued by borrowers according to λ_{0i}. When the housing target constraint binds, borrowers' housing choices are given by $h_{0i} = \underline{h_i}$ or $h_{0i} = \overline{h_i}$, and Equation (5) simply defines ν_{0i}, which captures the shadow value of relaxing the housing target constraint.

The optimality condition for borrowing equates the marginal benefit of increasing the promised repayment, which corresponds to the increase in the level of available 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 "marginal cost of borrowing" channel. More optimistic homebuyers expect to repay the mortgage in more states in the future, which increases their perceived marginal cost of borrowing. Intuitively, a pessimistic borrower that needs a house of a certain size but thinks that house prices might decrease should be 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

[17] The derivation of Equation (6) exploits 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 (3) — no additional terms appear in Equation (6) 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.

house prices are likely to increase, expects to repay their mortgage in more states of the world. This increase in the perceived marginal cost of borrowing leads this more optimistic borrower to make a larger downpayment (lower repayment and lower LTV ratio).

When borrowers can adjust housing freely (no collateral adjustment friction), the following relation must hold at the optimum:

$$\underbrace{u_i'(c_{0i})}_{\substack{\text{Mg. Benefit of}\\\text{Additional}\\\text{Consumption}}} = \underbrace{\frac{\beta\int_{\chi_i\delta_i}^{\overline{g}} dF_i(g)}{\Lambda_i'(\delta_i)}}_{\substack{\text{Mg. Benefit of Larger}\\\text{Downpayment}}} = \underbrace{\frac{\beta\left[-\phi_i\int_{\underline{g}}^{\chi_i\delta_i} g dF_i(g) + \int_{\chi_i\delta_i}^{\overline{g}}(g-\delta_i)\, dF_i(g)\right]}{1-\Lambda_i(\delta_i)}}_{\text{Mg. Benefit of Leveraged House Purchase}}. \tag{7}$$

Intuitively, at an optimum in which the housing target constraint is slack, a borrower is indifferent between (i) consuming a dollar, (ii) using a dollar to reduce her promised repayment by increasing today's downpayment, and (iii) leveraging the dollar to make a larger housing investment. The second and third terms in Equation (7) have an intuitive interpretation. A dollar of extra downpayment at date 0 allows borrowers to reduce their future repayment by $\frac{\partial\delta_i}{\partial\Lambda_i} = \frac{1}{\Lambda_i'(\delta_i)} > 1$ dollars. The per-dollar NPV of such a reduction corresponds to $\beta\int_{\chi_i\delta_i}^{\overline{g}} dF_i(g)$, since borrowers only repay in states of the world where 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 at date 0 allows borrowers to leverage their investment $\frac{1}{1-\Lambda_i(\delta_i)}$ times, while the per-dollar NPV of a housing investment corresponds to $\beta\left[-\phi_i\int_{\underline{g}}^{\chi_i\delta_i} g dF_i(g) + \int_{\chi_i\delta_i}^{\overline{g}}(g-\delta_i)\, dF_i(g)\right]$.

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 equilibrium leverage. However, by sequentially studying (i) a scenario with no collateral adjustment friction in which borrowers freely adjust their housing decision, and (ii) a scenario where borrowers' housing decision is fixed, because non-investment-related forces such as family size result in an infinite collateral adjustment friction, we can provide clear comparative statics on the effects of beliefs shifts. From now on, to ease the exposition, we focus on the case in which the costs of default are small, that is, $\phi_i \to 0$.

We refer to the case in which borrowers freely adjust their housing choice, as the *housing-as-investment* case. We adopt this terminology to capture the idea that borrowers' housing decisions are mostly driven by investment considerations. In this case, borrowers make housing decisions purely based on its return as a leveraged investment and there is no collateral investment friction.

We refer to the second case in which the housing decision is fixed as the *housing-as-consumption* case. We adopt this terminology to capture that idea that consumption considerations such as family size are mostly driving borrowers' housing decision, not necessarily the expected financial return on their housing investment.

Importantly, in practice, we expect borrowers' behavior to be a combination of the effects we identify under both polar scenarios, depending on the endogenous response of housing. The purpose of our empirical exercise is to determine which scenario more closely captures the dominant forces driving leverage in practice.

Housing-as-investment. 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

$$\rho_i = \max_{\delta_i} \frac{\int_{\delta_i}^{\overline{g}} (g - \delta_i) \, dF_i(g)}{1 - \Lambda_i(\delta_i)}. \tag{8}$$

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

$$\frac{\Lambda_i'(\delta_i)}{1 - \Lambda_i(\delta_i)} = \frac{1}{\mathbb{E}_i[g | g \geq \delta_i] - \delta_i}, \tag{9}$$

where the truncated expectation of house price growth corresponds to

$$\mathbb{E}_i[g | g \geq \delta_i] = \frac{\int_{\delta_i}^{\overline{g}} g dF_i(g)}{\int_{\delta_i}^{\overline{g}} dF_i(g)}. \tag{10}$$

Equation (9) can be derived directly from Equation (7) by combining borrowers' optimal borrowing and housing choices.[18] The numerator of Equation (10) captures the "expected return" channel described above, while its denominator captures the "marginal cost of borrowing" channel. Changes in the distribution of borrowers' beliefs affect leverage choices exclusively through the impact on the truncated expectation. Below, to derive unambiguous predictions, we will characterize conditions under which changes in beliefs shift the truncated expectation $\mathbb{E}_i\left[g | g \geq \tilde{\delta}\right]$ for any possible $\tilde{\delta}$ (point-wise).[19]

Equation (9) determines borrowers' optimal leverage choice independent of the choice of consumption and housing. This implies that the presence of a consumption-savings margin is not sufficient to generate ambiguous 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 or consumption:

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

where ρ_i, defined in (8), is the maximized levered return on a housing investment. Finally, given δ_i and

[18]Note that Equation (9) can be mapped to Equation (12) in Simsek (2013). In our case, lenders discipline borrowers' leverage choices through the term $\frac{\Lambda_i'(\delta_i)}{1-\Lambda_i(\delta_i)} = \frac{-d\log(1-\Lambda_i(\delta_i))}{d\delta_i}$, which is independent of borrowers' beliefs.

[19]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 exploits shifts in the distribution F_i and does not use information on actual default thresholds.

c_{0i}, borrowers choose h_{0i} to satisfy

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

Housing-as-consumption. In this scenario, borrowers choose δ_i to solve a consumption smoothing problem.[20] Formally, the optimal LTV ratio is fully characterized by an alternative single equation

$$u_i'\left(n_{0i} - p_0 h_{0i}\left(1 - \Lambda_i(\delta_i)\right)\right)\Lambda_i'(\delta_i) = \beta\left(1 - F_i(\delta_i)\right). \tag{11}$$

Equation (11) can be derived directly from Equation (7) by combining borrowers' optimal consumption and borrowing choices. In this case, only the "marginal cost of borrowing" channel is present, through the term $\int_{\delta_i}^{\overline{g}} dF_i(g) = 1 - F_i(\delta_i)$. Therefore, changes in the distribution of borrowers' beliefs only affect leverage choices through changes in the probability of repayment, $1 - F_i(\delta_i)$. In this scenario, as described below, unambiguous predictions can be found by comparing point-wise shifts in $F_i(\cdot)$. Once δ_i is determined, borrowers choose initial consumption to satisfy their budget constraint

$$c_{0i} = n_{0i} - p_0 h_{0i}\left(1 - \Lambda_i(\delta_i)\right), \tag{12}$$

where h_{0i} takes values $\overline{h_{0i}}$ or $\underline{h_{0i}}$.

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. First, we impose a parametric assumption on the distribution of beliefs — we assume that borrowers' beliefs follow a normal distribution — and develop comparative statics for changes in the mean and variance of the distribution of beliefs. We then study the non-parametric implications of our model.

2.1 Parametric Predictions

We adopt the normal distribution for our parametric predictions based on the empirical evidence about the distribution of house price movements that we observed in our data. Appendix Figure A2 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 Figure 6). 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 $\mathbb{E}_i[g | g \geq \delta_i]$ and $F_i(\cdot)$, and therefore on the relationship between beliefs and leverage in both the housing-as-investment and housing-as-consumption scenarios.

[20] In a more general setup, borrowers will also be indifferent at the margin between consuming and investing in other assets. See Chetty, Sándor and Szeidl (2016) for a recent treatment of how housing affects optimal asset allocation problems.

Proposition 1. (Parametric predictions for mean and variance shifts with normally distributed beliefs) *Assume that borrowers' beliefs about the expected growth rate of house prices follow a normal distribution, that is,* $g \sim_i N\left(\mu_i, \sigma_i^2\right)$ *.*

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. 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. The predictions for the LTV ratio can be formally expressed as:*

$$\frac{\partial \mathbb{E}_i\left[g|\, g \geq \tilde{\delta}\right]}{\partial \mu_i} > 0,\ \forall \tilde{\delta} \quad \Rightarrow \quad \frac{\partial \delta_i}{\partial \mu_i} > 0$$
$$\frac{\partial \mathbb{E}_i\left[g|\, g \geq \tilde{\delta}\right]}{\partial \sigma_i} > 0,\ \forall \tilde{\delta} \quad \Rightarrow \quad \frac{\partial \delta_i}{\partial \sigma_i} > 0.$$

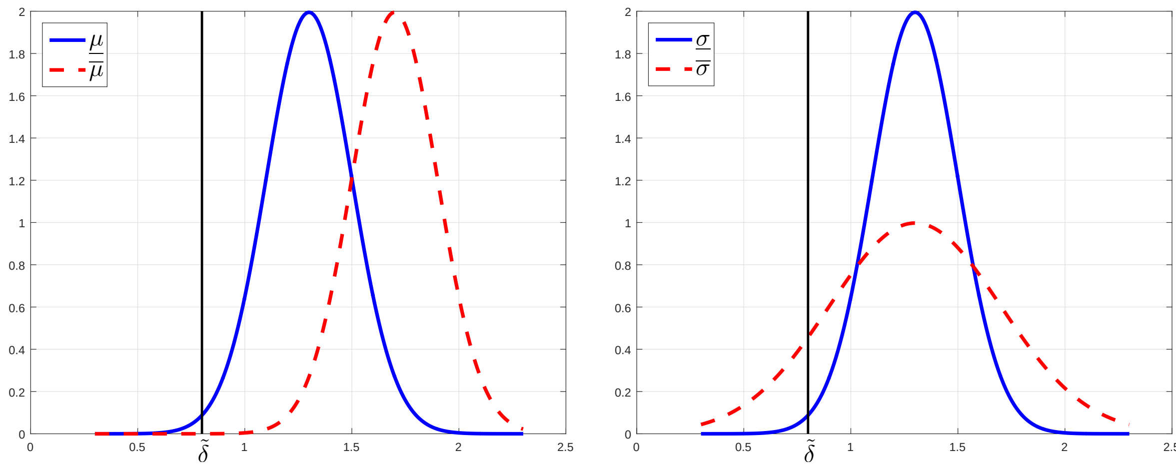
b) **[Housing-as-consumption predictions]** *In the housing-as-consumption scenario, holding all else constant, including the belief dispersion* σ_i*, borrowers with higher average belief* μ_i *choose a lower LTV ratio and lower consumption. In the housing-as-consumption scenario, holding all else constant, 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. The predictions for the LTV ratio can be formally expressed as:*

