Why did Household Mortgage Leverage Rise from the mid-1980s until the Great Recession?

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Abstract

Between 1985 and 2007, the share of household mortgage debt as a proportion of the total value of housing in the US increased substantially from 30% to an all-time high of 50%. With the decline in house prices, these high levels of leverage increased the propensity at which households defaulted. In this article, we examine household decisions on mortgage leverage using new extensive loan-level data from Fannie Mae over the sample period 1986 to 2010. We conceptualize a market for leverage per se and develop a theory of leverage demand-and-supply. Empirically, we find that borrower's preference for leverage is responsive to economic conditions, falling during major recessions and rising in periods of prosperity, including during the most recent real estate boom. The rise in leverage was also contributed to by shifts in leverage supply in the form of lower mortgage rates and concurrently higher average loan-to-value ratios. Furthermore, we find that in MSAs with higher house prices, households borrowed more and bought equally more expensive houses. That left leverage unchanged but raised households' risk of illiquidity by increasing their loan-to-income ratios. In MSAs with high house price volatility, we find that both leverage demand and supply were lower. We also identify that younger, poorer and less credit-worthy borrowers demand more leverage than their counterparts.

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1 Introduction

In the United States, household mortgage leverage increased dramatically in the run-up to the Great Recession. Figure 1 shows that between 1985 and 2007, the share of household mortgage debt as a proportion of the total value of housing in the US increased substantially from 30% to 50%. With the decline in house prices and subsequently slow de-leveraging, that share further increased to 60% by 2010. These high levels of mortgage leverage increased the propensity at which households defaulted on their mortgages and there is evidence that leverage was a primary driver of the recession (Mian and Sufi (2009), Mian and Sufi (2011)). In fact, it is a characteristic of highly leveraged economies that they seldom avoid a financial crisis (Reinhart and Rogoff (2008)). Furthermore, leverage also plays an important role in partly determining asset prices (Geanakoplos (2009), Lamont and Stein (1999)). As leverage goes up and down, asset prices also go up and down and that is damaging to the economy. Given the crucial role of leverage in the economy, it is imperative that we understand how households determine an optimal level of mortgage leverage. Thus, our objective in this article is two-folds. First, we seek to understand why household mortgage leverage rose so dramatically? Is it leverage demand or leverage supply that primarily lead to an increase in leverage? Second, and to enable us to empirically answer the research question, we conceptualize a market for leverage per se and develop a theory of leverage demand-and-supply.

In our theory of leverage, lenders and households endogenously choose an LTV ratio in a competitive market and under the possibility of default that depends on future house prices. The predictions of the models are intuitive. When house prices are volatile, lenders demand more collateral and if costs of default are high enough, rise-averse borrowers demand less leverage. If, however, default costs are low, then leverage demand increases with increasing house price volatility as the borrower receives all of the upside benefits of more variable house prices while bearing none of the costs. Furthermore, higher average prices (holding all else constant) positively affect future payoffs and thus increase both leverage demand and supply. The model also predicts that the poorer or more impatient the borrowers are, the higher the leverage they demand at any given interest rate.

The theoretical model yields structural demand and supply equations to test econometrically. We identify the demand curve by including the daily Fannie Mae 30-year current-coupon as a supply shifter. We estimate the demand equation and reduced forms of equilibrium interest rates and loan-to-value ratios using extensive loan-level data from Fannie Mae over the sample period 1986 to 2010. We estimate an interest rate elasticity of demand of -0.067, which implies that if the note interest rate dropped from 10% to 5%, then from an initial LTV ratio of 70%, leverage demand would rise by 3.35% to an LTV ratio of 73.3%. This suggests that households are only moderately sensitive to interest rates. Furthermore, we find that (holding all else constant) borrower's preference for leverage is responsive to general economic conditions, falling during major recessions and rising in periods of prosperity, including during the most recent real estate boom.

We also find evidence of an increase in the supply of leverage, effectively making it cheaper to lever up. Specifically, a fall of 1% in the Fannie Mae current-coupon is associated with an average fall of 55bps in the note interest rate. Given that historical rates have been falling, this result suggests that a part of the rise in household leverage is supply-driven, which is consistent with earlier studies (Mian and Sufi (2009)).

Our results on house prices reveal that greater house prices lead borrowers to not only borrow more but to also buy equally more expensive houses. Although this kept leverage virtually unchanged, it raised households' risk exposure. This is because, controlling for income, a high loan amount implies a higher loan-to-income ratio. This amounts to a greater debt service and exposure to greater risk of illiquidity in the future. We also find that in markets with greater house price volatility, both borrowers and lenders contracted at lower LTV ratios, which is consistent with theory.

Our article is related to the research on mortgage contract choice and demand for mortgage debt (Follain (1990), Jones (1993), Brueckner (1994), Follain and Dunsky (1997), Ling and McGill (1998), Hendershott et al. (2002), Hendershott and LaFayette (1997), Leece (2006), Elliehausen (2010)). We complement this research by using a long historical dataset and go beyond debt demand to look at a market for leverage per se. In particular, the demand-and-supply framework is unique in that it helps us in isolating the determinants of (changes in) leverage.

The rest of the paper proceeds as follows. The next section describes the data and certain stylized facts about leverage. Section 3 presents the theory of leverage. Section 4 outlines the empirical strategy and presents the results, and Section 5 concludes.

2 Data and Stylized Facts

Our data are a random sample of single-family home mortgages originated in the U.S. over the period 1986 to 2010 and purchased by Fannie Mae. The raw sample in each year includes approximately 120,000 observations with equal-sized shares of purchase mortgages versus refinance mortgages. For each mortgage we have data summarizing the characteristics of the loan and the underlying property as well as information on the borrower.

The loan-to-value (LTV) ratio is lender submitted and defined as the ratio of the loan amount to the lesser of the sale price or the appraised value of the property. For second mortgages, a combined LTV ratio is calculated using the sum of the current unpaid principal balances of the first and second mortgages. Figures 3 and 4 present empirical cumulative density functions of LTV ratios for purchases and refinances, respectively. For purchases, we see that close to 40% of the data contains LTV ratios below 80%. There is considerable bunching (over 20% of the data) at the 80% LTV ratio, the threshold beyond which Private Mortgage Insurance (PMI) is required for all conforming loans. We see similar bunching at the 90%, 95% and 100% LTV ratios. Some of the purchase LTV ratios even exceed 100%. For refinances, the bulk of the data (close to 80%) is at LTV ratios below 80%. These distributions are suggestive of interior as well as corner solutions to the borrower's problem of choosing an optimal LTV ratio. However, it does not appear to be the case that all borrowers situate themselves at the PMI threshold.

Next, we sub-divide our sample into three separate time periods, 1986 to 1992, 1993 to 2007 and 2008 to 2010. We choose 1992 as the end point of the first period because that year marked the passage of the Federal Housing Enterprises Financial Safety and Soundness Act (FHEFSSA) which had a major impact on the activities of the Government Sponsored Entities.[1] The second, largely prosperous, period between 1993 and 2007 was highlighted by economic growth, low unemployment and an unprecedented rise in house prices. This was followed by a period marking the beginning of the Great Recession from early 2008 which continued until the end of our data in 2010. We see in Figure 5 that the distribution of LTV ratios for purchase mortgages during the 1986 to 1992 period was skewed towards LTV ratios below 80% with relatively few LTV ratios close to 100%. In comparison, the panel for the 1993 to 2007 period shows that the left tail of the distribution became less pronounced with the effect that mass accumulated not only at an 80% LTV ratio but also at very high LTV ratios. In the period following the recession, we see that the mass at 80% LTV rose even further but largely due to a lower density at higher LTV ratios. There was also an increase in the fraction of the data with LTV ratios less than 80%. We see a similar but less pronounced effect for refinances (see Figure 6).

The above discussion suggests that the fraction of risky high LTV ratio mortgages increased over time. In Table 1, we document that the fraction of mortgages with an LTV ratio of greater than 90% increased from 7% in 1992 to over 15% by 1999. In 2007, such loans made up about a fifth of all mortgages in our sample. A similar pattern arises when we look at the behavior of the sampled mortgages' Debt-to-Income (DTI) ratios over time. The DTI ratio is defined as the fraction of the borrower's monthly income that is relied upon in paying the monthly mortgage debt (see histogram in Figure 7). Higher DTI ratios are consistent with riskier mortgages as a greater burden is placed on borrowers' existing incomes to service their mortgages. The fraction of risky high DTI ratio mortgages also increased over time in our sample. For example, in Table 2, we see that the share of DTI ratios between 0.42 and 0.65 increased from less than 10% prior to 1995 to 27% in 2000 and eventually peaked at 41% in 2007.

[1] For example, among other requirements, FHEFSSA mandated GSEs to reach a target percentage of their mortgage purchases to be secured by homes of low- and moderate-income households.

Figure 8 provides a histogram of homeowners' FICO scores. Notice that the histogram is noticeably skewed towards lower FICO scores. In Table 3 we use this FICO information and classify our sampled mortgages into the following three progressively riskier categories: LTV ratio $> 80\%$ and/or FICO score < 660, LTV ratio $> 90\%$ and/or FICO < 620 and finally LTV ratio $> 95\%$ and/or FICO < 580. The share of the latter two categories generally increased over time, particularly starting from 1993 onwards. The middle category saw a decrease in it's share after 2003 but the share of the most risky mortgages (the LTV > 95 and/or FICO < 580 category) kept rising until 2007, when it peaked at 14% of all loans. Consistent with arguments by Acharya et al. (2011) and others, this analysis suggests that the quality of loans purchased by Fannie Mae deteriorated over time.

Having investigated the characteristics of the home mortgages purchased by Fannie Mae, we turn our attention to summary statistics of borrower characteristics. In Table 4 we see that, on average, borrowers' income and FICO scores rose over time. However, if we instead turn to Table 5 where these characteristics are summarized for three different LTV ratio categories, we find that generally poorer, younger and riskier (those with low FICO scores) borrowers are leveraged the highest. Finally, looking at the occupancy status of the underlying properties, we note in Table 6 that the share of mortgages secured by second homes and investment properties steadily increased over time.

In summary, we note the following stylized facts about the mortgages purchased by Fannie Mae. The CDFs of LTV ratios suggest the existence of an interior solution to the problem of a household's LTV choice. The fraction of risky mortgages increased over time, especially after passage of FHEFSSA in 1992. In addition, we document that borrowers who are younger, poorer and with low FICO scores are leveraged more. Finally, the share of mortgages secured by second homes and investment properties has increased over time.

These stylized facts motivate the research questions to be answered in this article. First, how does the borrower arrive at an optimal leverage ratio? Second, what explains the increase in household mortgage leverage over time? Is it due to an increase in borrower demand for leverage or due to a greater supply of it? We now turn to addressing these questions.[2]

3 The Market for Leverage

To investigate households' demand for leverage requires an understanding of the determinants of lenders' incentives to supply leverage as well.

(a) Lender Supply

Lenders in our two-period model are assumed to be risk-neutral and function in a competitive market in which each lender is a price taker. A cash-constrained household must borrow funds from a lender to purchase a house with current value V. Without loss of generality, the initial house value is set equal to one, $V \equiv 1$. Hence, the choice of the loan size, $L < 1$, is analogous to choosing a loan-to-value (LTV) ratio.

