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Andreas Fuster
James Vickery

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Abstract

Fixed-rate mortgages (FRMs) dominate the U.S. mortgage market, with important consequences for monetary policy, household risk management, and financial stability. In this paper, we show that the share of FRMs is sharply lower when mortgages are difficult to securitize. Our analysis exploits plausibly exogenous variation in access to liquid securitization markets generated by a regulatory cutoff and time variation in private securitization activity. We interpret our findings as evidence that lenders are reluctant to retain the prepayment and interest rate risk embedded in FRMs. The form of securitization (private versus government-backed) has little effect on FRM supply during periods when private securitization markets are well-functioning.

Key words: mortgage finance, securitization, regression discontinuity design, difference-in-differences

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Fuster, Vickery: Federal Reserve Bank of New York (e-mail: andreas.fuster@ny.frb.org, james.vickery@ny.frb.org). The authors thank their discussants Gene Amromin (HULM), Tomek Piskorski (WFA), Ben Keys (NBER Summer Institute), Colin Lizieri (EFA), Kamila Sommer (AEA/AREUEA), as well as Richard Crump, Andrew Davidson, Chris Foote, Andra Ghent, Aurel Hizmo, Brian Melzer, Amit Seru, Paul Willen, and participants at numerous conferences and seminars for helpful comments and discussions. They also thank Caitlin Gorback for outstanding research assistance. This paper supersedes an older working paper by Vickery titled "Interest Rates and Consumer Choice in the Residential Mortgage Market." The views expressed in this paper are those of the authors and do not necessarily reflect the position of the Federal Reserve Bank of New York or the Federal Reserve System.

1 Introduction

The US residential mortgage market is dominated by prepayable 30-year fixed-rate mortgages (FRMs), a type of home loan observed in few other countries.[1] The popularity of FRMs has important consequences for monetary policy transmission, household risk management, and financial stability. Reflecting these considerations, policymakers and market commentators often evaluate proposals for mortgage finance reform in part based on their likely impact on the continued availability of FRMs (e.g., Department of Treasury 2011).

This paper studies the role of supply-side factors, and in particular securitization, in accounting for the high market share of long-term FRMs. We compare the contract structure of newly originated mortgages across two market segments: the government-backed "agency" market and the private "nonagency" market. While agency mortgages can be securitized quite easily throughout our sample period, nonagency securitization freezes at the onset of the 2007-09 financial crisis, and also experiences a period of illiquidity in 1999-2000. During these two episodes, we show that the FRM share is sharply lower among illiquid nonagency mortgages, compared to otherwise similar but still liquid agency loans. In contrast, during the rest of the sample when both types of loans can be easily securitized, we find at most a small difference in the FRM share between these two markets.

These results suggest that in periods when securitization liquidity is impaired and new mortgages are instead generally retained in portfolio, lenders reduce the supply of FRMs, causing substitution towards adjustable-rate mortgages (ARMs). Our interpretation is that lenders are averse to retaining the significant prepayment risk and interest rate risk embedded in FRMs due to their long duration and prepayment option. Securitization allows these risks

[1]FRMs make up 91 percent of US first-lien mortgages originated between 2009-13, and 83 percent of the stock of loans as of December 2013 (value-weighted shares based on data from LPS Applied Analytics). The corresponding shares for FRMs with a term of at least 30 years and no (or unknown) prepayment penalties are 71 percent and 64 percent respectively. Campbell (2013) and Green and Wachter (2005) review international differences in mortgage contracts; among the countries discussed by these authors, Denmark and the US are the only cases in which prepayable long-term FRMs predominate.

to be pooled and transferred to a diverse set of mortgage-backed securities (MBS) investors. Consistent with this "risk management" interpretation, we show that our results are strongest for the subset of FRMs with the greatest risk, and that, among other stylized facts, lenders disproportionately securitize FRMs and retain ARMs throughout our sample period.