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

Our model highlights 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 (9), when borrowers perceive their housing choice to be an investment decision (the housing-as-investment scenario without a collateral adjustment friction), leverage increases when the truncated expected return on a housing investment, $\mathbb{E}_i\left[g|\, g \geq \tilde{\delta}\right]$, is higher for any leverage choice $\tilde{\delta}$. In Figure 1, this is the expected value of the house price change, conditional on the value being to the right of the default threshold, which is given by the black line. Panel (a) shows that, under normally-distributed beliefs, an increase in average optimism increases the perceived net return on their housing investment, which pushes borrowers 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 borrowers value the increase in the probability of extremely good states of the world, but discount the associated 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 and σ affect $\mathbb{E}_i\left[g|\, g \geq \tilde{\delta}\right]$ and $1 - F_i\left(\tilde{\delta}\right)$

(a) Mean shift (b) Variance shift



Note: Figures 1 illustrates shifts in the parameters of the distribution of beliefs. The parameters used in the left figure are $\underline{\mu} = 1.3$, $\overline{\mu} = 1.7$, and $\sigma = 0.2$. The parameters used in the right figure are $\mu = 1.3$, $\underline{\sigma} = 0.2$, and $\overline{\sigma} = 0.4$. This figure illustrates how shifts in μ_i and σ_i modify $\mathbb{E}_i\left[g|\, g \geq \tilde{\delta}\right]$ and $1 - F_i\left(\tilde{\delta}\right)$ for a given threshold $\tilde{\delta}$.

On the other hand, Equation (11) highlights that when a borrower finds it optimal not to adjust her housing choice, perhaps because her housing choice 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, $1 - F_i\left(\tilde{\delta}\right)$, for a given default threshold $\tilde{\delta}$. In Figure 1, this is given by the probability-mass to the right of the default threshold. Panel (a) shows that an increase in optimism is perceived by the borrower as an increase in the marginal cost of borrowing, since now loans have to be repaid more frequently. In that case, more optimistic borrowers optimally decide to borrow less. 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 making borrowing less costly from the perspective of borrowers. Higher variance of expected house price changes will therefore 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 ($\phi_i \to \infty$), the marginal cost of borrowing channel would be inactive, and changes in borrowers' beliefs would have no impact 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.

2.1.1 Boom-bust predictions

The results in Proposition 1 establish that changes in the average belief and the dispersion of beliefs have different implications for borrowers' leverage choices depending on the active margins of adjustment. We next use our framework to derive additional testable predictions regarding the relative importance of beliefs in determining leverage choices across the housing cycle. Specifically, we show that the effects of a belief shift differ depending on whether the average growth rate of house prices is higher (boom), or lower (bust), to begin with. We again find opposite predictions in both polar scenarios. In Proposition 2, we characterize the second-order direct impact of belief shifts on leverage.

Proposition 2. (Boom/Bust predictions) *Assume that borrowers' beliefs about the expected growth rate of house prices follow a normal distribution, that is, $g \sim_i N\left(\mu_i, \sigma_i^2\right)$.*

a) **[Housing-as-investment predictions]** *In the housing-as-investment scenario, a given increase in the average belief, μ_i, induces a larger increase in leverage when borrowers' average belief, μ_i, is higher to begin with. A given increase in belief dispersion σ_i induces a smaller increase in leverage when borrowers' average belief, μ_i, is higher to begin with. Hence, housing booms amplify the effect of changes in the average belief, μ_i, on leverage, but they dampen the effect of changes in belief dispersion, σ_i. These predictions for equilibrium LTV ratios are formally expressed as:*

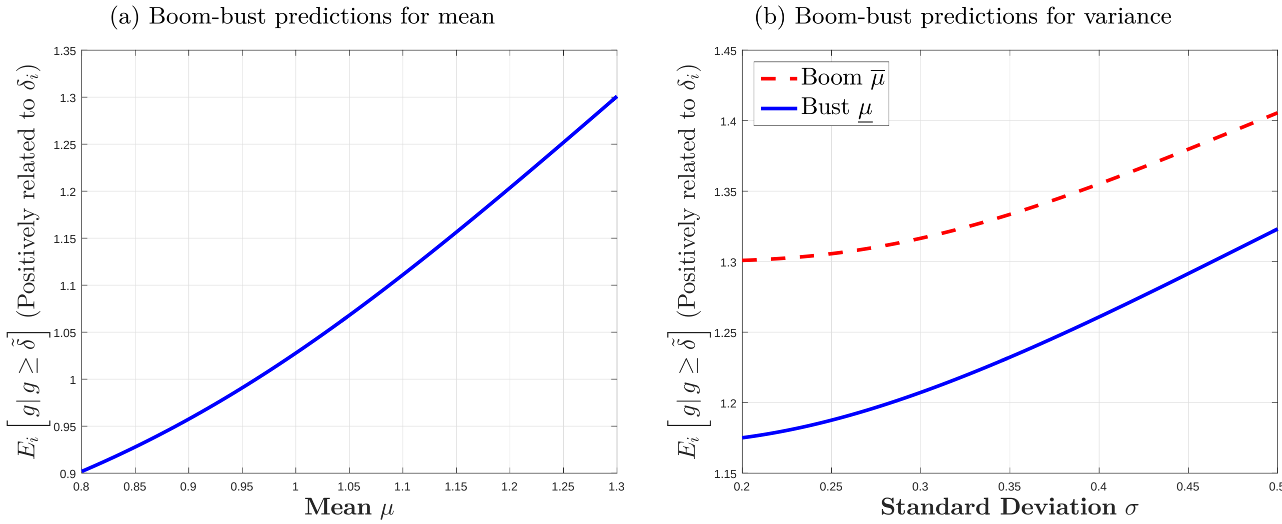
$$\frac{\partial^2 \mathbb{E}_i\left[g \middle| g \geq \tilde{\delta}\right]}{\partial \mu_i^2} > 0,\ \forall \tilde{\delta} \quad \Rightarrow \quad \frac{\partial^2 \delta_i}{\partial \mu_i^2} > 0$$
$$\frac{\partial^2 \mathbb{E}_i\left[g \middle| g \geq \tilde{\delta}\right]}{\partial \sigma_i \partial \mu_i} < 0,\ \forall \tilde{\delta} \quad \Rightarrow \quad \frac{\partial^2 \delta_i}{\partial \sigma_i \partial \mu_i} < 0, \quad \text{if } \tilde{\delta} - \mu_i < 0.$$

b) **[Housing-as-consumption predictions]** *In the housing-as-consumption scenario, a given increase in average belief, μ_i, generates a smaller decrease in leverage when borrowers' average belief, μ_i, is higher to begin with. 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. Hence, housing booms dampen the effects on leverage of both changes in the average belief, μ_i, and changes in belief dispersion, σ_i. These predictions for equilibrium LTV ratios are formally expressed as:*

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

In the housing-as-investment scenario, the effect of truncation on the attractiveness of the investment declines as borrowers become more optimistic, and so further increases in optimism will have a larger and larger effect on the attractiveness of the investment and thus the leverage choice. This can be seen in Panel (a) of Figure 2, which shows that $\mathbb{E}_i\left[g|\, g \geq \tilde{\delta}\right]$ is increasing and convex in μ_i. On the other hand, increases in the variance of the belief distribution, σ_i, have smaller effects on the truncated expectation during a housing boom period; indeed, in the extreme case when borrowers expect to repay the mortgage with certainty, increases in σ_i have no effect on the truncated expectation, and therefore on leverage choice. This can be seen in Panel (b) of Figure 2, which shows that the slope of the change in $\mathbb{E}_i\left[g|\, g \geq \tilde{\delta}\right]$ with respect to σ_i is steeper when average expectations are lower.

Figure 2: Housing-as-investment scenario



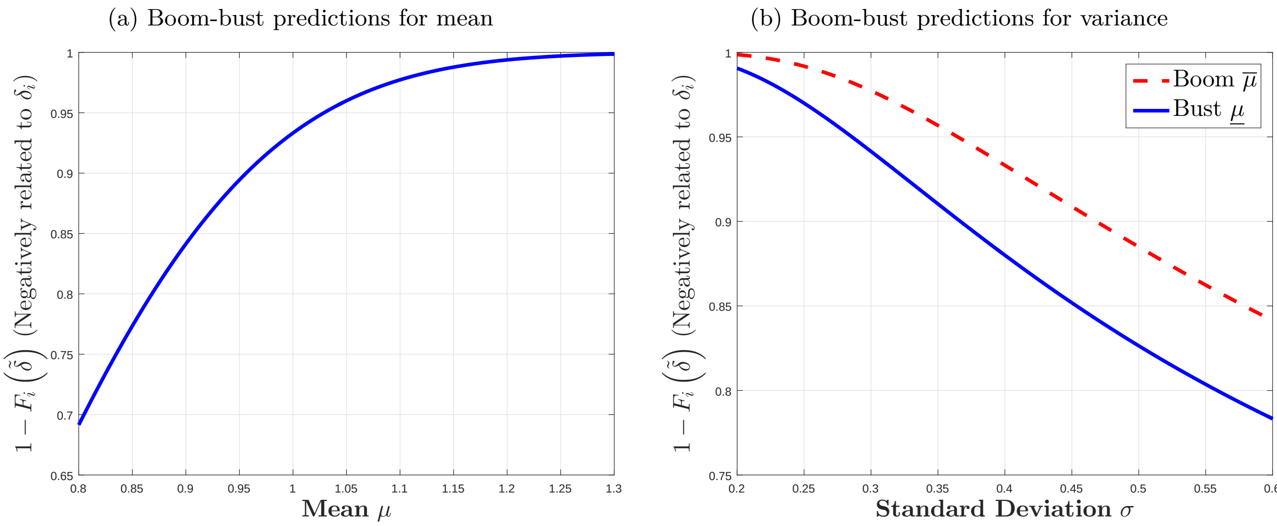
Note: The parameters used in Panel (a) are $\tilde{\delta} = 0.7$ and $\sigma = 2$. The parameters used in Panel (b) are $\tilde{\delta} = 0.7$, $\overline{\mu} = 1.3$ and $\underline{\mu} = 1.17$.