The mortgage loan is assumed to be secured by the underlying property and is non-recourse. The lender lends the borrower L in the first period. After consuming the house's service flows, the borrower sells the house at the end of the second period for its then prevailing price, P. The borrower relies on these sale proceeds to pay off the loan. In particular, if P is sufficiently high, the lender receives both principal and interest, which accrues at the exogenously specified rate r. Otherwise, the borrower defaults and the lender's payoff is simply P.

The lender's expected profit is therefore given by:

$$\pi = -L + \eta \int_0^{L(1+r)} P f(P) dP + \eta \int_{L(1+r)}^{\infty} L(1+r) f(P) dP$$

where $f(P)$ is the probability density function of second period house prices and $\eta < 1$ denotes a discount factor.

To derive an analytic solution for the optimal LTV that a lender will supply, we make the simplifying assumption that second period house prices follow a one-period

[2] For further details on the data cleaning process, please refer to the appendix.

binomial distribution

$$P = \begin{cases} P_H \geq L(1+r) & \text{with probability } \theta \\ P_L < L(1+r) & \text{with probability } 1-\theta. \end{cases}$$

In this case, the lender's expected profit simplifies to

$$\pi = -L + \eta(1-\theta)P_L + \eta\theta L(1+r).$$

Assuming zero profits in a competitive market, $\pi = 0$, the lender's supply function is given by

$$L^S = \frac{\eta(1-\theta)P_L}{1-\eta\theta(1+r)}$$

and since $\frac{\partial L^S}{\partial r} > 0$, the lender's leverage supply is an increasing function of the interest rate, r.

The amount of leverage that a lender is willing to supply will also respond to changes in the distribution of second period house prices. Because the borrower can default if second period house prices are not sufficiently high means that the lender has provided the borrower a put option and this will affect the amount of leverage that the lender supplies. In fact, the problem facing the lender of determining how much to lend is precisely the risky debt valuation problem solved by Merton (1974). It follows then that the lender's leverage supply must satisfy

$$L^S = L^S_F - \mathcal{P}$$

where L^S_F is the amount of leverage the lender would be willing to supply if the borrower were risk-free and would not default and $\mathcal{P}$ is the value of a European put option written on second period house prices with strike price equal to amount owed to the lender.[3]

Since the value of a European put option increases when the volatility of the

[3]Valuing the option requires all economic agents have symmetric information and be price takers and that financial markets be complete and frictionless.

underlying security increases, it follows immediately that lenders will supply less leverage in the face of more volatile house prices, all else being equal. Alternatively, the value of the European put option decreases when mean second period house prices increase, implying that lenders increase the supply of leverage with higher mean second period house prices, all else being equal.

(b) Household Demand

In a competitive market for leverage, borrowers are price takers and demand that amount of leverage L which maximizes their expected utility. In addition to purchasing a house and consuming its housing services, borrowers can maximize expected utility by investing in a risk-free asset earning the rate $r_F \leq r$. Unlike lenders who are risk-neutral, a borrower in our two-period model is risk-averse with a utility function assumed to be concave and additively separable over the two periods. In particular, if u denotes the utility function, it follows that $u' > 0$ and $u'' < 0$.

Households must borrow funds to purchase a house because they are cash-constrained. The tradeoff borrowers face is that while increasing leverage increases their first period consumption, expected second period consumption would decrease because of the commensurately higher second period loan payments and the fact that costly bankruptcy becomes more likely.

To fix matters, we assume a household is endowed with wealth of W at the beginning of the first period. The household demands to borrow $L < 1$ and uses a downpayment of $1 - L > 0$ to purchase a house with current value $V \equiv 1$. The surplus remaining in the first period, $W - (1 - L) > 0$, will be consumed by the borrower then.[4] Notice that the household foregoes investing any of this surplus in the risk-free asset because the proceeds can otherwise be used to buy down the household's indebtedness, thereby reducing relatively expensive interest payments and so making the household better off.

The borrower consumes fixed service flows $\alpha > 0$ from the house in both the first

[4] Harrison et al. (2004) make this assumption explicit in their borrower's objective function. It is implicitly assumed in the model by Brueckner (2000).

as well as second periods. The house is then sold at the end of the second period for P and these sale proceeds are used by the borrower to pay off the loan. If the second period house price P exceeds the amount owed, $L(1+r)$, the household pays the amount owed in full. If, however, the second period house price falls below the amount owed, the borrower defaults and incurs bankruptcy costs which depend on both the amount of leverage and prevailing house prices, $C = c(L, P)$ with $\frac{\partial c}{\partial L} > 0$ and $\frac{\partial c}{\partial P} < 0$.

The bankruptcy cost function attempts to realistically capture in the context of our two period model the cost implications of resolving financial distress. To do so, bankruptcy costs are explicitly linked to the severity of the borrower's financial distress. The more severe financial distress is, the less likely an inexpensive resolution of the borrower's difficulties through, for example, a loan modification or loan forgiveness and the more likely foreclosure, Foreclosure is expensive and results in the borrower being evicted. We capture the severity of the borrower's financial distress by measuring the borrower's leverage, L, relative to the house price in default, P_L. In particular, the greater the leverage L relative to a given house price P_L, the more severe the borrower's financial distress and the higher bankruptcy costs. Alternatively, the lower the house price P_L for a given amount of leverage L, the more severe the borrower's financial distress and the higher bankruptcy costs.

Continuing with the simplifying assumption that second period house prices follow a one-period binomial distribution, the household's expected utility is therefore given by:

$$\mathcal{E} = u[W - 1 + L + \alpha] + \delta\theta u[P_H - L(1+r) + \alpha] + \delta(1-\theta)u[\alpha - c(L, P_L)]$$

where $\delta < 1$ denotes the borrower's patience or discount factor.

Maximizing the borrower's expected utility with respect to leverage, L, gives the following first-order condition:

$$u'[W - 1 + L + \alpha] - \delta\theta(1+r)u'[P_H - L(1+r) + \alpha] - \delta(1-\theta)\frac{\partial c}{\partial P_L}u'[\alpha - c(L, P_L)] \overset{set}{=} 0 \quad (3.1)$$

From expression (3.1), the household's optimal leverage demand can be implicitly written as:

$$L^D = L^D[r, P, W, \delta].$$

Comparative statics of optimal leverage demand provide a number of insights into borrowers' behavior. First, taking the derivative of expression (3.1) with respect to r, we have that[5]:

$$\frac{\partial L^D}{\partial r} < 0.$$

That is, a household's demand for leverage decreases as the interest rate charged by lenders increases. Intuitively, a higher r decreases second period consumption, all else being equal, and the household decreases leverage in response to smoothen consumption across the two periods.

The optimal demand for leverage is also decreasing in borrower patience δ:

$$\frac{\partial L^D}{\partial \delta} < 0.$$

This implies that less patient borrowers, for example, younger borrowers, who value future consumption less will demand more leverage.

Also, the optimal demand for leverage is decreasing in borrower wealth:

$$\frac{\partial L^D}{\partial W} < 0.$$

That is, the marginal increase in first period consumption resulting from an increase in leverage is less desirable for wealthier households and so these households demand comparatively less leverage.

Finally, the optimal demand for leverage depends on the distribution of second period house prices. For example, leverage demand is increasing in average second period house prices holding the variability of second period house prices, as measured by their range, constant. In particular, by increasing both P_H and P_L by one unit,

[5]Proofs of this and the other following properties are available upon request.

the mean of second period house prices increases while leaving the range unaffected and we have

$$\frac{\partial L^D}{\partial P_H} + \frac{\partial L^D}{\partial P_L} > 0.$$

That is, if the second period house price distribution P first-order stochastically dominates a distribution P' then

$$L^D[P] \geq L^D[P'].$$

However, the effect on leverage demand if the range of second period house prices increases while holding the mean second period house price constant is ambiguous. That is, increasing P_H by one unit while decreasing P_L by one unit preserves mean house prices while being riskier in the Diamond-Rothschild-Stiglitz mean-preserving spread sense but gives

$$\frac{\partial L^D}{\partial P_H} - \frac{\partial L^D}{\partial P_L} \lesseqgtr 0.$$

Intuitively, the effect of house price volatility on leverage demand depends on how large the bankruptcy costs are relative to the service flow α provided by the house. If costs are low enough then leverage demand increases with increasing house price volatility as the borrower receives all of the upside benefits of more variable house prices while bearing none of the costs. Alternatively, if costs are large enough then leverage demand will fall with increasing house price variability.

To derive additional results regarding household leverage demand requires us to specify the borrower's utility function. We assume that the borrower's utility function is iso-elastic

$$u(c) = \begin{cases} \frac{c^{1-\rho}}{1-\rho} & \text{for } \rho > 0, \rho \neq 1 \\ log(c) & \text{for } \rho = 1 \end{cases}$$

where γ denotes the borrower's coefficient of relative risk aversion.

Unfortunately, the borrower's first-order condition can now no longer be solved analytically even with second period house prices following a one-period binomial distribution. We therefore use numerical methods to derive the household's optimal leverage demand for various parameter assumptions.

In our base case, we assume that the borrower has wealth of only $W = 0.5$ in the first period to purchase a house having value of $V = 1$. The house provides a service flow of $\alpha = 0.1$ in each of the first and second periods and with probability $\theta = 0.5$ the house price is either $P_H = 1$ or $P_L = 0.7$ in the second period. We assume a borrower's discount factor of $\delta = 0.8$ while the borrower's coefficient of relative risk aversion is $\rho = 0.9$. In the event of default by the borrower, bankruptcy costs of $c = 0.05 \times \frac{L}{P_L}$ are incurred. The resultant borrower's leverage demand function is graphically displayed in Figure 9 (a) where we also depict the corresponding lender's leverage supply function where, in addition, we assume a discount rate of $\eta = 0.9$.

Figure 9 (b) explores the effects of changing relative risk aversion on the borrower's leverage demand function. In particular, we increase the coefficient of relative risk aversion to $\gamma = 2$, holding all other parameter values unchanged. Notice that with greater risk aversion, the borrower's leverage demand function shifts inwards as the borrower now demands less leverage for a given interest rate r. Intuitively, being more risk averse means that the borrower is less willing to take the larger gamble on second period house prices that more leverage entails.

In Figure 9 (c) we increase bankruptcy costs to $c = 0.08 \times \frac{L}{P_L}$ in the event of default by the borrower, holding all other parameter values unchanged. As expected, borrowers now demand less leverage for a given interest rate r and the borrower's demand function shifts inwards.

The effects of an increase in the variability of second period house prices on borrower's leverage demand is investigated in Figure 9 (d). When default costs are low relative to the baseline, ($c = 0.03 \times \frac{L}{P_L}$), a mean-preserving spread in the house price distribution leads the borrower to demand more leverage, a type of option effect. If, however, the default costs are high relative to the baseline ($c = 0.08 \times \frac{L}{P_L}$), a risker house price distribution leads the borrower to demand less leverage. In the figure, we also show that in a market with higher average house prices than in the baseline (but similar volatility), households would demand more leverage.