Our empirical approach makes use of a regulatory cutoff determining whether a loan is eligible to be securitized by Fannie Mae and Freddie Mac (F&F), two government-sponsored enterprises that play a central role in the US mortgage finance system. By regulation, only mortgages up to a size threshold known as the "conforming loan limit" (CLL) are eligible to be purchased and securitized by F&F. "Jumbo" mortgages larger than the CLL may only be securitized through the nonagency MBS market, in which the securities issuer is a private financial institution rather than F&F.

Using the CLL as a source of identification, we employ two complementary strategies to estimate the causal relationship between the source of mortgage funding and the FRM share: a difference-in-differences (DiD) analysis exploiting time-series changes in the CLL, and a fuzzy regression discontinuity design (RDD) exploiting cross-sectional variation near the CLL. Since loan size itself is endogenous, we use the appraised home value as an instrument for mortgage amount, along similar lines to Kaufman (2012) and Adelino, Schoar, and Severino (2012). This strategy makes use of the fact that many borrowers select a mortgage amount close to 80 percent of the home value. Thus, we analyze variation in mortgage contracts for homes with appraised values near $125\%(= 1/0.8)$ of the CLL.

We apply these methods over different subperiods between 1996 and 2009, using a large national loan-level mortgage dataset from LPS Applied Analytics.[2] During the 2007-09 financial crisis, when the nonagency MBS market is effectively frozen, our estimates imply that the share of 30-year FRMs without prepayment penalties is 29 percentage points lower among illiquid jumbo mortgages that are ineligible to be securitized via F&F. Similarly, the

[2]We also replicate our main results using an alternative dataset, the Monthly Interest Rate Survey conducted by the Federal Housing Finance Agency.

30-year no-penalty FRM share is 27 percentage points lower for jumbo loans during the period of low jumbo MBS liquidity in 1999-2000, which followed the collapse of the hedge fund Long Term Capital Management. In contrast, pooling the data over the remainder of the sample period, when the agency and nonagency MBS markets are *both* liquid, results in an estimated effect of jumbo status on the FRM share of only -3 percentage points. This latter result suggests that private securitization markets (by comparison to securitization involving implicit or explicit government guarantees) are able to fund the origination of long-term FRMs quite effectively during periods when those private markets are liquid.

An important consideration in interpreting our results is that the periods of jumbo MBS illiquidity we study (in 2007-09 and 1999-2000) may also differ in other important ways from the rest of the sample period. A first potential concern is that many mortgage lenders experienced financial distress during 2007 and 2008. Theoretically, this could either amplify or dampen the effect of the securitization freeze. On the one hand, financial constraints may have led lenders to be particularly averse towards bearing prepayment and interest rate risk during this time period, amplifying the effects of illiquidity on the jumbo FRM share. On the other hand, risk-shifting incentives may have induced undercapitalized banks to become *less* risk-averse (e.g., Jensen and Meckling 1976; Boyd and Hakenes 2014), attenuating our results. We expect these effects to influence our results from the financial crisis period at least to some extent. However, we also find substantial effects of jumbo MBS illiquidity on the FRM share during the earlier nonagency illiquidity episode in 1999-2000, a period when we document that US banks were profitable and measured lending standards were stable. This, as well as additional evidence discussed in section 5, suggests that our findings have relevance to the relationship between mortgage funding and FRM supply both during and outside of periods of banking sector distress.

A second possible concern is that jumbo mortgage borrowers may have been credit rationed during the financial crisis, generating selection effects in the type of borrowers that could still obtain credit. We test this hypothesis by reestimating our main results on subsamples of the most creditworthy borrowers, who are least likely to be affected by rationing. Our results are actually stronger for these subgroups, suggesting that such selection if anything attenuates our baseline results. Furthermore, we also show that following the onset of nonagency illiquidity in 2007, offered interest rates on jumbo FRMs rise more quickly than for jumbo ARMs (relative to non-jumbo loans of the same type). This provides direct evidence that FRM supply in the illiquid jumbo market declined during this period.