On the other hand, Proposition 2 suggests that in the housing-as-consumption scenario, the effect of changes in μ_i and σ_i are smaller in magnitude during housing booms when μ is high to begin with. Figure 3 shows that the probability of repayment, $1 - F_i(\delta_i)$, is concave in μ. Intuitively, an increase in average optimism changes the probability of repayment less when the average expectation is already high. Panel (b) of Figure 3 also shows that the dashed line, which corresponds to repayment probability in booms as a function of the variance of beliefs, is flatter than the solid line, which corresponds to periods in which average beliefs are lower to begin with. Intuitively, when μ starts from a low level, more mass of the belief distribution is around the default threshold, increasing the sensitivity of $1 - F_i(\delta_i)$ to changes in variances. As we described below, our empirical findings are also consistent with the boom-bust predictions of the housing-as-consumption scenario.

2.1.2 Role of Lenders' Beliefs

Although our empirical findings exploit 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

Figure 3: 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 $\underline{\mu} = 1.17$.

leverage in both the housing-as-consumption and the housing-as-investment scenarios.

Proposition 3. (Parametric predictions for 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 point-wise 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.

When combined, the findings of Propositions 1 and 3 show that belief shifts by borrowers or lenders, when considered in isolation, can have opposite predictions for equilibrium leverage. Our results also imply that an aggregate increase in optimism by both borrowers and lenders can be associated with higher or lower levels of equilibrium leverage, depending on the magnitude of the collateral adjustment friction. In the housing-as-consumption scenario, which is consistent with our empirical findings, an increase in lenders' optimism is necessary (but not sufficient) to guarantee that aggregate optimism is associated with higher equilibrium leverage. Although a richer model, like that of Kaplan, Mitman and Violante (2015), is needed to provide a full general equilibrium analysis of how belief shifts determine house prices and leverage, our results can be used to rationalize their finding that an increase in optimism of both buyers and lenders is associated with lower leverage.

2.2 Non-Parametric Predictions

Although the parametric assumption underlying Proposition 1 and 2 is 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 exploits 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 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 employ three different stochastic orders to define optimism. Given two distributions with cumulative distribution functions F_j and F_i with support $\left[\underline{g}, \overline{g}\right]$, we define truncated expectation 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

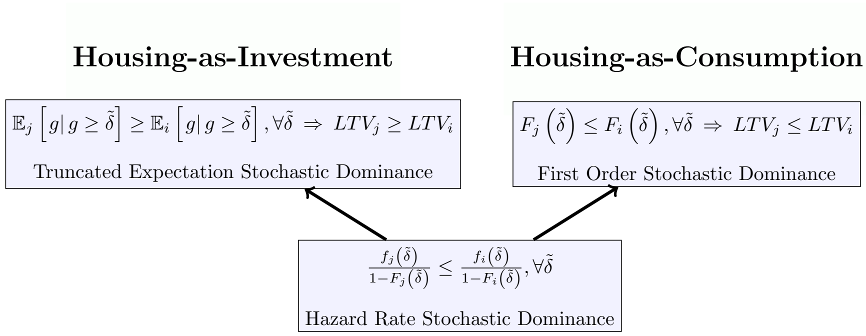
$$F_j\left(\delta\right) \leq F_i\left(\delta\right), \quad \forall \delta \in \left[\underline{g}, \overline{g}\right].$$

3. **Hazard rate stochastic dominance**: F_j stochastically dominates F_i (borrower j is more optimistic than i) in a hazard rate sense if

$$\frac{f_j\left(\delta\right)}{1-F_j\left(\delta\right)} \leq \frac{f_i\left(\delta\right)}{1-F_i\left(\delta\right)}, \quad \forall \delta \in \left[\underline{g}, \overline{g}\right].$$

All three definitions capture different notions of optimism. We show in Appendix A.2 that if F_j dominates F_i in a hazard rate sense, then F_j also dominates F_i 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 4 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 4: Relation between stochastic orders



In Section 2.1, we showed that in the housing-as-investment scenario there were 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. 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 4.

Proposition 4. (Non-parametric predictions) *Compare two borrowers i and j with different distributions F_i and F_j about the growth rate of house prices changes.*
a) In the housing-as-investment scenario, if F_j dominates F_i in a hazard rate sense (or in a truncated expectation sense), 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 dominates F_i 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 4 shows that borrowers' optimism, measured as hazard rate dominance, has opposite predictions in the polar scenarios we consider. 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 4. 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 fact 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.

3 Beliefs and Leverage: Empirical Investigation

The previous sections established that the effect of homebuyer beliefs on leverage choice is ambiguous. If households are willing and able to substantially adjust the size of their property in response to changes in expected house price growth (i.e., the collateral adjustment friction is small), then more optimistic buyers will lever up existing resources more to purchases larger houses. On the other hand, some homebuyers' property choice might be determined by factors related to the consumption aspect of the house, such as family size. In that case, which features a sizable collateral adjustment friction, more optimistic buyers may not increase their housing market investment substantially. When these individuals become more optimistic, the only way to increase their exposure to the housing market is by increasing their downpayment. Similarly, more pessimistic homebuyers might be willing to promise substantially larger repayments in return for having to make a smaller downpayment, because they anticipate a relatively higher probability of defaulting on the mortgage.

In practice, individuals' behavior will be in between the extreme cases studied in Section 2.1. Indeed, whether the collateral adjustment friction is sufficiently large such that more optimistic individuals will choose lower leverage is an empirical question that is central to understanding the role played by homebuyer optimism during housing boom periods. In this section, we analyze the effects on equilibrium leverage of changes in the distribution of borrower beliefs, holding lender beliefs fixed.

Our tests exploit 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. (2016), who show that the recent house price changes experienced within an individual's social network affect that individual's beliefs about the attractiveness of housing market investments; these experiences also affect the actual housing market investment decisions of these individuals, including whether to buy a house and how large a house to buy. 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. (2016) 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 exploit 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 based on IP login information. In addition, for each user we observe 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).

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 two snapshots from Acxiom InfoBase for the years 2010 and 2012.[21] These data are collected by Acxiom, a leading marketing services and analytics company, and contain a wide range of individual-level demographic information 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.[22]

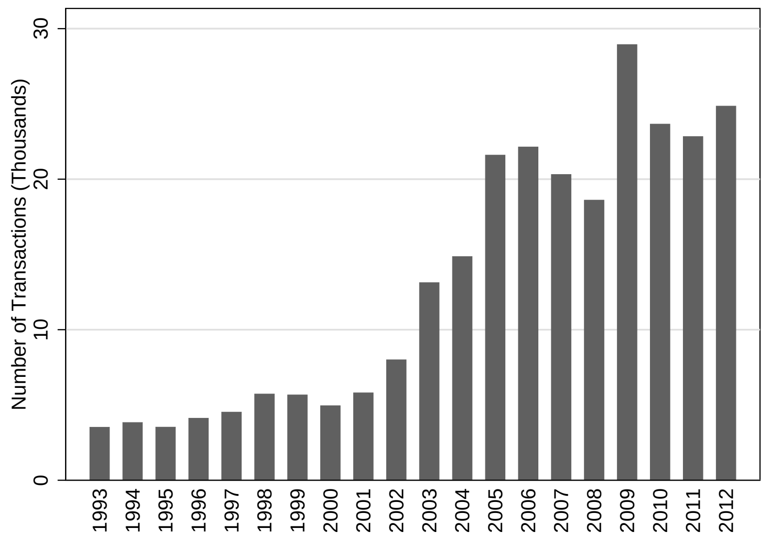
To ensure uniform data in the transaction deeds data, which are originally recorded at the county level, we choose to analyze the leverage choice in transactions within one county. We focus on property transactions from Los Angeles County, the largest U.S. county by population, and are able to match the

[21] 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.

[22] 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.

buyers in about 250,000 housing transactions between 1993 and 2012 to the Facebook data.[23] Figure 5 shows how these transactions are distributed over time. Since we only observe information on transactions that led to ownership spells that were still ongoing as of either one of the snapshots, the number of transactions declines as we go back further in time.

Figure 5: 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.[24] The average combined loan-to-value (CLTV) ratio across all mortgages used to finance the transactions in our sample is 85.5%, but there is substantial heterogeneity in this number. The average purchase price is $474,500, while the median purchase price is $375,000. At the point of purchase, the average buyer was 37 years old, but this ranges from 22 years old at the 10th percentile to 53 years old at the 90th percentile of the distribution.

For the average individual, we observe 400 friends, with a 10-90 percentile range of 60 to 893. The average person has 159 friends that live outside of the Los Angeles commuting zone, and 121 friends that live outside of California. Figure 6 shows the full distribution of the number of friends (Panel (a)) and number of out-of-commuting zone friends (Panel (b)) across individuals 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 50 different counties, with individuals at the 90th percentile having friends in more than 100 different counties. Many of these friends live in housing markets that are far from Los Angeles County: the average person has 27.8% of her U.S. based friends living more than 500 miles away.

There is significant heterogeneity across the homebuyers in our sample in the geographic distribution

[23]In the U.S., whether or not mortgage lenders can pursue defaulting borrowers for any difference between collateral value and outstanding mortgage is determined at the state level. In California, purchase mortgages are considered non-recourse loans, allowing borrowers to walk away from an underwater home; this mirrors our modeling assumption in Section 1.