4 Empirical Analysis

(a) Empirical Strategy

The model of leverage derived in the previous section yields two structural equations describing the demand and supply of leverage, which we specify as follows:

$$L = \beta_0 + \beta_1 r + X\beta_2 + T\beta_3 + \epsilon \tag{4.1}$$

$$r = \gamma_0 + \gamma_1 L + X\gamma_2 + T\gamma_3 + \gamma_4 \text{FMAE CRNT-COUPON} + \nu \tag{4.2}$$

Leverage demand is given by (4.1), where LTV (L) is a linear function of the note rate (r), a matrix of exogenous variables representing borrower and market characteristics (X), and a matrix of yearly time dummies (T). Similarly, leverage supply is given by (4.2), where the note rate (r) is a linear function of LTV (L) and the same X and T matrices of characteristics and time dummies. In addition, we include the daily Fannie Mae 30-year current-coupon (FMAE CRNT-COUPON) as a supply-shifter. Since lenders refer to the current coupon's interest rate for a baseline rate when they are writing mortgages, the current-coupon is an ideal instrument as it is both exogenous to the rate written on individual mortgages and also affects the cost of borrowing for all households.

In both of our structural equations, X does not contain any specific demand-only or supply-only variable. This is because our dataset does not contain any variable that is observed only by the borrower and not by the lender, and vice versa. Thus, the only variable excluded from the demand equation is the Fannie Mae current-coupon (FMAE CRNT-COUPON). It is easy to see that (4.1) is just-identified.[6] Furthermore, since there are no demand-only variables, the supply equation, (4.2),

[6] The demand equation, (4.1), has one exclusion restriction and one normalization (coefficient on L is 1). Thus, the sum of the restrictions (2) adds up to the number of endogenous variables (2). Since the order condition is satisfied with equality, (4.1) is just-identified. The rank condition also holds as long as the coefficient on (FMAE CRNT-COUPON) in the supply equation is not zero ($\gamma_4 \neq 0$). The supply equation, (4.2), fails the order condition as there is only one restriction (normalization on r) which is less than the number of endogenous variables (2). Thus, (4.2) is not identified.

is not identified. However, looking at the reduced form, the coefficient on FMAE CRNT-COUPON is uncontaminated and it's estimate would help answer how leverage supply has changed due to exogenous changes in this supply-shift variable:

$$L = \pi_0 + X\pi_1 + T\pi_2 + \beta_1\gamma_4 \text{FMAE CRNT-COUPON} + u_1 \tag{4.3}$$

$$r = z_0 + Xz_1 + Tz_2 + \gamma_4 \text{FMAE CRNT-COUPON} + u_2 \tag{4.4}$$

The coefficient on FMAE CRNT-COUPON in (4.4) also allows for an indirect least squares estimate of the interest rate elasticity of leverage demand (β_1). This would be obtained by dividing the reduced form coefficient on FMAE CRNT-COUPON in (4.3) by that in (4.4).

We estimate (4.3) and (4.4), equation by equation using OLS.[7] We also estimate the leverage demand equation, (4.1), via 2SLS. Since leverage demand is just-identified, a limitation is that we cannot perform a test of over-identifying restrictions. In the case of purchase mortgages, we also separately estimate the numerator and denominator in LTV, i.e. loan and housing demand (V) regressions, using the same exogenous variables. This is because in our theory, we derived results on leverage under the assumption that the housing demand decision was given outside the model. Empirically, the house purchase decision cannot be included in the leverage regressions as it is an endogenous decision. By including it as a separate reduced form regression, it allows us to better understand the leverage decision.

(b) Results

The estimates for the structural leverage demand equation are shown in Table 7 while the reduced form estimates are shown in Table 8.

Leverage Demand: The 2sls estimates for purchase mortgages are shown in the first column of Table 7. The estimate on the note interest rate is -0.65, which is also

[7] It is well known that in a system of linear *seemingly unrelated regression* equations with identical regressors, equation by equation OLS yields efficient parameter estimates.

verified via indirect least squares.[8] Equivalently, a log-log estimate[9] gives an interest rate elasticity of leverage demand of -0.067.[10] This implies that a 10% increase in the note rate leads to a -0.67% decrease in the loan-to-value ratio. A few numerical examples illustrate this effect. From an *r-LTV* combination of (5%, 100%), if the rate increases to 6%, then this would lead to 1.34% [2 x 0.67%] fall in LTV to 98.6%. Starting from an *r-LTV* combination of (10%, 70%), a subsequent fall in interest rates to 5% would lead to a 3.35% [5 x 0.67%] increase in LTV to 73.3%. These estimates suggest that, holding all else constant, households are only moderately sensitive to interest rates on 30-year fixed purchase mortgages. Furthermore, holding note rate and all else constant, the year dummies can be interpreted as changes in taste or preference of borrowers for LTV. These dummies are used in Figure 10 to trace the evolution of LTV demand, starting with an LTV of 72% (sample mean) for 1986. The first thing to note is that LTV demand is responsive to general economic conditionals. Historical events, such as major recessions, that would be expected to negatively effect households and real estate markets are indeed reflected in down-ticks or falls in leverage demand. LTV demand was relatively healthy during periods of steady economic growth and particularly strong in the most recent real estate boom. We now turn to look at leverage supply.

Leverage Supply: As argued in the previous section, the coefficient on FMAE CRNT-COUPON in the reduced form note rate regression in Table 8 is uncontaminated and gives it's structural marginal effect. In the note rate regression (first column of Table 8), an increase in the yield on the current-coupon by 1% is associated with a correspondingly higher average note rate by 55 basis points. This of-course reflects the fact that the current coupon is a measure of a rate that most accurately reflects the current state of the market. This also implies that the general trend of falling yields over the past couple of decades have lead to drops in the av-

[8] The coefficients on FMAE CRNT-COUPON in Table 8 provide an indirect estimate by dividing the coefficient in the LTV column by that in the Note Rate column ($\frac{-0.3599}{0.5532} = -0.6506$).

[9] There is however a slight attenuation bias in that regression due to the fact that ln(1) is undefined.

[10] This estimate is slightly lower (-0.0416) when using real note interest and real Fannie Mae current-coupon.

erage note rate, implying that there has been a general outward shift in the supply of leverage over this period.

House Prices: We next turn to the MSA Ln House Price Level variable in Table 7, constructed by first creating a series of average house price levels (for MSAs) in 2000 using the 5% PUMS sample of the Census, and then extrapolating those price levels using the quarterly MSA house price (repeat-sales) indices published by the Federal Housing Finance Agency (FHFA).[11] Thus, this variable measures, over time, the log house price level both across MSAs and within an MSA. In Table 7, we find that a 10% increase in the average house price level leads to a fall in the LTV ratio demanded by an economically small 0.56 percentage points (combined with a virtually insignificant fall in the rate shown in Table 8). Examining the Ln Loan and Ln Price regressions in Table 8, we find that this 10% increase in house prices leads borrowers to increase the size of their loans by 4.9% and to buy houses that are 5.7% more expensive.[12] Our borrower model predicted that with higher average prices, the borrower should be levered more. However, that result was derived based on a fixed value of house whereas empirically we find that borrowers roughly offset larger loans with equally expensive house purchases (holding all else equal), which implies that they put down more in equity. Moreover, since we control for income in the regression, a higher loan amount implies a higher loan-to-income ratio. This may mean greater debt service and exposure to greater risk of illiquidity in the future. There is corroborating evidence in a study at the aggregate MSA level in which Goetzmann et al. (2011) find that based on past price appreciation, households borrowed more and purchased more expensive houses. This subsequently lead to an increase in the loan-to-income ratio, again implying that households were at a greater risk.

House Price Volatility: The 2-year back, MSA De-trended Ln HPI Quarterly Volatility variable in Table 7 is simply the de-trended log volatility of the FHFA repeat-sales indices (lagged by 8 quarters).[13] In Table 7, a increase of 10% in the

[11] Further details on the construction of this variable can be found in the data appendix.

[12] The difference 5.7% - 4.9% = 0.8%, fall in LTV can be shown in a regression where the dependent variable is Ln LTV.

[13] These results are robust to slightly shorter and slightly larger windows of lag. We do not

past house price volatility leads to a fall in the demand for leverage by 0.2 percentage points, which is consistent with the borrower theory. This latter figure is small because the magnitude of log volatility is less than 0.5, which implies that a 10% increase is a small change (e.g 10% increase from 0.1 is 0.11). Moving to the reduced form estimates in Table 8, the coefficient on HPI Volatility is positive in the note rate regression and more negative in the LTV regression, suggesting that the net effect of higher past price volatility is that lenders supply less leverage. This is because greater house price volatility increases the risk of borrower default which adversely affects expected profits. Consistent with our theoretical model, lenders would supply less leverage. Also in Table 8, the same 10% increase in past volatility, leads to a fall in the loan amount and the purchase price by 2.5% and 2.3%, respectively.

Borrower Characteristics: Looking at the Borrower's Total Monthly Income Amount variable in Table 7, we find that borrowers with monthly incomes higher by $5,000 lever less by an economically insignificant amount (0.38 percentage points) and (in Table 8) pay a rate that's only 1.6 bps less. Furthermore, the coefficients in the Ln Loan and Ln Price columns reveal that such borrowers not only carry a loan that's bigger by 11.4% [2.28e-05 x 5,000 x 100%] but they also buy a house that's 11.8% more expensive. This would explain why the leverage ratio would fall by a very small amount.

Next, we find in Table 7 that borrowers with bad credit scores demand more leverage. For example, a decrease in the Borrower Credit Score by 100 leads to an LTV ratio that is higher by 5.4 percentage points and (in Table 8) a note rate higher by 23 bps. Also from Table 8, borrowers with credit scores lower by 100 take out loans smaller by 4% and buy houses that are less expensive by 11%. To the extent that credit scores serve as a signal of riskiness and/or reflect the (asymmetric) default costs of a borrower, this result would be consistent with the predictions of models by Brueckner (2000) and Harrison et al. (2004). The reason is that riskier borrowers (those with low default costs) self-select into higher LTV ratios.

Our next finding is that the demand for leverage is monotonically decreasing

use longer windows as we lose considerable data. Shorter windows, on the other hand, make the calculation of standard deviation much less reliable.

with age. In Table 7, the base age group is 16-to-24 years and we add four age group dummies of 25-to-34, 35-to-49, 50-to-64 and above 64 years. Each age group demands lower leverage relative to the base group and to groups that are younger to it. For instance, the age group 35-to-49 levers 5.9 percentage points less than the base group and about 4.2 percentage points less than the 25-to-34 age group. Furthermore, a test of equality on the leverage ratios for every pair of these dummy variables rejects the null hypothesis that these groups behave the same. To the extent that older borrowers are more patient and value future wealth more than younger borrowers, we would expect to find that the demand for leverage falls with age (consistent with our borrower model).

Gender, Race, Occupancy and Refinances: In Table 7, women demand less leverage than men. Relative to whites, the demand for leverage is higher for all other races. These results are interesting but inconclusive due to a lack of information on other unobservables, such as other wealth, that may be correlated with these characteristics. The demand for leverage on second homes and investment properties is greater than that on first homes. Interestingly, the rate on an investment property is about 53 bps higher whereas it is higher by only 6 bps for second homes (Table 8), possibly reflecting more stringent underwriting for investment properties in general. Also, the reduced form LTV estimate is less positive than it's structural counterpart. This implies that leverage supply is lower for investment properties. Finally, results for refinance mortgages are consistent with the findings for purchases.