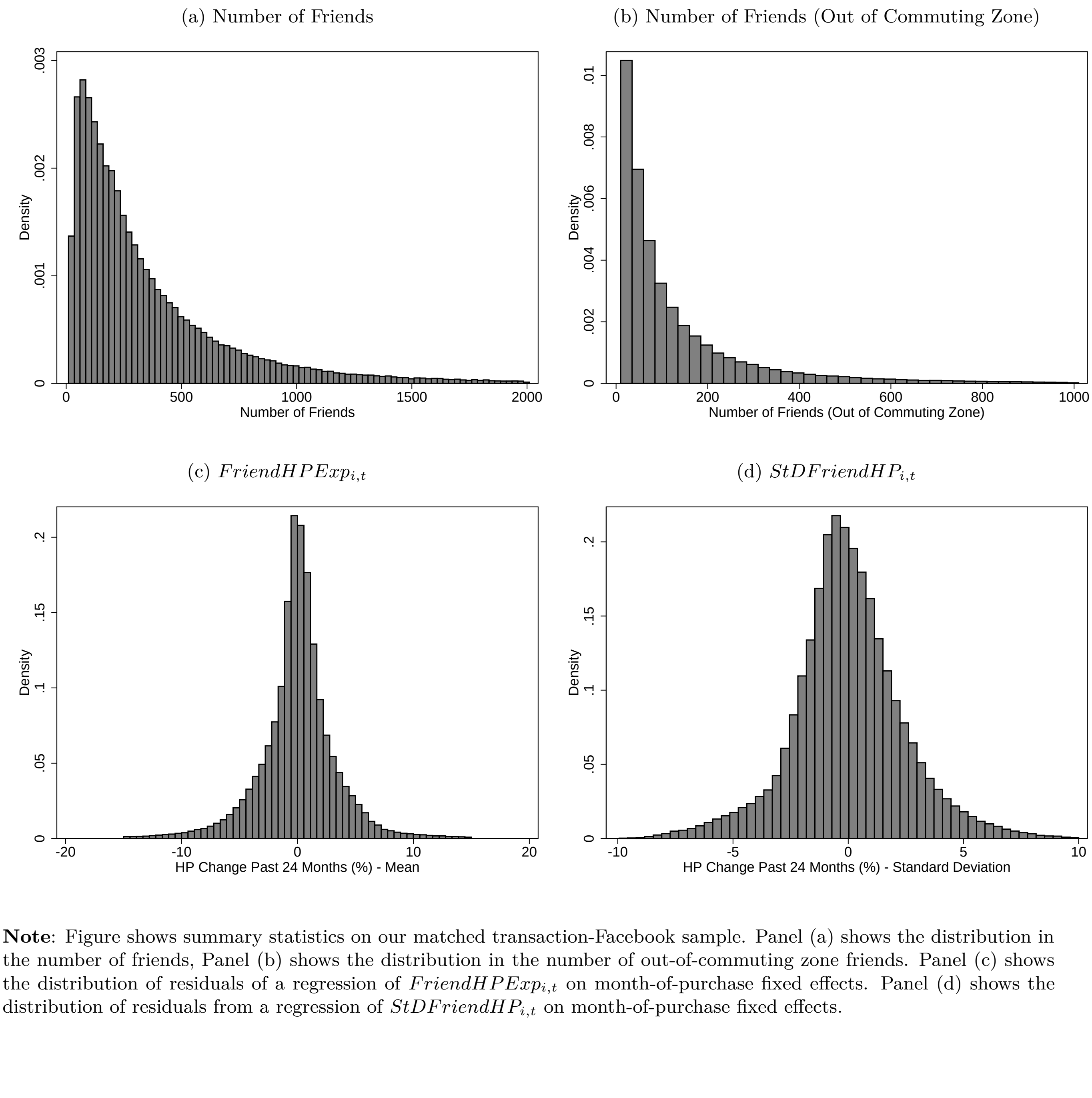
[24]For some of the transactions, the property is purchased by more than one individual, and we can match both individuals to their Facebook accounts. In these cases, we average the set of characteristics, and pool the friends of the two buyers in our calculation of the house price experiences of their friends. Only considering the characteristics and friends' house price experiences of the head of household yields very similar results.

Table 1: Summary statistics

	Mean	Standard Deviation	P10	P25	P50	P75	P90
Network Statistics							
Number of Friends	400.3	491	60	117	244	493	893
Number of Out-of-Commuting Zone Friends	159.4	264	18	34	75	176	370
Number of Out-of-State Friends	121.2	226	12	24	53	125	278
Number of Counties with Friends	50.3	55	12	19	35	62	102
Share friends within 50 miles (%)	50.6	22.4	14.4	36.0	55.3	68.1	76.4
Share friends within 100 miles (%)	53.3	22.3	17.7	39.1	58.1	70.5	78.4
Share friends within 200 miles (%)	61.6	22.8	25.0	48.7	68.2	79.1	85.5
Share friends within 500 miles (%)	72.2	21.3	39.4	62.9	79.5	87.6	92.2
Share friends within 750 miles (%)	74.1	20.4	42.6	65.5	81.2	88.8	93.0
Share friends within 1000 miles (%)	77.6	19.1	48.6	70.6	84.6	91.0	94.5
Share Out-CZ in Pacific CD (%)	36.7	21.2	10.3	20.0	34.7	50.0	66.9
Share Out-CZ in Mountain CD (%)	17.1	13.9	3.1	6.6	13.5	24.2	36.2
Share Out-CZ in West North Central CD (%)	3.3	6.5	0.0	0.0	1.6	3.8	7.4
Share Out-CZ in East North Central CD (%)	7.2	10.2	0.0	1.7	4.4	8.3	15.5
Share Out-CZ in Mid-Atlantic CD (%)	9.6	12.2	0.0	1.6	5.6	12.5	24.0
Share Out-CZ in New England CD (%)	3.0	6.1	0.0	0.0	1.2	3.7	7.1
Share Out-CZ in West South Central CD (%)	9.4	10.3	0.0	3.3	6.7	11.8	19.8
Share Out-CZ in East South Central CD (%)	2.1	4.5	0.0	0.0	0.8	2.7	5.3
Share Out-CZ in South Atlantic CD (%)	11.7	11.1	1.3	4.9	9.1	15.2	23.6
Δ Friends House Prices - Past 24 Months (%)							
Mean - All Friends	4.14	22.52	-29.11	-9.55	2.11	22.19	35.31
St.D. - All Friends	5.59	3.48	1.71	2.89	4.79	7.76	10.69
Mean - Out-of-Commuting Zone Friends	2.94	17.86	-22.63	-9.37	4.72	16.82	25.08
St.D. - Out-of-Commuting Zone Friends	8.41	3.95	4.13	5.32	7.60	10.73	14.12
Purchase Characteristics							
Transaction Price (k$)	474.5	316.5	175	275	375	550	900
Combined Loan-To-Value (CLTV) Ratio	85.5	17.5	68.2	73.3	84.6	100.0	100.0
Buyer Characteristics							
Age at Purchase	36.9	13.6	22.0	29.0	35.0	44.0	53.0
Has Max High School Degree in 2010	0.43	0.50	0	0	0	1	1
Has Max College Degree in 2010	0.38	0.49	0	0	0	1	1
Has Max Graduate Degree in 2010	0.18	0.38	0	0	0	0	1
Income in 2010 (K$)	77.6	41.0	25.0	45.0	62.5	112.5	150.0
Household Size in 2010	2.88	1.62	1	2	3	4	5
Married in 2010	0.57	0.49	0	0	1	1	1
Property Characteristics							
Is SFR	0.73	0.45	0	0	1	1	1
Property Size (Sqft)	1,750	891	954	1,188	1,539	2,081	2,824
Lot Size (Sqft)	9,767	10,296	2,500	7,500	7,500	7,500	17,500
Age of Property (Years)	42.5	25.7	5	22	45	59	78
Has Pool	0.22	0.42	0	0	0	0	1

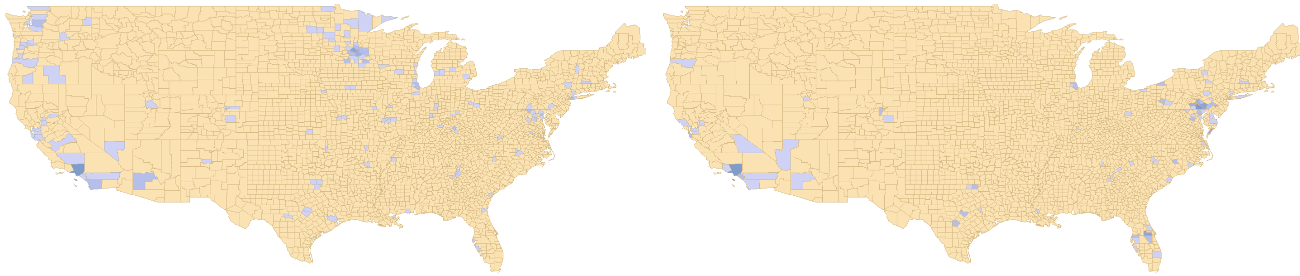
Note: Table shows summary statistics on our matched transaction-Facebook sample. It provides information on the sample mean and standard deviation, as well as the 10th, 25th, 50th, 75th, and 90th percentiles of the distribution.

Figure 6: Summary statistics



Note: Figure shows summary statistics on our matched transaction-Facebook sample. Panel (a) shows the distribution in the number of friends, Panel (b) shows the distribution in 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.

Figure 7: 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.

of their friends. Figure 7 shows a heatmap of the distribution of the friendship networks of two individuals buying a house at the same time and in the same zip code in our Los Angeles sample. Both individuals have a substantial share of their friends live locally. In addition, the individual in the left panel has many friends in the area around Minneapolis, while the individual in the right panel has many friends in Pennsylvania and Florida. Table 1 documents more systematically that the share of out-of-commuting zone friends that individuals have in different census divisions varies widely. For example, the 10-90 percentile range of the share of out-of-commuting zone friends that live in the South Atlantic census division (CD) is 1.3% to 23.6%.

These 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 Los Angeles properties at the same point in time. Let us define the average house price movements across homebuyer i's friends in the 24 month prior to purchasing a property at point t as:[25]

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

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 6 shows the distribution of the residual when regressing $FriendHPExp_{i,t}$ on fixed effects for each purchase month t. The standard deviation of this residual is 3.7%, showing significant variation in friends' house price changes across individuals buying houses in Los Angeles 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

[25] 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.

price experiences across homebuyer i's friends in the 24 months prior to time t as:

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

The average value of $StDFriendHP_{i,t}$ across the transactions in our sample is 5.6%, with a 10-90 percentile range of 1.7% to 10.7%. Panel (d) of Figure 6 shows the distribution of the residual when regressing $StDFriendHP_{i,t}$ on fixed effects for the purchase month t. The standard deviation of this residual is 2.5%: among individuals buying homes at the same point in time, there is substantial variation in house price experiences they are exposed to through their friends.

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 8 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.

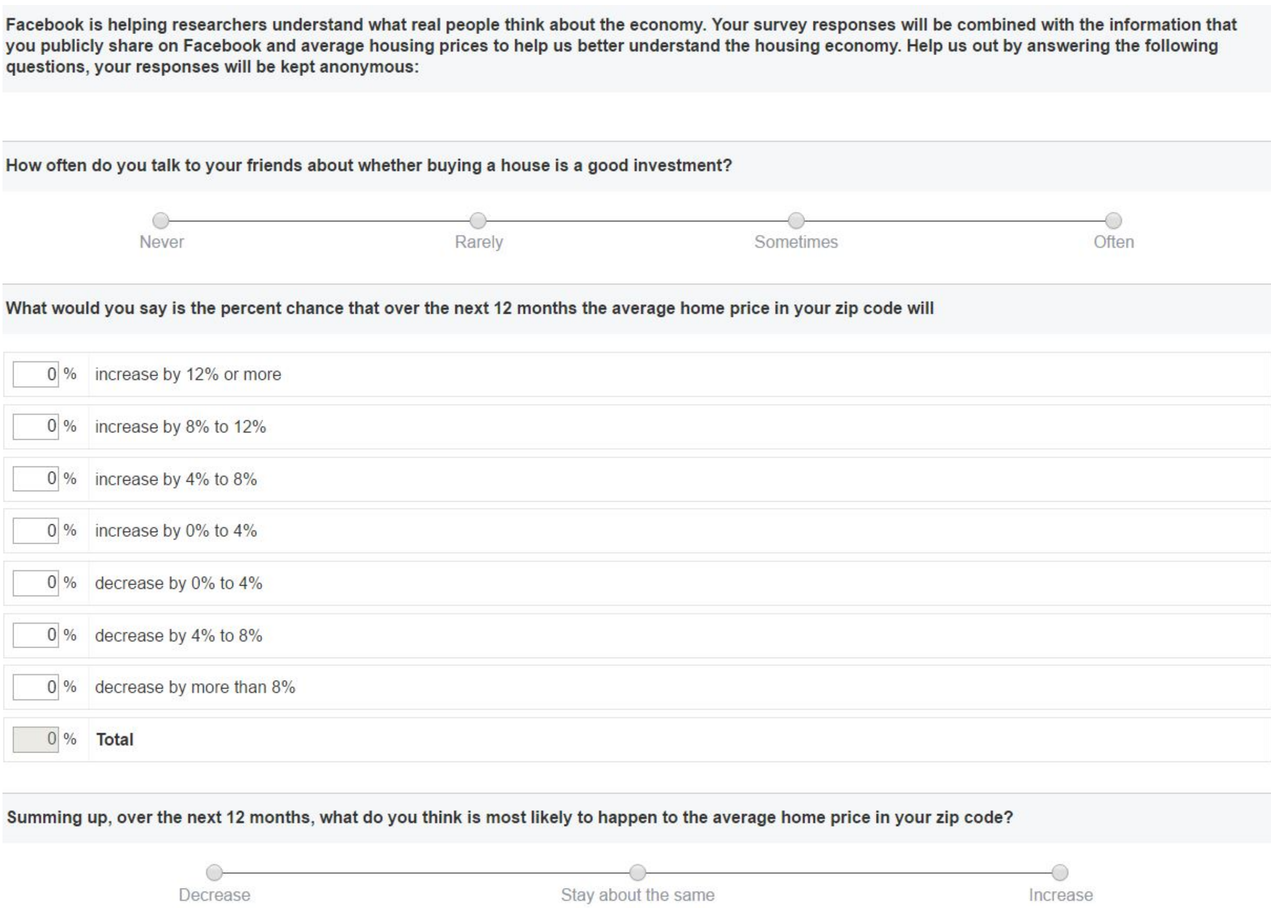
The first survey question elicits how often individuals talk to their friends about whether buying a house is a good investment. Regular conversations with friends about housing investments are important in order for there to be a channel through which the house price experiences of friends can influence an individual's own house price beliefs. Panel (a) of Figure 9 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 possible outcomes 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 determine the mean and standard deviation of the distribution of individuals' house price beliefs.[26] Panels (b) and (c) of Figure 9 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, we analyze how the mean of the belief distribution varies with the answer to the qualitative question 3. Panel (d) of Figure 9 shows the distribution of the means of the belief distributions for

[26] 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 8: Survey Interface


Facebook is helping researchers understand what real people think about the economy. Your survey responses will be combined with the information that you publicly share on Facebook and average housing prices to help us better understand the housing economy. Help us out by answering the following questions, your responses will be kept anonymous:

How often do you talk to your friends about whether buying a house is a good investment?

Never Rarely Sometimes Often

What would you say is the percent chance that over the next 12 months the average home price in your zip code will

0 % increase by 12% or more

0 % increase by 8% to 12%

0 % increase by 4% to 8%

0 % increase by 0% to 4%

0 % decrease by 0% to 4%

0 % decrease by 4% to 8%

0 % decrease by more than 8%

0 % Total

Summing up, over the next 12 months, what do you think is most likely to happen to the average home price in your zip code?

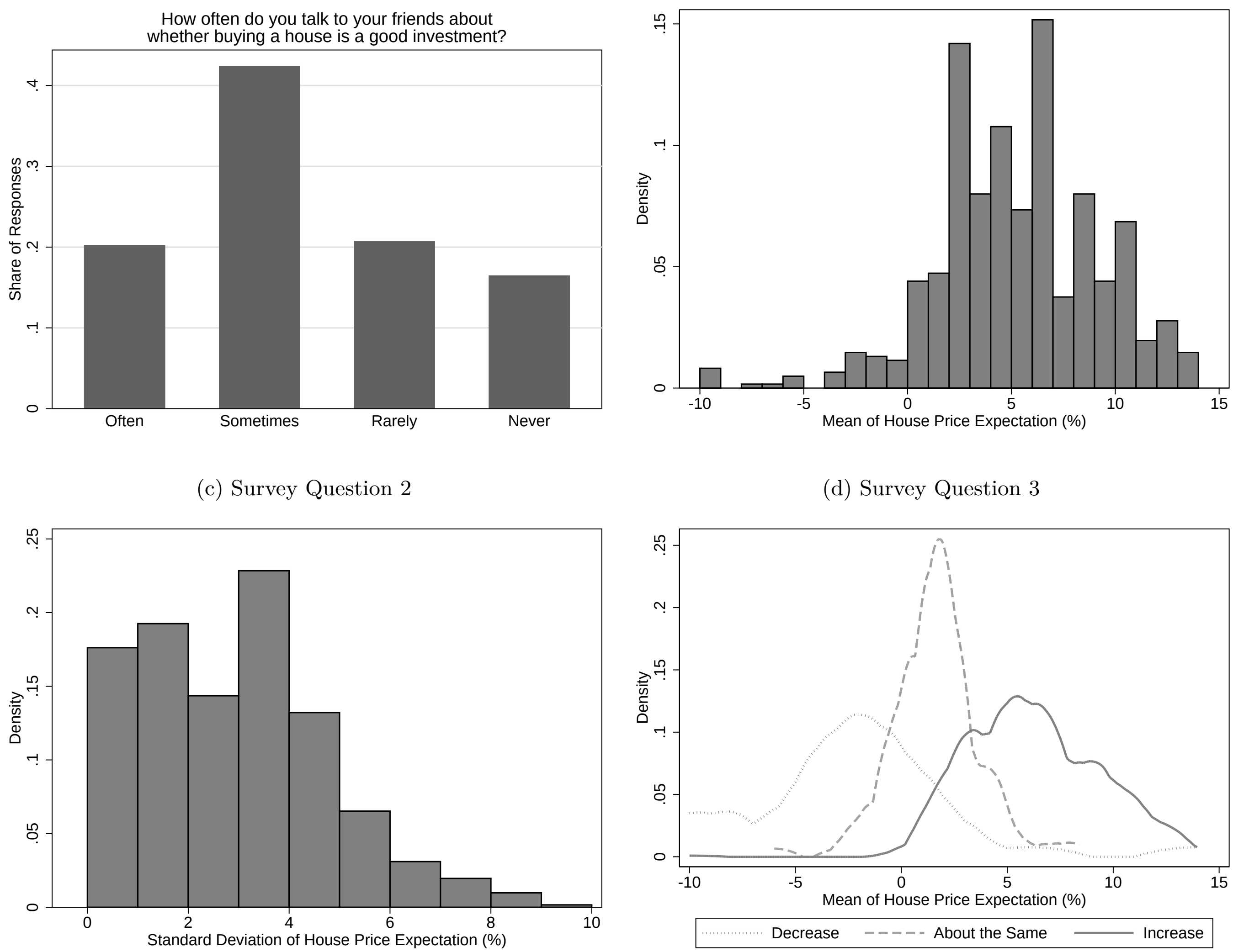
Decrease Stay about the same Increase

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

individuals separately by their responses to Question 3. 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 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

Figure 9: Summary statistics - Survey Responses



(a) Survey Question 1

(b) Survey Question 2

(c) Survey Question 2

(d) Survey Question 3

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.

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: 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** (0.144)	0.322** (0.148)			-0.024 (0.055)
All Friends - St. D			0.027 (0.145)		0.182** (0.089)	0.184** (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 future house price changes in their own zip codes over the subsequent 12 months. In columns 1 to 3, the dependent variable is the mean of individuals' belief distribution, based on their responses to Question 2 of the expectation survey (see Figure 8); in columns 4 to 6, the dependent variable is the standard deviation of this belief distribution. All regression 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, an 6 present instrumental variables regressions, where the moments of the house price experiences of an individual's total 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: * ($p<0.10$), ** ($p<0.05$), *** ($p<0.01$).

Table 2 shows results from regressions of moments of the belief distribution on moments of the experience distribution among a 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 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.[27]

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' geographically distant 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 points increase in individuals' mean belief about house price growth over the coming twelve months. In column 3, we also include the 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 points (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 have the ability to 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 Parametric Tests

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. (2016), we argue that these house price experiences provide shifters of individuals' distributions of beliefs about future house price changes that

[27]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.

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 ratio for transaction i at time t in zip code z, on moments of the distribution of the house price experiences of the friends of the buyer in transaction i. The combined loan-to-value ratio includes all mortgages originated to finance the home purchase. We also control for a rich set of homebuyer characteristics,[28] and include zip code by time fixed effects. This allows us to compare the leverage choice in purchases by otherwise similar individuals at the same point in time.