5 Conclusion

Why did household mortgage leverage rise from the mid-1980's until the Great Recession? We conclude that outward shifts in leverage supply and an increase borrower preference for leverage during the recent real estate boom both contributed to the rise in household leverage. In this article, we developed a theory of leverage demand-and-supply. Our empirical results document the effects of house prices and borrower characteristics on household leverage. We find that greater house price volatility reduces LTV ratios while greater house prices lead borrowers to borrow more and buy more expensive houses. The effect of the latter was to keep leverage unchanged but it raised households' exposure to risk of illiquidity by increasing their loan-to-income ratios. We find that poorer, more impatient and less credit-worthy borrowers demand more leverage than their counterparts.

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Appendices

A Figures

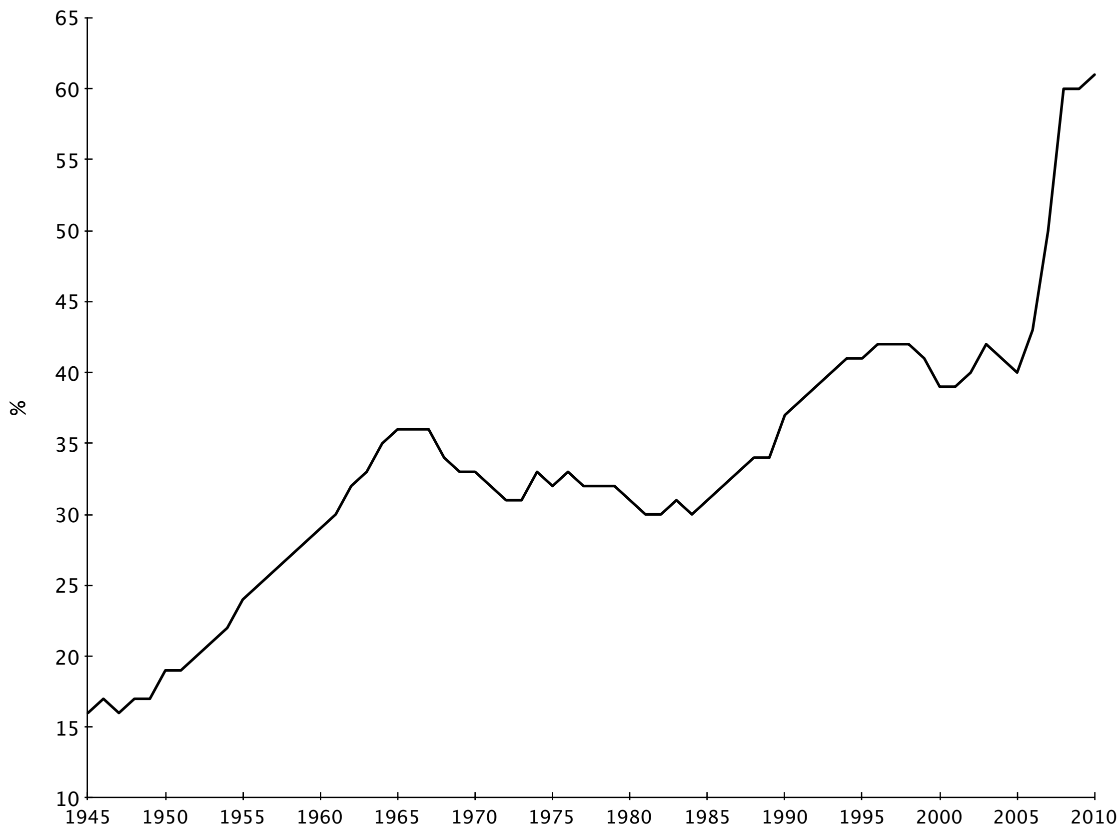


Figure 1: Mortgage Debt as a Percentage of Total Value of Housing

Source: Federal Reserve Household Balance Sheet

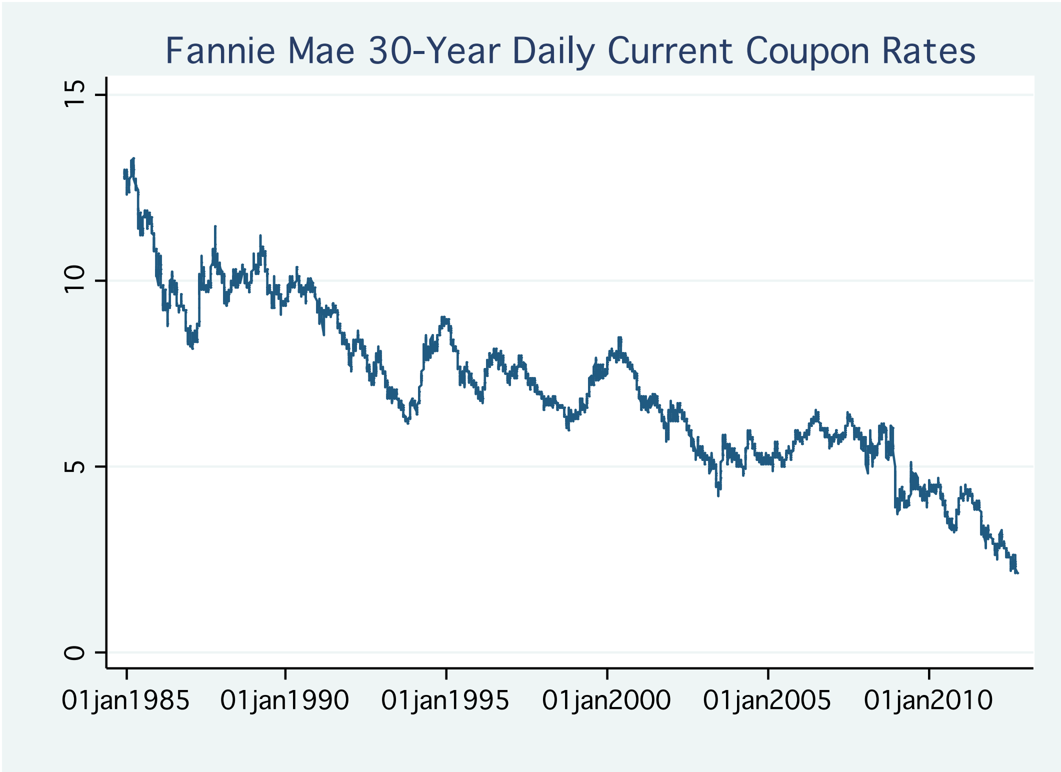


Figure 2: Daily Fannie Mae 30-Year Current Coupon Rates - 1985 to 2012

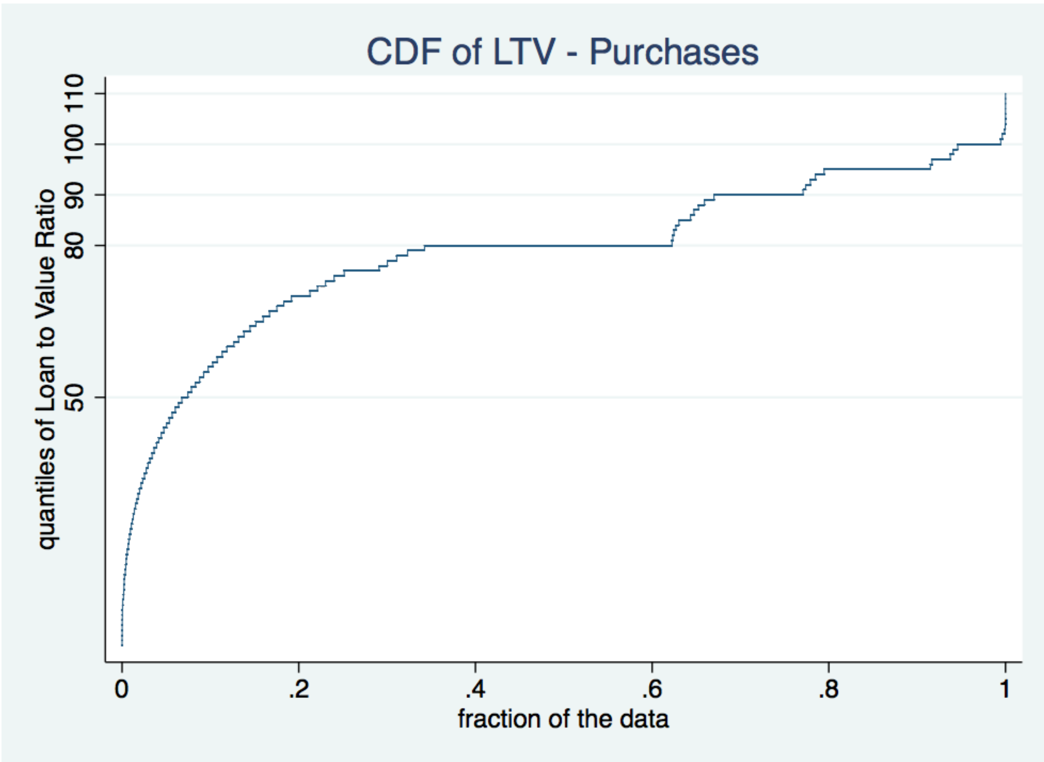


Figure 3: Cumulative Density Function of LTV - Purchases

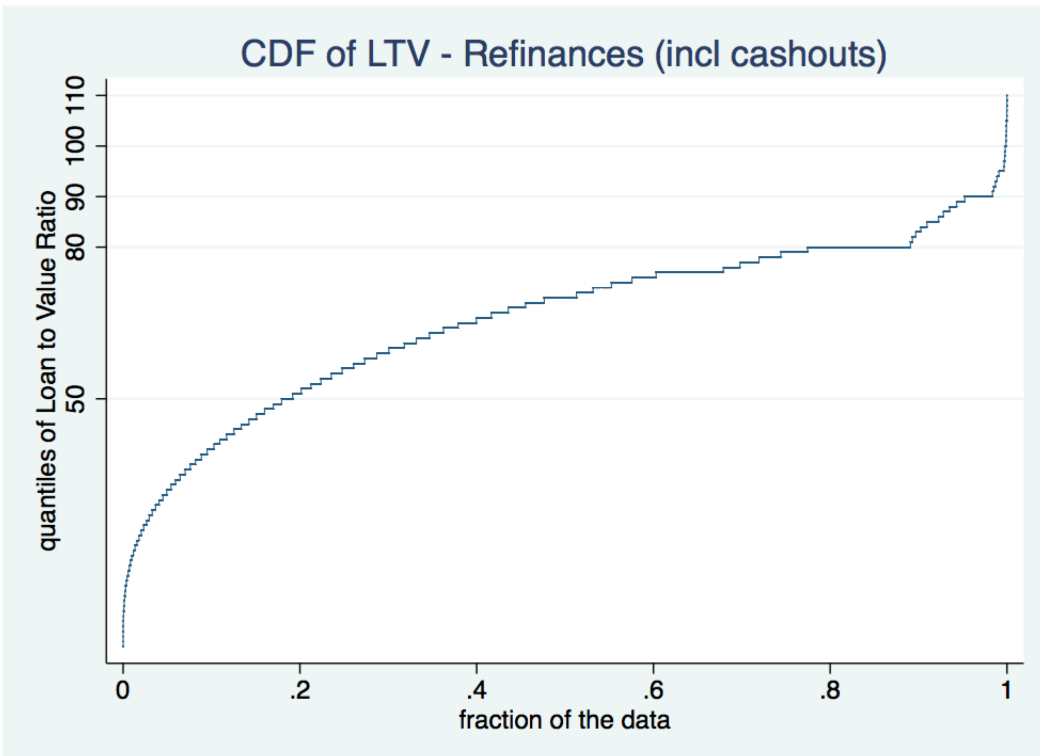


Figure 4: Cumulative Density Function of LTV - Refinances (incld. Cashouts)