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

In order to use estimates of β_1 and β_2 to differentiate between the housing-as-consumption scenario and the 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 in Los Angeles, and for whom higher Los Angeles house prices would thus lead to a higher $MeanFriendHP$, might also be more affected by Los Angeles 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.[29]

Table 3 shows the results of regression R1. The baseline estimates in column 1 suggest that individuals whose friends experienced a one-percentage-point higher house price appreciation over the previous 24 months increase their downpayment (and reduce their CLTV ratio) by about 8 basis points. A one within-purchase-month standard deviation increase in friends' house price appreciation is thus associated with a 32 basis points larger downpayment. Combining this with the estimates from the survey analyzed in Section 3.2 suggests that individuals that perceive a one-percentage-point higher house price growth over the coming twelve months would choose a 27 basis points lower downpayment.

Importantly, this finding suggests that individuals behave more like in the housing-as-consumption scenario rather than in the housing-as-investment scenario. This does not mean that more optimistic individuals did not also increase their housing market investments, as in the extreme case with infinite

[28]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.

[29]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 $StDFriendHP_{i,t}$.

Table 3: Main results

	(1)	(2)	(3)	(4)	(5)	(6)
Δ Friends House Prices - Past 24 Months (%)						
Mean	-0.088***	-0.115***	-0.088***	-0.032	-0.278***	-0.132***
	(0.016)	(0.020)	(0.022)	(0.038)	(0.025)	(0.019)
Standard Deviation	0.454***	0.482***	0.567***	0.118*	0.639***	0.276***
	(0.068)	(0.056)	(0.061)	(0.064)	(0.061)	(0.042)
Mean x Mean						0.003***
						(0.000)
Standard Deviation x Mean						-0.006***
						(0.002)
Month FE, Zip x Year FE	Y	Y	N	Y	Y	Y
Borrower Controls	Y	Y, x Year	Y, x Year	Y, x Year	Y, x Year	Y, x Year
Additional Controls and Sample Notes			Zip x Month	1999-2006	2008-2010	
N	249,550	249,544	237,183	92,202	65,431	249,544
R-Squared	0.153	0.164	0.297	0.147	0.164	0.164
Mean Dependent Variable	85.5	85.5	85.6	84.8	85.7	85.5

Note: Table shows results from regression R1. The unit of observation is a home transaction, the dependent variable is the combined loan-to-value ratio in the transaction. All specifications control for homebuyer characteristics (dummy variables for income groups, dummy variables for unique values of household size, family status, occupation, education levels, and age, and dummy variables for each outcome of the number of friends, the number of out-of-commuting zone friends, and the number of unique counties with friends. We also control for zip code by year fixed effects, and month of transaction fixed effects. In Columns 2 to 6, we interact borrower controls with year fixed effects. In column 3 we also include zip code by month fixed effects. Column 4 focuses on the sample of transactions between 1999 and 2006 (a period of rising house prices), while column 5 focuses on the sample of transactions between 2008 and 2010 (a period of falling house prices). Standard errors are double-clustered at the zip code and transaction-month level. Significance Levels: * ($p<0.10$), ** ($p<0.05$), *** ($p<0.01$).

collateral adjustment friction studied above. Indeed, Bailey et al. (2016) document that individuals whose friends experienced higher house price growth did buy larger houses: a one-percentage-point increase in friends' house price experience was associated with purchasing a 0.3 percentage points larger property. Instead, the estimate in column 1 suggests that as individuals got more optimistic, the perceived cost of mortgage financing increased sufficiently fast that more optimistic individuals ended up buying the (slightly) larger and more expensive houses with lower overall leverage. 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 previous 24 months is associated with about half a percentage point increase in leverage. 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 expect to repay their mortgage in fewer states of the world (see Section 2.1). This reduces the perceived cost of mortgage financing, and increases their optimal leverage choice.

In column 2 of Table 3, we interact borrower characteristics with year-of-purchase fixed effect. 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 Los Angeles residents have friends, and would increase the ability of these less-educated Los Angeles residents to make larger downpayments. Reassuringly, our results are essentially unchanged from our baseline specification, suggesting that correlated shocks are not a key driver of our results. We provide additional evidence for this conclusion in Section 3.4.

Our specification in column 1 controls for zip code by purchase year fixed effects, allowing us to compare the leverage choices of similar individuals buying property in the same year and zip code. We argue that these individuals are likely to face a similar set of credit offers from lenders, and that any differences in equilibrium leverage are thus the result of choices by the homebuyers. One possible concern is that lenders might have changed the menu of mortgages choices on offer for different zip codes within the year. To rule out such confounding effects, column 3 includes zip code by purchase month fixed effects. The number of observations declines somewhat, as we drop single observations within a given zip code-month. Again, our results are essentially unchanged.

In columns 4 to 6 of Table 3, we test the predictions from Section 2.1.1, which highlight that in the housing-as-consumption scenario, the effects on optimal leverage of both higher average expected house price growth and higher dispersion in expected house price growth would be smaller during periods when house price expectations were generally high. In these periods, 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.

In column 4, we only consider mortgage originations between 1999 and 2006, a period when most of the U.S. experienced large house price increases, and a period where homebuyers were expecting future house price increases (see Case, Shiller and Thompson (2012), Kuchler and Zafar (2015), and Armona, Fuster and Zafar (2016) for evidence on such extrapolative house price expectations). In column 5, we focus on leverage choice in transactions between 2008 and 2010, a period when most individuals were expecting further house price decreases. Consistent with the predictions from the housing-as-consumption framework, the effects of both the mean and standard deviation of friends' house price changes on leverage choice are significantly larger in absolute terms during the housing bust period than they are during the housing boom period. For example, during the housing boom period, the coefficient on the mean of friends' house price experiences is about a quarter of the size of the average coefficient, and is no longer statistically significant. Column 6 pools transactions across transaction years, but interacts both the mean and standard deviation across friends' recent house price changes with the mean of friends' recent house price changes. Again, we find the effects of both mean and standard deviation of beliefs on leverage to be particularly large during periods of relatively-pessimistic beliefs, when there is a comparatively large disagreement between optimists and pessimists about the probability of default.

Overall, the results in this section suggest that the behavior of the individuals in our sample most closely corresponds to predictions from the housing-as-consumption scenario, with a sizable collateral adjustment friction preventing relatively optimistic homebuyers from purchasing a substantially larger home to live in. 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. Existing research has shown an important role played by investment buyers in the housing market, in particular at the peak of the housing boom (e.g., Bayer et al., 2011). 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 should therefore respond to increasing optimism by buying more houses with higher leverage.

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 leverage choice. As we address these alternative explanations, we note that most of the alternative stories we rule out could have potentially explained the effect of average beliefs on leverage. However, the effect of the dispersion of friends' house price experiences on beliefs and leverage choice are much harder to rationalize with alternative mechanisms. In addition, most alternative channels would not naturally deliver the differential effect of beliefs on leverage during housing boom and housing bust periods.

A first concern we address is that the instruments in our baseline regression, moments of the house price experiences of out-of-commuting zone friends, might still be correlated with the individual's own house price experiences, and therefore potentially with 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 Los Angeles. 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 our sample to transactions 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 aim to 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. 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

Table 4: Robustness Checks

	(1)	(2)	(3)	(4)	(5)	(6)
Δ Friends House Prices - Past 24 Months (%)						
Mean	-0.154***	-0.133***	-0.145***	-0.079***	-0.123***	-0.105***
	(0.027)	(0.023)	(0.027)	(0.021)	(0.067)	(0.058)
Standard Deviation	0.465***	0.339***	0.398***	0.492***	0.259***	0.884***
	(0.057)	(0.064)	(0.079)	(0.056)	(0.191)	(0.161)
Δ Friends Income - Past 24 Months (%)				-0.222***		
				(0.030)		
Month FE, Zip x Year FE	Y	Y	Y	Y	Y	Y
Borrower Controls	Y, x Year	Y, x Year	Y, x Year	Y, x Year	Y, x Year	Y, x Year
Specification Notes	Out-of-State Friends' Experience As Instrument	> 50 Out-of-CZ Friends	> 35 Unique Counties		Non-Geographically Clustered Profession	LA Hometown
N	249,481	156,847	121,850	249,544	29,819	74,456
R-Squared	0.164	0.172	0.174	0.164	0.310	0.240
Mean Dependent Variable	85.5	85.2	85.0	85.5	84.0	86.8

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 R1. 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). In column 6, we focus on transactions in which the buyers grew up in Los Angeles. Standard errors are double-clustered at the zip code and transaction-month level. Significance Levels: * (p<0.10), ** (p<0.05), *** (p<0.01).

moves house prices 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. 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. 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. Reassuringly, 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.

Table 5: Additional robustness checks

	Same Employer		Same College		Family	
	(1)	(2)	(3)	(4)	(5)	(6)
Δ Friends House Prices - Past 24 Months (%)						
Mean	-0.166***	-0.214***	-0.172***	-0.179	-0.119***	-0.148***
	(0.035)	(0.079)	(0.040)	(0.121)	(0.024)	(0.055)
Standard Deviation	0.466***	0.439***	0.407***	0.403***	0.282***	0.269***
	(0.110)	(0.116)	(0.123)	(0.139)	(0.068)	(0.071)
Month FE, Zip x Year FE	Y	Y	Y	Y	Y	Y
Borrower Controls	Y, x Year	Y, x Year	Y, x Year	Y, x Year	Y, x Year	Y, x Year
Specification Notes	All Friends	Same Work	All Friends	Same College	All Friends	Family
N	79,624	79,624	60,397	60,397	149,535	149,535
R-Squared	0.206	0.206	0.229	0.229	0.179	0.179
Mean Dependent Variable	84.3	84.3	84.7	84.7	86.2	86.2

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 R1. In columns 1 and 2, we focus on purchases by people for whom we can identify a network of work friends, in columns 3 and 4 on purchases by people for whom we can identify a network of college friends, and in columns 5 and 6 on purchases by people for whom we can identify a network of 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. Standard errors are double-clustered at the zip code and 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, in column 6 of Table 4, we restrict our sample to individuals who report their hometown to be Los Angeles. For those individuals, the exposure of their expected bequest to non-Los Angeles house price movements is more limited, yet we find the same correlation between the house price experiences of their geographically distant friends and their leverage choice.

In Table 5, we 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 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.[30] 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.

3.5 Non-Parametric Tests

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 2.2, 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.[31] 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 zip code and in the same year, to see whether one distribution dominates the other in a hazard rate dominance sense. We observe about 15 unique transactions in the average zip code-year, and 26 in the median zip code-year. Of all the pairwise comparisons across these transactions, we can rank the distribution of friends' house price experiences for 18.6% of transaction pairs in a hazard rate dominance sense. When comparing the distribution of house price experiences of out-of-commuting zone friends, we can rank the distribution of friends' house price experiences of 18.0% of all transaction pairs in the same zip code and year. About 62% of the transaction pairs that can be ranked using the experience distribution of all the buyers' friends can also be ranked using the experience distribution across the buyers' out-of-commuting zone friends; 65% of the transaction pairs that can be ranked using the experience distribution of the buyers' out-of-commuting zone friends can be ranked using the experience distribution of all of the buyers' friends.

When comparing the mortgage leverage choices across the individuals with a clear ranking using

[30] Bailey et al. (2016) 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.

[31] 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.

the experience distribution of all friends, we find that individuals with an experience distribution that is hazard rate dominant will choose 36 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 54 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.

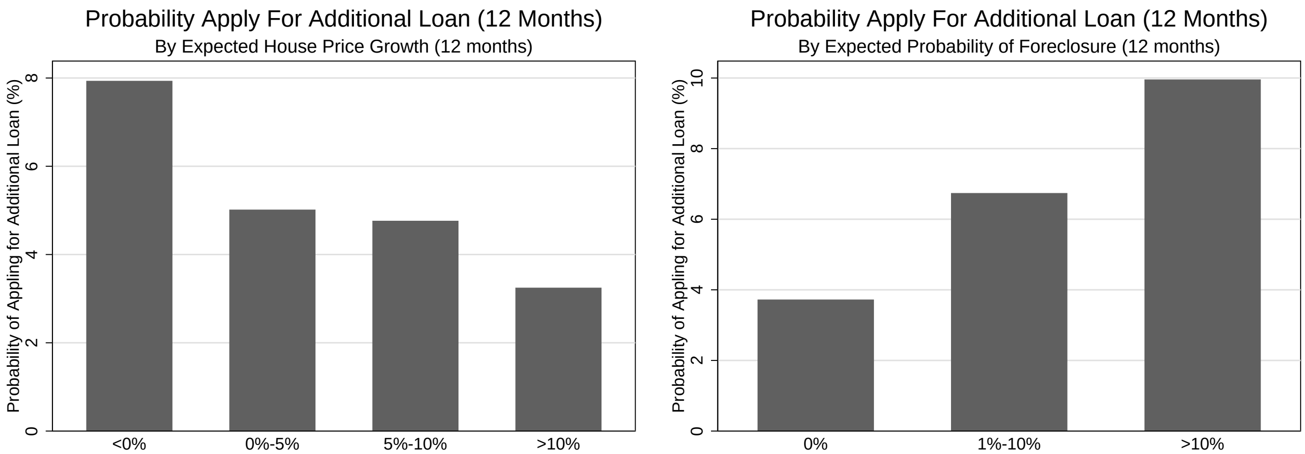
3.6 Leverage Choice and Perceived Probability of Default: Ancillary Evidence

The previous sections documented that more optimistic individuals make larger downpayments, consistent with a significant collateral adjustment friction, and consistent with the directional predictions of the housing-as-consumption scenario. In this section, we provide ancillary evidence for the mechanisms underlying the housing-as-consumption scenario, namely that individuals' beliefs about the probability of default affect their equilibrium leverage choices. First, we consider data from the New York Fed Survey of Consumer Expectations to show that individuals' leverage choice varies systematically with their beliefs about future house price movements. In the second part of this section, we document that financial advice websites and blogs regularly highlight the tradeoffs behind the housing-as-consumption scenario when discussing how large a downpayment households should make.

Survey of Consumer Expectations. First, we analyze survey data from the 2014 Real Estate and Housing Module of the New York Fed Survey of Consumer Expectations.[32] Within these data, we consider the determinants of individuals' 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 10, we consider how the answer to this question differs by characteristics of the respondent. In the left panel, we sort respondents by the expected house price growth they assign to their local neighborhood over the coming 12 months. 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?"

[32] The Survey of Consumer Expectations (SCE) 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.

Figure 10: 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.

In both panels, there is evidence that individuals who are more optimistic are less likely to want to increase leverage going forward. This is consistent with the predictions from the housing-as-consumption scenario, and shows that individuals' leverage choice varies systematically with their house price beliefs and their perceived probability of default. However, 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 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.

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 the extent to which considerations about future house price changes affect leverage choices. We detect many instances of financial advisors highlighting the risk-shifting benefits of taking out smaller mortgages that are at the heart of the predictions of the housing-as-consumption scenario. For example, Ric Edelman, 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. Appendix B.2 shows additional examples of financial advice websites and blogs highlighting that one benefit of a small downpayment is the limited exposure to potential house price declines.

4 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 investment friction), more optimistic homebuyers take on more leverage to purchase larger houses and profit from the greater perceived house appreciation (housing-as-investment scenario). However, when the collateral investment friction is large and considerations such as family size pin down the desired property size, more optimistic homebuyers take on less leverage to finance that property of fixed size, since they perceive a higher marginal cost of borrowing (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 optimistic individuals take on lower leverage, in particular during periods of declining house prices. These findings are consistent with a large collateral investment friction, and map most closely to the housing-as-consumption scenario.

These results contribute to an ongoing research effort trying to understand the drivers of the recent boom-bust cycle in house prices. In particular, increasing homebuyer optimism has become one of the leading explanations of this episode. Our cross-sectional results indicate that, by itself, such increasing homebuyer optimism would have pushed towards counter-factually declining aggregate leverage ratios. On the other hand, we show that changes in the credit supply function, for example because lenders become more optimistic, can naturally induce increases in leverage. This suggests that shifts in credit supply are likely an important component of understanding aggregate price and leverage movements during this period.

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Appendix

A Theoretical Derivations

A.1 Proofs

Properties of $\Lambda_i(\delta_i)$

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

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

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

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

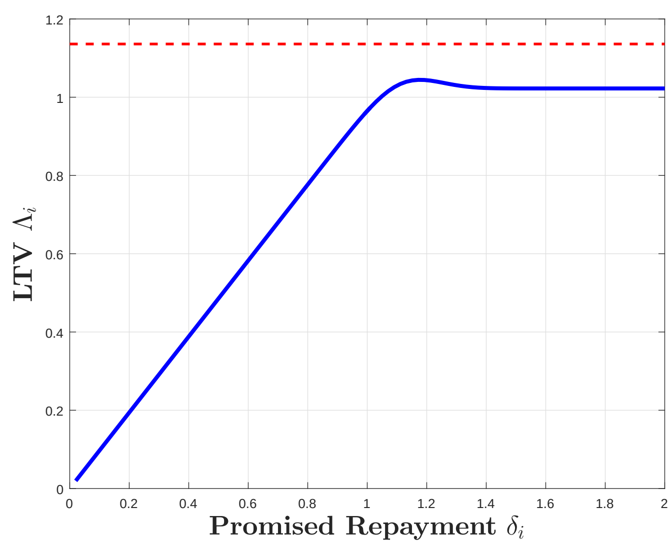
where $\lambda_L(\chi_i \delta_i) = \frac{f_L(\chi_i \delta_i)}{1-F_L(\chi_i \delta_i)}$. In general, $\Lambda_i'(\delta_i)$ can take positive or negative values, depending on the sign of $1 + (\kappa\chi_i - 1)\chi_i \delta_i \lambda_L(\chi_i \delta_i)$. When $\kappa < 1$ or $\chi_i < 1$, the function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

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

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

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: The parameters used in this figure are $\mu_L = 1.3$, $\sigma_L = -0.2$, $\kappa = 0.7$, and $\phi_i = 0$ ($\chi_i = 1$). The dashed line corresponds to $\frac{\mu_L}{1+r}$.

Borrowers' problem

The specification of target regions in Equation (1) guarantees equilibrium existence provided that $n_{0i} > p_0 \underline{h}$, which guarantees that the feasible choice set is non-empty. Exploiting its homogeneity, the problem solved by borrowers can be expressed in terms of the following Lagrangian:

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

The optimality conditions of this problem regarding consumption, promised repayment, and housing choice, correspond to Equations (4) to (5) in the text.

We derive all regularity conditions for the leading case $\phi_i = 0$ ($\chi_i = 1$). Similar conditions apply to the general case. In this case, the borrowers' problem in the housing-as-investment scenario simplifies to

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

and

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

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 leveraged 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 $\chi_i = \kappa = 1$, $\rho_i\left(\delta_i\right)$ 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 $\kappa < 1$, which we assume throughout (or $\chi_i < 1$). In that case, the problem that maximizes the leveraged return on a housing investment always has a well defined interior solution, since $\Lambda_i'\left(\delta_i\right)$ 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 $\frac{\partial J}{\partial c_{0i}} = u_i'\left(c_{0i}\right) - \beta R_i\left(\delta_i\right) = 0$ and $\frac{\partial^2 J}{\partial c_{0i}^2} = u_i''\left(c_{0i}\right) < 0$.

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

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

Borrowers' first order condition corresponds to

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

Borrowers' second order condition satisfies

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

where the second line is only valid at an optimum. 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 (9) and the sustained regularity conditions, it is sufficient to determine the behavior of $\mathbb{E}_i\left[g|g \geq \tilde{\delta}\right]$ to characterize the effect of beliefs on leverage. From Equation (9), it directly follows that if $\mathbb{E}_i\left[g|g \geq \tilde{\delta}\right]$ is point-wise higher for any $\tilde{\delta}$, then δ_i is higher in equilibrium. Under the assumption that $g \sim N\left(\mu_i, \sigma^2\right)$, we can express $\mathbb{E}_i\left[g|g \geq \tilde{\delta}\right]$ as

$$\mathbb{E}_i\left[g|g \geq \tilde{\delta}\right] = \mu_i + \sigma_i \lambda\left(\alpha_i\right),$$

where $\lambda\left(\alpha_i\right) = \frac{\phi(\alpha_i)}{1-\Phi(\alpha_i)}$ and $\alpha_i = \frac{\tilde{\delta}-\mu_i}{\sigma_i}$. The relevant comparative statics of $\mathbb{E}_i\left[g|g \geq \tilde{\delta}\right]$ in μ_i and σ_i are given by

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

where we have used the properties of the Normal hazard rate from Fact 2. These derivations rely on the following two facts: $\frac{\partial \alpha_i}{\partial \mu_i} = -\frac{1}{\sigma_i}$ and $\frac{\partial \alpha_i}{\partial \sigma_i} = -\frac{1}{\sigma_i}\alpha_i$. These results establish the conclusions for the housing-as-investment scenario.