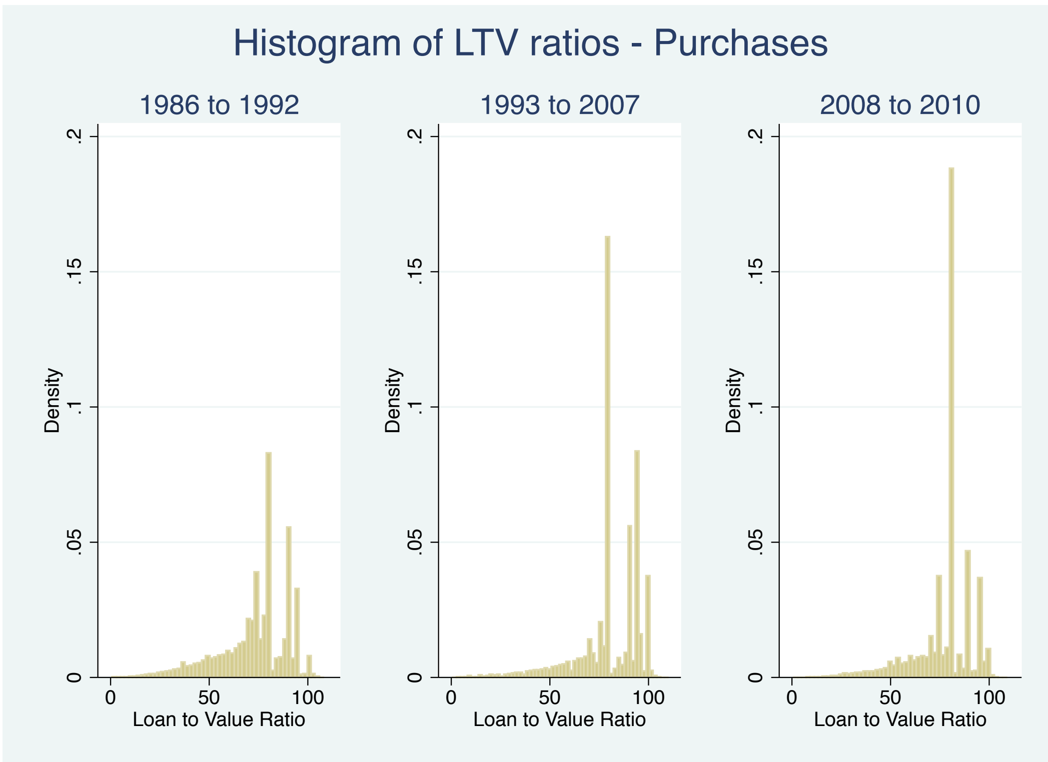


Figure 5: Histogram of LTV - Purchases over time

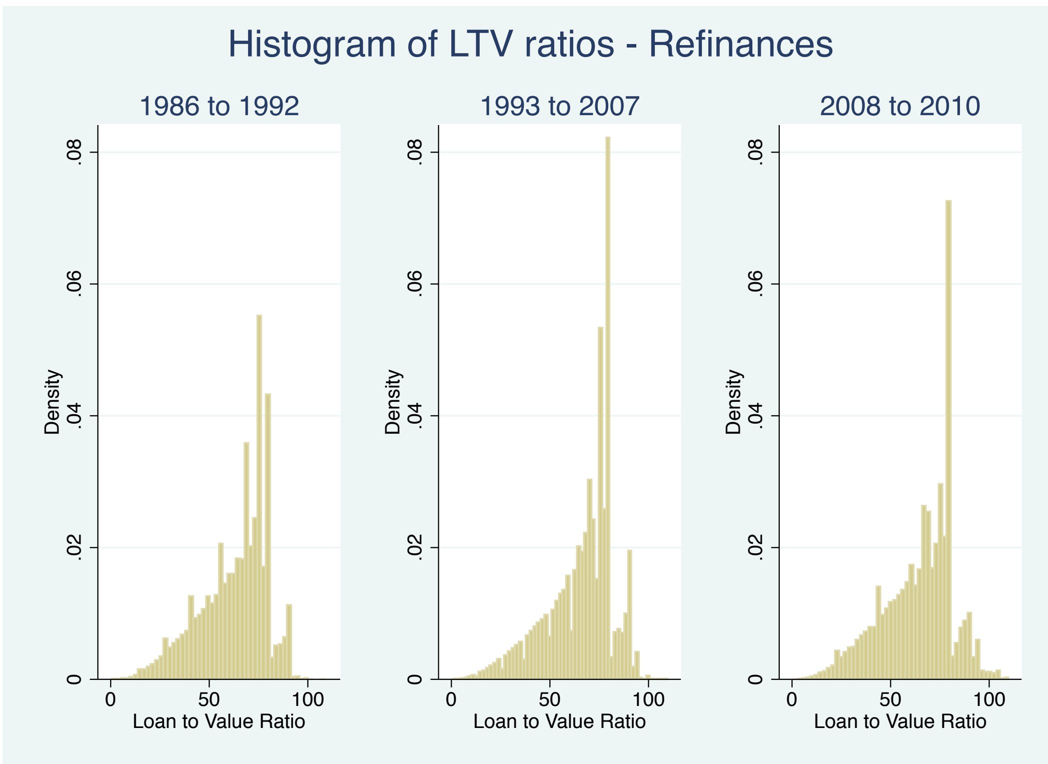


Figure 6: Histogram of LTV - Refinances over time

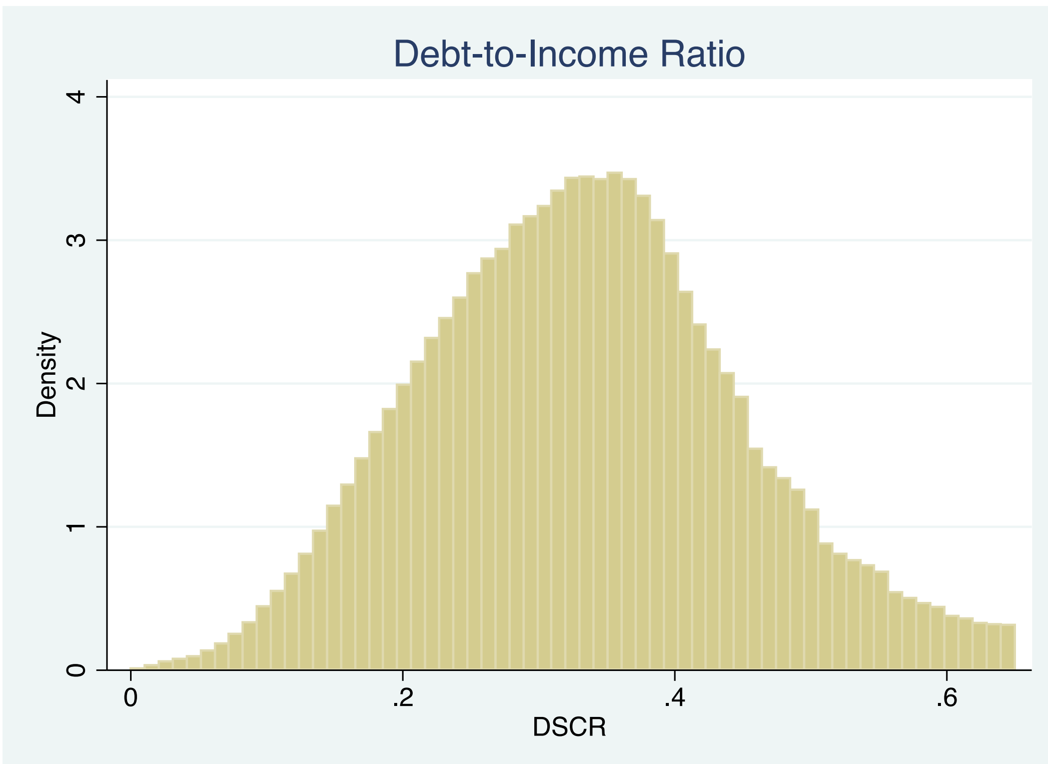


Figure 7: Histogram of Debt-to-Income Ratios

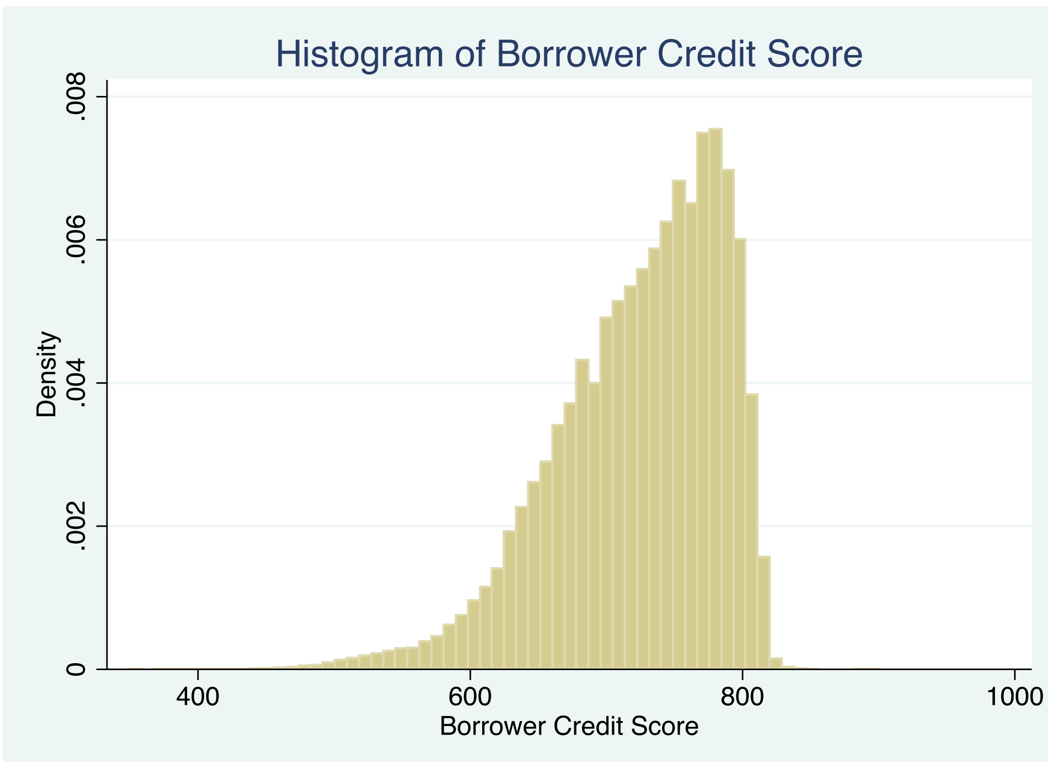
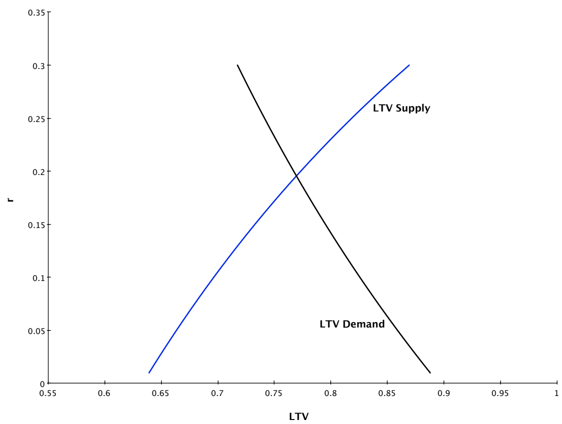
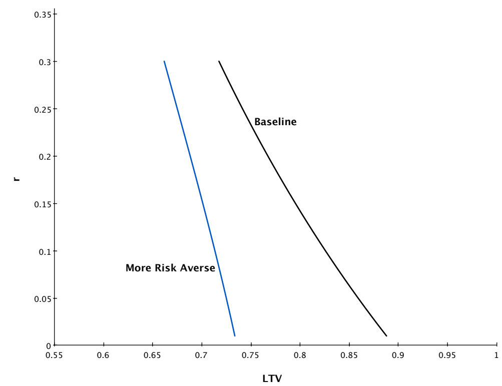