In the housing-as-consumption scenario, given Equation (12) and the sustained regularity conditions, it is sufficient to determine the behavior of $\int_{\tilde{\delta}}^{\overline{g}} dF_i\left(g\right)$ to characterize the effect of beliefs on leverage. Note that

$$\int_{\tilde{\delta}}^{\overline{g}} dF_i\left(g\right) = 1 - F_i\left(\tilde{\delta}\right) = 1 - \Phi\left(\frac{\tilde{\delta}-\mu_i}{\sigma_i}\right).$$

The relevant comparative statics of $1 - F_i\left(\tilde{\delta}\right)$ in μ_i and σ_i are given by

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

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

Proof of Proposition 2. (Boom-bust predictions)

In Proposition 2, we only seek to characterize the direct second-order effect of beliefs shifts. In general, for a general problem of the form $\max_x F\left(x;\theta\right)$, the second derivative of an endogenous variables x to changes in a parameters θ, $\frac{d^2x}{d\theta^2}$, takes the form $\frac{d^2x}{d\theta^2} = \frac{F_{x\theta\theta}}{-F_{xx}} + \frac{F_{xxx}}{-F_{xx}}\frac{dx}{d\theta}$. We focus on characterizing the direct effect $F_{x\theta\theta}$.

In the housing-as-investment scenario, we find that

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

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

In the housing-as-consumption scenario, we find that

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

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

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

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

Proof of Proposition 3. (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 $\frac{\partial \Lambda_i'(\delta_i)}{\partial \mu_L}$.[33] 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:

$$\begin{aligned}\frac{\partial \Lambda_i\left(\delta_i\right)}{\partial \mu_L} &= \frac{\Phi_L\left(\frac{\delta_i - \mu_L}{\sigma_L}\right) + \frac{\delta_i - \mu_L}{\sigma_L}\phi_L\left(\frac{\delta_i - \mu_L}{\sigma_L}\right) + \phi_L'\left(\frac{\delta_i - \mu_L}{\sigma_L}\right)}{1 + r} > 0, \\ \frac{\partial \Lambda_i'\left(\delta_i\right)}{\partial \mu_L} &= \left(1 + (1-\kappa)\,\delta_i\frac{\lambda_L'\left(\delta_i\right)}{\sigma_L}\right)\frac{1 - F_L\left(\delta_i\right)}{1 + r} + \left(1 - (1-\kappa)\,\delta_i\lambda_L\left(\delta_i\right)\right)\frac{1}{\sigma_L}\frac{\Phi_L\left(\frac{\delta_i - \mu_L}{\sigma_L}\right)}{1 + r} > 0,\end{aligned}$$

where we exploit the fact that the cdf of the Normal distribution satisfies $\phi'(x) = -x\phi(x)$. 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 (9) 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 (11) directly implies that upward point-wise shifts on $u_i'\left(n_{0i} - p_0 h_{0i}\left(1 - \Lambda_i\left(\delta_i\right)\right)\right)\Lambda_i'\left(\delta_i\right)$ are associated with a higher equilibrium leverage choice δ_i. Note that

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

whose sign is ambiguous. An increase in μ_L generates both a substitution and an income effect. More optimistic

[33] Note that we can express LTV schedules as

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

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, established the result in Proposition 3.

Proof of Proposition 4. (Non-parametric predictions)

In the housing-as-investment scenario, from Equation (9), it follows that an upward pointwise shift in $\mathbb{E}_i\left[g|g \geq \tilde{\delta}\right]$, $\forall\tilde{\delta}$ is associated with a higher equilibrium value of δ_i.

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.

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

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

to conclude that the more optimistic borrower j takes on more leverage. To this purpose, we can define $h\left(\delta\right)$ 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

$$\begin{aligned} h'\left(\tilde{\delta}\right) &= \frac{\partial\mathbb{E}_j\left[g|\, g \geq \tilde{\delta}\right]}{\partial\delta} - \frac{\partial\mathbb{E}_i\left[g|\, g \geq \tilde{\delta}\right]}{\partial\delta} \\ &= \frac{f_j\left(\tilde{\delta}\right)}{1-F_j\left(\tilde{\delta}\right)}\left[\mathbb{E}_j\left[g|\, g \geq \tilde{\delta}\right] - \tilde{\delta}\right] - \frac{f_i\left(\tilde{\delta}\right)}{1-F_i\left(\tilde{\delta}\right)}\left[\mathbb{E}_i\left[g|\, g \geq \tilde{\delta}\right] - \tilde{\delta}\right] \\ &= \underbrace{\left(\frac{f_j\left(\tilde{\delta}\right)}{1-F_j\left(\tilde{\delta}\right)} - \frac{f\left(\tilde{\delta}\right)}{1-F\left(\tilde{\delta}\right)}\right)}_{>0}\mathbb{E}_j\left[g|\, g \geq \tilde{\delta}\right] + \frac{f_i\left(\tilde{\delta}\right)}{1-F_i\left(\tilde{\delta}\right)}h\left(\tilde{\delta}\right). \end{aligned} \tag{A1}$$

When $\tilde{\delta} \to 0$, it follows from hazard-rate dominance that $\mathbb{E}_j\left[g\right] - \mathbb{E}_i\left[g\right] > 0$. Note that all elements in A1 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.

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 $\phi\left(\cdot\right)$ and $\Phi\left(\cdot\right)$.

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

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

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

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

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

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

3. $\lambda(\alpha)<\frac{1}{\alpha}+\alpha$, $\lambda'(\alpha)=\lambda(\alpha)(\lambda(\alpha)-\alpha)>0$, $\lambda'(\alpha)<1$ 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 $\lambda_j>\lambda_j$, $\forall g$, then it trivially follows that $F_i>F_j$.*

A.3 Generalized environment

Two assumptions crucially allow us to derive tractable analytical results: the risk neutrality of borrowers and our target zone 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,

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

where $w_{1i}^{\mathcal{N}}=n_{1i}+p_1h_{0i}-b_{0i}=n_{1i}+p_0h_{0i}\left(g-\delta_i\right)$ and $w_{1i}^{\mathcal{D}}=n_{1i}-\phi_ip_1h_{0i}=n_{1i}-\phi_igp_0h_{0i}$.

Borrowers' optimality conditions in this case correspond to

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

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

which are the counterparts of Equations (5) and (6) in the main text. We highlight the terms through which the expected return and marginal cost of borrowing channels materialize. Equation (7) corresponds in this case to

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

In this more general scenario, changes in borrowers' beliefs only affect borrowers' decisions insofar as they affect the expected return and marginal cost of repayment terms, which now include marginal utilities. We now study again two particular scenarios.

Risk aversion

First, we 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 (9):

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

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, available under request, 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

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

In this case, it is easy to show that more optimistic borrowers (in a first-order stochastic dominance sense), decide to borrow more. Intuitively, higher optimism is associated with lower precautionary savings and 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 $\frac{\frac{\partial u_i}{\partial h_{0i}}}{p_0} = \alpha \frac{h_{0i} - \bar{h}}{p_0}$. We can in that case express borrowers' optimality condition for housing as

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

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

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

as in the housing-as-consumption scenario.

B Additional Evidence

B.1 Downpayment and Expected Default

As discussed in Section 3.6, 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:

> 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 loose. Yep if you are upside down on your home and have to walk away (or loose to foreclosure) the less down payment you put into it the less you loose.

Similarly, the financial advice website The Mortgage Report discusses:

> A third reason to consider a smaller downpayment is the link between the economy and U.S. home prices. In general, as the U.S. economy improves, home values rise. And, conversely, when the U.S. economy sags, home values sink. Because of this link between the economy and home values, buyers who make a large down payment find themselves over-exposed to an economic downturn as compared to buyers whose down payments are small.
>
> We can use a real-world example from last decade's housing market downturn to highlight this type of connection. Consider the purchase of a $400,000 home and two home buyers, each with different

ideas about how to buy a home. One buyer is determined to make a twenty percent downpayment in order to avoid paying private mortgage insurance to their bank. The other buyer wants to stay as liquid as possible, choosing to use the FHA mortgage program, which allows for a downpayment of just 3.5% At the time of purchase, the first buyer takes $80,000 from the bank and converts it to illiquid home equity. The second buyer, using an FHA mortgage, puts $14,000 into the home.

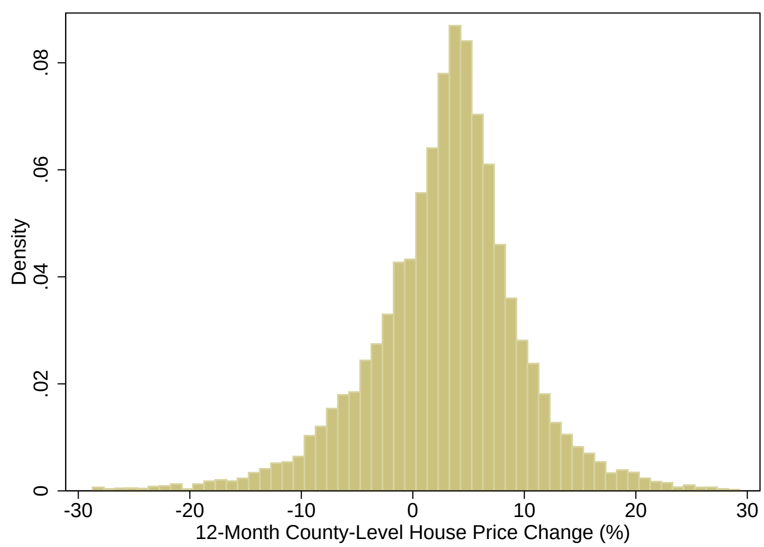
Over the next two years, though, the economy takes a turn for the worse. Home values sink and, in some markets, values drop as much as twenty percent. The buyers' homes are now worth $320,000 and neither home owner has a lick of home equity to its name. However, there's a big difference in their situations.

To the first buyer – the one who made the large downpayment – $80,000 has evaporated into the housing market. That money is lost and cannot be recouped except through the housing market's recovery. To the second buyer, though, only $14,000 is gone. Yes, the home is "underwater" at this point, with more money owed on the home than what the home is worth, but that's risk that's on the bank and not the borrower.

B.2 House Price Changes

Figure A2 shows the distribution of county-year level annual house price changes in the United States since 1993, as measured by Zillow.

Figure A2: 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.