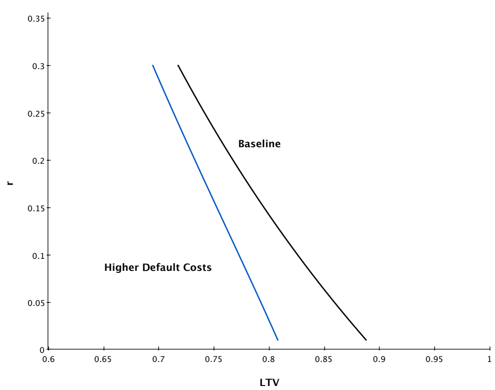
Figure 8: Histogram of FICO Scores



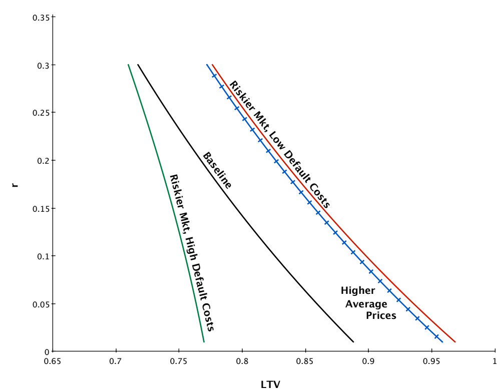
(a) Equilibrium Market Leverage



(b) Risk Aversion



(c) Default Costs



(d) House Price Distributions

Figure 9: Summary of Results

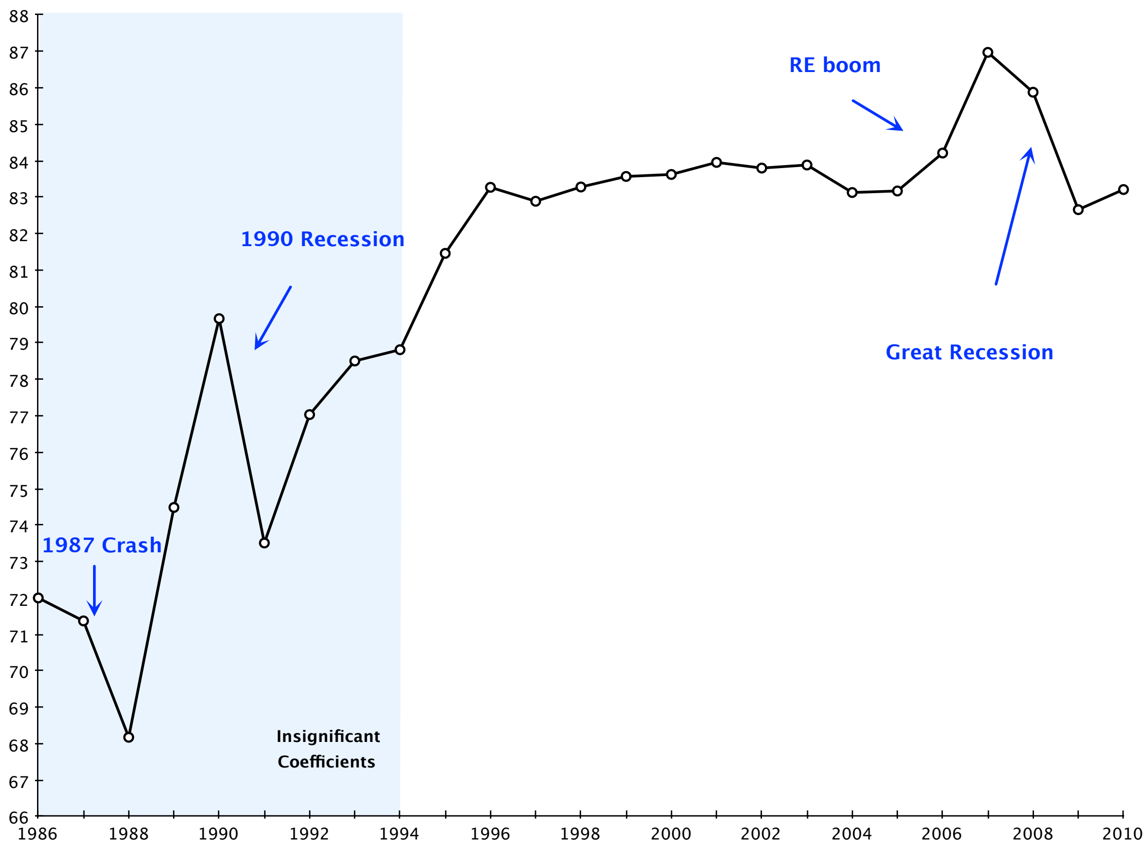


Figure 10: LTV Demand - Estimated from Yearly Dummies

B Tables

Origination Year	LTV Category							
	LTV ≤ 80%		80% < LTV ≤ 90%		90% < LTV ≤ 110%		Total	
	No.	Row %	No.	Row %	No.	Row %	No.	Row %
1986	94940	81	17024	14	5510	5	117474	100
1987	90567	78	20482	18	4943	4	115992	100
1988	87585	74	23839	20	6160	5	117584	100
1989	92402	78	19003	16	6449	5	117854	100
1990	92007	78	18230	15	7882	7	118119	100
1991	93985	79	16390	14	8481	7	118856	100
1992	94661	80	15894	13	7873	7	118428	100
1993	86679	74	17980	15	12619	11	117278	100
1994	80752	69	18619	16	17936	15	117307	100
1995	79281	68	17388	15	20059	17	116728	100
1996	79995	69	17652	15	18244	16	115891	100
1997	82260	71	16207	14	16651	14	115118	100
1998	82153	71	15585	13	18776	16	116514	100
1999	80440	70	15288	13	19139	17	114867	100
2000	80792	71	16579	15	16890	15	114261	100
2001	81038	70	16023	14	18688	16	115749	100
2002	86395	74	13227	11	16827	14	116449	100
2003	88868	76	11215	10	16217	14	116300	100
2004	91089	79	9848	9	13851	12	114788	100
2005	94857	82	9172	8	12060	10	116089	100
2006	94315	81	8557	7	13984	12	116856	100
2007	83432	71	11823	10	21806	19	117061	100
2008	87780	75	14798	13	13719	12	116297	100
2009	102266	86	9850	8	6353	5	118469	100
2010	100090	85	10059	9	7984	7	118133	100
N	2,208,629		380,732		329,101		2,918,462	

Table 1: Percentage of Data by LTV Category

Origination Year	DTI Category							
	DTI < 0.26		0.26 ≤ DTI < 0.42		0.42 ≤ DTI ≤ 0.65		Total	
	No.	Row %	No.	Row %	No.	Row %	No.	Row %
1986	264	49	242	45	36	7	542	100
1987	427	48	402	45	62	7	891	100
1988	1614	31	3391	65	201	4	5206	100
1989	1756	23	5394	72	353	5	7503	100
1990	1610	22	5239	73	332	5	7181	100
1991	1441	26	3895	70	208	4	5544	100
1992	3629	36	5892	59	483	5	10004	100
1993	40746	38	61044	57	5854	5	107644	100
1994	34544	32	66365	61	7501	7	108410	100
1995	29919	27	69551	63	10903	10	110373	100
1996	30829	28	68101	62	11341	10	110271	100
1997	32032	30	64091	59	12159	11	108282	100
1998	37393	35	57635	53	13162	12	108190	100
1999	34013	32	51910	49	19228	18	105151	100
2000	26411	25	49846	48	27497	27	103754	100
2001	32073	30	50233	47	25301	24	107607	100
2002	34141	31	47899	44	26401	24	108441	100
2003	33777	31	46515	43	28060	26	108352	100
2004	27925	26	46571	44	31495	30	105991	100
2005	21627	20	49655	47	35115	33	106397	100
2006	18296	17	48738	45	40213	37	107247	100
2007	17322	16	47149	43	45503	41	109974	100
2008	23640	20	49751	43	42122	36	115513	100
2009	34664	29	53333	45	29988	25	117985	100
2010	35564	30	59601	51	22457	19	117622	100
N	555,657		1,012,443		435,975		2,004,075	

Table 2: Percentage of Data by Debt-to-Income Category

Year	LTV $>$ 80 &/or FICO $<$ 660	LTV $>$ 90 &/or FICO $<$ 620	LTV $>$ 95 &/or FICO $<$ 580	Other	Total	LTV $>$ 80 &/or FICO $<$ 660	LTV $>$ 90 &/or FICO $<$ 620	LTV $>$ 95 &/or FICO $<$ 580	Other	Total
	No.	No.	No.	No.	No.	Row %	Row %	Row %	Row %	Row %
1986	17110	4856	829	94679	117474	15	4	1	81	100
1987	20642	3953	1283	90114	115992	18	3	1	78	100
1988	24109	4858	1709	86908	117584	21	4	1	74	100
1989	19176	5485	1278	91915	117854	16	5	1	78	100
1990	18449	7318	902	91450	118119	16	6	1	77	100
1991	16591	7925	851	93489	118856	14	7	1	79	100
1992	16159	7338	815	94116	118428	14	6	1	79	100
1993	18236	11053	2034	85955	117278	16	9	2	73	100
1994	19235	15905	2926	79241	117307	16	14	2	68	100
1995	17849	15777	5217	77885	116728	15	14	4	67	100
1996	22235	16798	6334	70524	115891	19	14	5	61	100
1997	22354	15807	5990	70967	115118	19	14	5	62	100
1998	20816	15439	6851	73408	116514	18	13	6	63	100
1999	21936	14756	8220	69955	114867	19	13	7	61	100
2000	25262	15570	7855	65574	114261	22	14	7	57	100
2001	21897	15565	8357	69930	115749	19	13	7	60	100
2002	19101	13420	8090	75838	116449	16	12	7	65	100
2003	16929	11222	8634	79515	116300	15	10	7	68	100
2004	16663	8945	9161	80019	114788	15	8	8	70	100
2005	16475	7479	9174	82961	116089	14	6	8	71	100
2006	16418	7275	11947	81216	116856	14	6	10	70	100
2007	18299	10395	16883	71484	117061	16	9	14	61	100
2008	18940	10440	5872	81045	116297	16	9	5	70	100
2009	11609	5466	1371	100023	118469	10	5	1	84	100
2010	11674	5756	2415	98288	118133	10	5	2	83	100
N	468,164	258,801	134,998	2,056,499	2,918,462					

Table 3: Fraction of Risky Mortgages

	FICO			Income			Age		
Origination Year	N	Mean	Sd	N	Mean	Sd	N	Mean	Sd
1986	2300	682	91	697	6408	19679	764	44	16
1987	3785	696	87	1268	5230	4601	1393	44	16
1988	5099	704	79	6229	5147	4306	6433	40	13
1989	3984	698	81	8478	5716	10223	8925	39	11
1990	3839	699	76	8287	5640	4560	9039	40	12
1991	3413	694	82	6541	5404	4496	6756	40	13
1992	5069	712	77	13162	5619	5413	12542	42	12
1993	8320	705	84	110089	5469	5370	98897	42	11
1994	15222	709	75	110977	5143	4418	102663	42	12
1995	13819	692	80	112668	5056	4220	102635	42	12
1996	90529	710	62	112003	5282	5094	100619	42	12
1997	112709	713	60	110154	5588	5907	98961	43	12
1998	114702	718	58	110855	5940	4819	101080	43	12
1999	113028	715	60	108959	6028	5465	100393	43	12
2000	112222	707	63	108130	6023	5315	98785	43	12
2001	114644	715	64	109994	6590	5902	103265	43	12
2002	115791	721	60	112666	6865	6833	105766	43	12
2003	115850	725	57	113348	6962	6785	106167	44	13
2004	114248	722	58	110538	6871	9293	97527	44	13
2005	115698	723	59	110864	7150	6059	96790	44	13
2006	116585	719	61	111057	7603	7473	100114	44	13
2007	116913	718	63	112573	7747	6665	108099	44	13
2008	116183	742	53	115720	8690	7931	106804	45	13
2009	118285	763	41	118178	9298	9091	106372	46	13
2010	117984	766	41	117737	9899	9219	105611	47	13

Table 4: Summary Statistics by Year

	FICO			Income			Age		
LTV Category	N	Mean	Sd	N	Mean	Sd	N	Mean	Sd
LTV $\leq$ 80%	1334225	733	56	1546528	7191	7396	1416242	45	12
80% < LTV $\leq$ 90%	198632	713	58	249593	6075	5126	228678	40	11
90% < LTV $\leq$ 110%	237364	686	72	265051	5101	3305	241480	36	11

Table 5: Summary Statistics by LTV Category

	Occupancy Status Code							
	First Home		Second Home		Investment Home		Total	
ORIGTN_YEAR	No.	Row %	No.	Row %	No.	Row %	No.	Row %
1986	113074	96	1528	1	2872	2	117474	100
1987	111178	96	1804	2	3010	3	115992	100
1988	111564	95	2576	2	3444	3	117584	100
1989	112240	95	2786	2	2828	2	117854	100
1990	112996	96	2420	2	2703	2	118119	100
1991	114032	96	2243	2	2581	2	118856	100
1992	113718	96	1580	1	3130	3	118428	100
1993	111455	95	1864	2	3959	3	117278	100
1994	109957	94	2110	2	5240	4	117307	100
1995	110765	95	2320	2	3643	3	116728	100
1996	109912	95	2408	2	3571	3	115891	100
1997	108809	95	2625	2	3684	3	115118	100
1998	110198	95	2766	2	3550	3	116514	100
1999	106926	93	3038	3	4903	4	114867	100
2000	104324	91	3174	3	6763	6	114261	100
2001	106477	92	3238	3	6034	5	115749	100
2002	105204	90	3971	3	7274	6	116449	100
2003	104719	90	4732	4	6849	6	116300	100
2004	102076	89	5344	5	7368	6	114788	100
2005	100619	87	5865	5	9605	8	116089	100
2006	101099	87	5902	5	9855	8	116856	100
2007	102664	88	5413	5	8984	8	117061	100
2008	100817	87	6240	5	9240	8	116297	100
2009	104374	88	7397	6	6698	6	118469	100
2010	101437	86	7696	7	9000	8	118133	100
N	2,690,634		91,040		136,788		2,918,462	

Table 6: Occupancy Status by Year

Table 7: Structural Leverage Demand Estimation (2sls)

	LTV - Purchases	LTV - Refinances
Loan Original Note Rate	-0.6506	-0.5164
	(0.1029)	(0.1210)
15 YR FRM	-12.6162	-10.4051
	(0.1022)	(0.0772)
20 YR FRM	-6.6908	-3.3894
	(0.2050)	(0.0893)
25 YR FRM	-3.1527	-1.3907
	(0.3853)	(0.1707)
40 YR FRM	5.6335	4.3150
	(0.3513)	(0.4494)
Borrowers Total Monthly Income Amount	-7.50e-05	-2.15e-05
	(6.89e-06)	(4.32e-06)
Borrowers Count	-1.5970	-0.0155
	(0.0409)	(0.0457)
$25 \leq$ Borrower's Age ≤ 34	-1.4764	0.3656
	(0.0802)	(0.2033)
$35 \leq$ Borrower's Age ≤ 49	-5.7328	-4.2753
	(0.0824)	(0.2011)
$50 \leq$ Borrower's Age ≤ 64	-9.9254	-9.3277
	(0.0935)	(0.2038)
Borrower's Age > 64	-13.7903	-15.3017
	(0.1368)	(0.2195)
Borrower Credit Score	-0.0540	-0.0435
	(0.0004)	(0.0005)
MSA Ln House Price Level	-5.6420	-10.1107
	(0.0555)	(0.0613)
MSA Detrended Ln HPI Qtrly Vol - 2 yr bk	-1.9565	-10.6959
	(0.5319)	(0.7283)
Second or Vacation Home	2.1034	0.3777
	(0.0985)	(0.1951)
Investment Property	1.4235	-0.1234

Table 7: Structural Leverage Demand Estimation (2sls)

	LTV - Purchases	LTV - Refinances
	(0.0892)	(0.0988)
Female	-0.7656	-1.2177
	(0.0456)	(0.0530)
American Indian/Alaskan Native	1.6022	1.5302
	(0.3152)	(0.3394)
Asian/Pacific Islander	0.4110	3.0457
	(0.0746)	(0.1016)
Black (and not Hispanic)	4.9435	3.9817
	(0.0849)	(0.0989)
Hispanic	3.8033	2.8394
	(0.0711)	(0.0854)
Other	0.3846	1.1504
	(0.0971)	(0.1008)
1987	-0.6304	0.6662
	(4.4216)	(4.5125)
1988	-3.8244	-6.0904
	(4.4517)	(7.2414)
1989	2.4832	3.9935
	(4.4534)	(4.6574)
1990	7.6652	-5.5073
	(4.0157)	(5.6073)
1991	1.5089	1.6113
	(3.8298)	(4.2249)
1992	5.0322	2.4420
	(3.6174)	(3.8224)
1993	6.5036	4.5592
	(3.4916)	(3.7482)
1994	6.8132	3.9893
	(3.4789)	(3.7344)
1995	9.4574	5.9548
	(3.4722)	(3.7352)

Table 7: Structural Leverage Demand Estimation (2sls)

	LTV - Purchases	LTV - Refinances
1996	11.2696	9.2669
	(3.4555)	(3.7148)
1997	10.8876	9.6970
	(3.4566)	(3.7154)
1998	11.2791	11.0154
	(3.4610)	(3.7214)
1999	11.5684	11.2515
	(3.4589)	(3.7205)
2000	11.6232	11.2659
	(3.4553)	(3.7131)
2001	11.9539	13.1788
	(3.4611)	(3.7230)
2002	11.7984	11.9180
	(3.4641)	(3.7289)
2003	11.8827	10.1531
	(3.4718)	(3.7392)
2004	11.1273	10.4844
	(3.4708)	(3.7382)
2005	11.1696	11.2618
	(3.4707)	(3.7361)
2006	12.2112	12.7113
	(3.4652)	(3.7281)
2007	14.9733	14.4715
	(3.4656)	(3.7285)
2008	13.8799	14.3197
	(3.4685)	(3.7348)
2009	10.6572	13.5807
	(3.4803)	(3.7500)
2010	11.2093	16.0497
	(3.4843)	(3.7553)
Constant	188.4187	220.5111

Table 7: Structural Leverage Demand Estimation (2sls)

	LTV - Purchases	LTV - Refinances
	(3.7122)	(4.0682)
R^2	0.24	0.25
N	511,448	524,826

Table 8: Reduced Form Regressions (Purchases)

	Note Rate	LTV	Ln Loan	Ln Price
15 YR FRM	-0.4468	-12.3255	-0.2616	-0.0501
	(0.0027)	(0.0914)	(0.0039)	(0.0039)
20 YR FRM	-0.0640	-6.6492	-0.1983	-0.0975
	(0.0082)	(0.2041)	(0.0060)	(0.0060)
25 YR FRM	0.0380	-3.1774	-0.1617	-0.1156
	(0.0163)	(0.3840)	(0.0112)	(0.0113)
40 YR FRM	0.0709	5.5874	0.0693	-0.0052
	(0.0135)	(0.3498)	(0.0109)	(0.0109)
Borrowers Total Monthly Income Amount	-3.20e-06	-7.30e-05	2.28e-05	2.36e-05
	(2.55e-07)	(6.74e-06)	(1.84e-06)	(1.90e-06)
Borrowers Count	-0.0660	-1.5540	0.1417	0.1662
	(0.0014)	(0.0402)	(0.0039)	(0.0040)
$25 \leq$ Borrower's Age ≤ 34	-0.0441	-1.4477	0.2042	0.2187
	(0.0036)	(0.0797)	(0.0037)	(0.0038)
$35 \leq$ Borrower's Age ≤ 49	-0.0594	-5.6942	0.2416	0.3181
	(0.0036)	(0.0818)	(0.0053)	(0.0054)
$50 \leq$ Borrower's Age ≤ 64	-0.0395	-9.8997	0.1205	0.2691
	(0.0037)	(0.0930)	(0.0051)	(0.0052)
Borrower's Age > 64	0.0032	-13.7924	-0.0207	0.1990
	(0.0043)	(0.1365)	(0.0042)	(0.0041)
Borrower Credit Score	-0.0023	-0.0525	0.0004	0.0011
	(0)	(0.0004)	(0)	(0)
MSA Ln House Price Level	-0.0275	-5.6241	0.4895	0.5763
	(0.0017)	(0.0552)	(0.0041)	(0.0043)
MSA Detrended Ln HPI Qtrly Vol - 2 yr bk	0.3210	-2.1653	-0.2532	-0.2257
	(0.0172)	(0.5291)	(0.0196)	(0.0198)
FMAE Current-Coupon (30-year, daily)	0.5532	-0.3599	-0.0161	-0.0104
	(0.0020)	(0.0568)	(0.0018)	(0.0018)
Second or Vacation Home	0.0654	2.0609	-0.2115	-0.2576
	(0.0030)	(0.0979)	(0.0095)	(0.0099)
Investment Property	0.5346	1.0756	-0.5437	-0.5809
	(0.0029)	(0.0701)	(0.0069)	(0.0071)

Table 8: Reduced Form Regressions (Purchases)

	Note Rate	LTV	Ln Loan	Ln Price
Female	0.0052	-0.7689	-0.0768	-0.0639
	(0.0016)	(0.0455)	(0.0022)	(0.0023)
American Indian/Alaskan Native	0.0236	1.5868	0.0048	-0.0187
	(0.0113)	(0.3144)	(0.0098)	(0.0095)
Asian/Pacific Islander	-0.0464	0.4412	0.0787	0.0608
	(0.0024)	(0.0743)	(0.0026)	(0.0027)
Black (and not Hispanic)	0.1112	4.8712	-0.0495	-0.1142
	(0.0040)	(0.0837)	(0.0036)	(0.0037)
Hispanic	0.1132	3.7296	-0.0921	-0.1450
	(0.0028)	(0.0698)	(0.0034)	(0.0035)
Other	-0.0003	0.3848	0.0122	0.0048
	(0.0032)	(0.0968)	(0.0031)	(0.0031)
1987	-0.5561	-0.2686	0.0551	0.1044
	(0.3183)	(4.3937)	(0.0987)	(0.1024)
1988	-0.7609	-3.3293	0.0448	0.0660
	(0.3226)	(4.4320)	(0.0911)	(0.1012)
1989	-0.5099	2.8150	-0.1380	-0.1224
	(0.3306)	(4.4253)	(0.1014)	(0.1077)
1990	-0.3500	7.8930	-0.2008	-0.2745
	(0.3159)	(3.9854)	(0.1009)	(0.1052)
1991	-0.0613	1.5488	-0.0692	-0.0639
	(0.2895)	(3.8016)	(0.0834)	(0.0936)
1992	-0.4096	5.2987	0.0640	0.0265
	(0.2771)	(3.5891)	(0.0768)	(0.0806)
1993	-0.6797	6.9459	0.1482	0.0958
	(0.2744)	(3.4605)	(0.0723)	(0.0765)
1994	-0.9206	7.4121	0.1629	0.1101
	(0.2743)	(3.4477)	(0.0715)	(0.0757)
1995	-0.6670	9.8914	0.1400	0.0552
	(0.2742)	(3.4417)	(0.0714)	(0.0756)
1996	-0.4571	11.5670	0.2878	0.1870
	(0.2738)	(3.4260)	(0.0707)	(0.0749)

Table 8: Reduced Form Regressions (Purchases)

	Note Rate	LTV	Ln Loan	Ln Price
1997	-0.5086	11.2185	0.3145	0.2175
	(0.2738)	(3.4266)	(0.0707)	(0.0749)
1998	-0.8210	11.8132	0.3526	0.2475
	(0.2738)	(3.4283)	(0.0708)	(0.0750)
1999	-0.7600	12.0629	0.3728	0.2648
	(0.2738)	(3.4273)	(0.0708)	(0.0750)
2000	-0.3992	11.8829	0.3896	0.2847
	(0.2738)	(3.4261)	(0.0707)	(0.0749)
2001	-0.8248	12.4905	0.4205	0.3060
	(0.2738)	(3.4284)	(0.0709)	(0.0751)
2002	-0.8671	12.3625	0.4370	0.3252
	(0.2739)	(3.4302)	(0.0710)	(0.0752)
2003	-1.2039	12.6660	0.4599	0.3442
	(0.2739)	(3.4332)	(0.0711)	(0.0753)
2004	-1.1819	11.8963	0.4435	0.3433
	(0.2739)	(3.4329)	(0.0710)	(0.0752)
2005	-1.2438	11.9788	0.4799	0.3786
	(0.2739)	(3.4324)	(0.0711)	(0.0753)
2006	-1.0301	12.8814	0.5205	0.4047
	(0.2739)	(3.4301)	(0.0711)	(0.0753)
2007	-1.0372	15.6481	0.5723	0.4192
	(0.2739)	(3.4302)	(0.0711)	(0.0753)
2008	-1.0923	14.5905	0.5705	0.4270
	(0.2739)	(3.4318)	(0.0713)	(0.0755)
2009	-1.4849	11.6233	0.5284	0.4228
	(0.2740)	(3.4366)	(0.0716)	(0.0758)
2010	-1.5908	12.2443	0.5695	0.4545
	(0.2740)	(3.4384)	(0.0718)	(0.0760)
Constant	6.3958	184.2575	4.8637	3.4853
	(0.2754)	(3.5277)	(0.0887)	(0.0931)
R^2	0.84	0.24	0.48	0.52
N	511,448	511,448	511,448	511,448

Table 8: Reduced Form Regressions (Purchases)

	Note Rate	LTV	Ln Loan	Ln Price

C Data Appendix

(a) Data Cleaning

We dropped loan-to-value ratios greater than 110%. For purchase mortgages, where loan-to-value was missing, we calculated it as the ratio of the unpaid loan balance at origination to the purchase amount. After making this calculation we dropped observations with missing loan-to-values or note rates. We also could not use the observations that had missing borrower age, income or gender. We calculated the Debt Service Coverage Ratio (or Debt to Income Ratio) as the ratio of the Borrower's Total Monthly (non housing) Debt Expenses to their Total Monthly Income. DSCRs greater than 0.65 we dropped. We dropped monthly incomes below $1000 and dropped credit scores above 850 and below 350. For credit score, we use credit scores at mortgage origination and where that information is not available, we instead use the credit score at the acquisition of the mortgage by Fannie Mae. To the extent that there is a large delay between origination and acquisition, these scores could potentially be different and introduce a measurement error in the credit score. Robustness tests using only the credit score at origination reveal that there is no substantial difference in the point estimates. We also drop observations that may have represented companies instead of a borrower. Finally, for the purposes of this paper, we restrict our sample to Fixed Rate Mortgages only.

(b) Construction of MSA Price Level and Volatility

The MSA price levels for the year 2000 were constructed by running a hedonic regression of the log house value on housing characteristics and MSA dummies, using the 2000 PUMS 5% sample. The regression results are shown in Table C.1. The coefficients from this regression were weighted by sample means and proportions of housing characteristics in each MSA. The predicted log house value was then the sum of the MSA specific dummy and the hedonic sum of characteristics in each market. The log value was exponentiated to arrive at the 2000 MSA price level. These price levels are mapped in Figure D.1 and show a very reasonable distribution across the

US. The final step in calculating the MSA price level for the years 1986 to 2010 was achieved by extrapolating the 2000 price level using the MSA repeat sale price indices published by FHFA.

The detrended HPI volatility variable was calculated by first running a regression of Ln MSA House Price Level (constructed as detailed above) on a continuous time variable plus MSA dummies. The log residuals from this regression were then used to calculate the 2-year lagged, standard deviation used in the text.

Table C.1: Price Level Regression - PUMS 5 percent sample

	Log House Value
rooms==2	0.20
	(0.03)
rooms==3	0.35
	(0.03)
rooms==4	0.35
	(0.03)
rooms==5	0.50
	(0.03)
rooms==6	0.65
	(0.03)
rooms==7	0.81
	(0.03)
rooms==8	0.97
	(0.03)
rooms==9	1.24
	(0.03)
builtyr==2-5 years	-0.05
	(0.00)
builtyr==6-10 years	-0.12
	(0.00)
builtyr==11-20 years	-0.23
	(0.00)
builtyr==21-30 years	-0.36

Table C.1: Price Level Regression - PUMS 5 percent sample

	Log House Value
	(0.00)
builtyr==31-40 years	-0.42
	(0.00)
builtyr==41-50 years	-0.48
	(0.00)
builtyr==51-60 years	-0.56
	(0.00)
builtyr==61+ years	-0.57
	(0.00)
unitsstr==1-family house, attached	-0.20
	(0.00)
kitchen==Yes	0.34
	(0.01)
msa/cbsa dummies	yes
Constant	10.36
	(0.03)
R^2	0.50
N	2,318,561

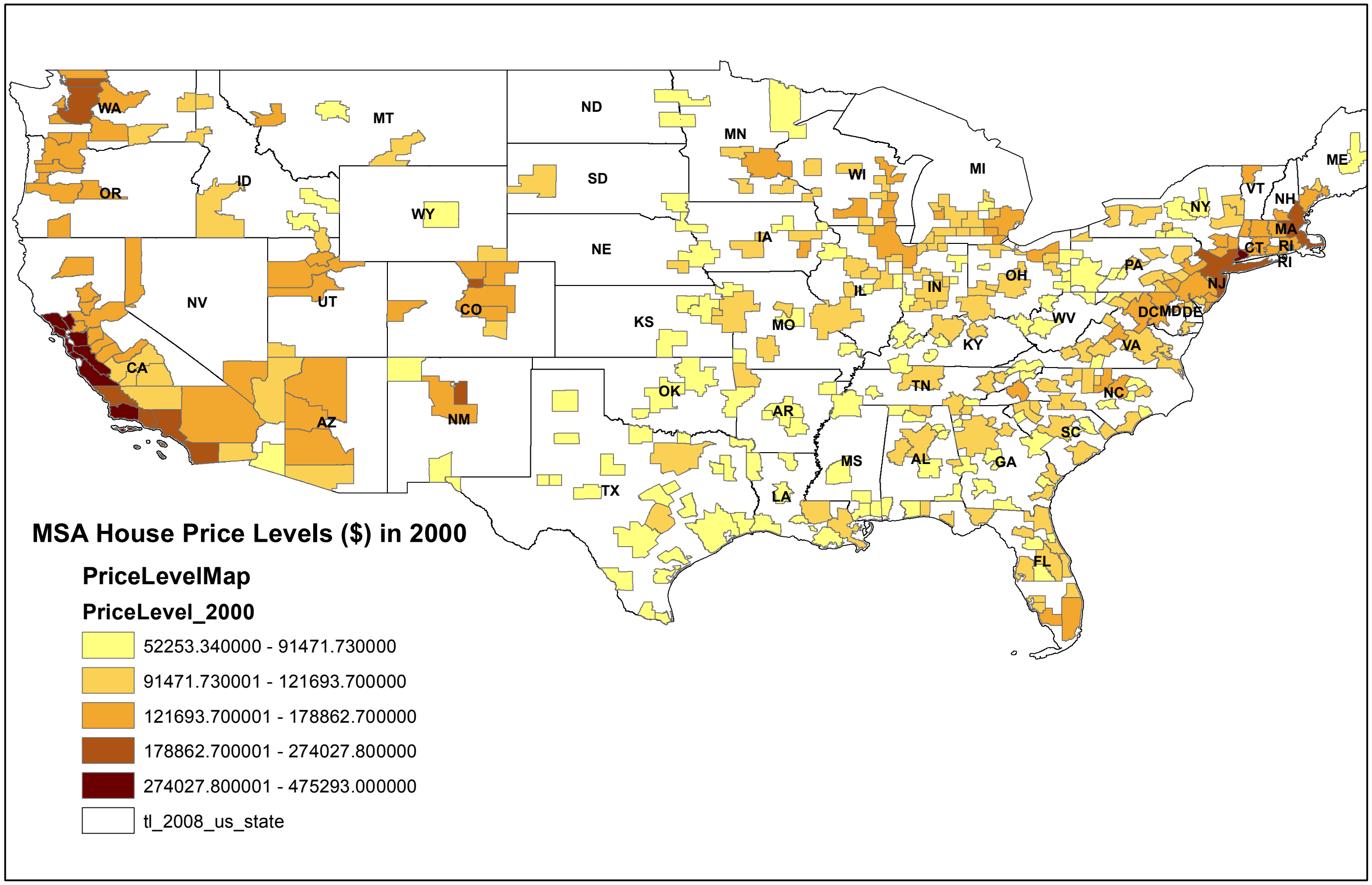


Figure C.1: MSA 2000 Price Levels