A third concern is that our results may be affected by residual shifts in mortgage demand. Existing research has established that affordability, expected home price growth, and various household characteristics are important cross-sectional determinants of the choice between FRM and ARM (e.g., Campbell and Cocco 2003; Barlevy and Fisher 2011), and that time-series variation in the FRM share is explained well by a proxy for the risk premium on long-term bonds (Koijen, Van Hemert, and Van Nieuwerburgh 2009). Drawing from this literature, we investigate whether variation in affordability or expectations could influence our results by violating the exclusion restriction assumed by our empirical strategy. For instance, we show that during the housing boom period, adding additional controls for housing market conditions or looking at subsamples based on realized home price appreciation leaves our qualitative results unchanged. In addition, using a time-series approach, we show that the jumbo FRM share is indeed low in periods of jumbo MBS illiquidity after controlling for the Koijen et al. (2009) bond risk premia variable. These findings suggest that our results represent supply-side factors, rather than variation in demand.

While we do not take a normative stance on whether FRMs are desirable from a public policy point of view, our results have several implications for ongoing housing finance reforms and their effects on the availability of different mortgage types. In particular, our results suggest that financial regulations that discourage or limit securitization (e.g., stringent risk retention rules) may constrain the supply of long-term FRMs, by limiting lenders' ability to transfer risks associated with these loans. Our findings also shed light on whether public credit guarantees, as provided by F&F, are necessary to maintain FRM supply. This is a widely debated yet unsettled public policy question.[3] We find that access to the government-backed agency securitization market has a relatively small effect on the FRM share (no larger than 5 percent based on our confidence intervals) in periods when a liquid private securitization market is available as an alternative funding source. Subject to the important caveat that our analysis is partial equilibrium in nature, this suggests that reducing the footprint of F&F would have only a limited effect on the supply of FRMs, as long as private MBS markets are active. Recent US experience suggests however that credit guarantees may make securitization less susceptible to market freezes; consequently, FRM supply could be less stable in a system without guarantees.

Summing up, we find that securitization plays a significant role in financial contract design and the allocation of risk between borrowers, lenders and investors. In our case, financial intermediaries are less likely to originate long-term FRMs, which carry substantial interest rate risk and prepayment risk, when securitization is not available to diversify those risks via the capital markets. Our findings contribute both to the literature on securitization and to research on household finance and mortgage choice. In the former, Nadauld and Sherlund (2013) find that securitization increased subprime credit supply, while Loutskina and Strahan (2009) and Calem, Covas, and Wu (2013) use changes in secondary market liquidity near the CLL to establish that securitization attenuates the relationship between bank financial condition and lending volume. Unlike these papers, we study the effect of securitization on mortgage contract design and the allocation of interest rate and prepayment risk, rather than

[3]Illustrating the lack of consensus, in a US Senate hearing on housing reform, held in September 2011, two of four expert witnesses argued that the 30-year FRM would decline or disappear without public guarantees, while the other two argued that a purely private mortgage finance system could support FRMs. This hearing, titled "Housing Finance Reform: Should There Be A Government Guarantee?", featured Richard Green (University of Southern California), Adam Levitin (Georgetown University), Dwight Jaffee (UC Berkeley) and Peter Wallison (American Enterprise Institute). Written testimony of these experts is available here: http://banking.senate.gov/public/index.cfm?Fuseaction=Hearings.Hearing&Hearing_ID=a7b4b965-7291-4741-8507-f1dbbb860ac0.

on the quantity of credit. Also related, Kaufman (2012) employs an RDD to analyze the effect of F&F on mortgage characteristics as well as delinquencies and foreclosures during 2003–07.[4] We instead present an in-depth analysis of the FRM contract feature, and how it is affected by jumbo securitization illiquidity. Our key contribution to the household finance literature is to show that in addition to demand factors, the way in which mortgages are funded plays an important role in equilibrium mortgage choice.

2 Institutional Background

Before turning to our analysis, we describe the risks associated with FRMs, and present some necessary institutional details, particularly regarding the evolution of the CLL, which is at the core of our identification strategy.

2.1 Risks of Fixed-Rate Mortgages

FRMs in the US involve fixed nominal monthly payments over the term of the loan, usually 30 years, although shorter maturities are also offered. Borrowers may also prepay the mortgage in part or in full, often without prepayment penalties. ARMs, the main alternative contract type, instead usually involve an initial fixed rate period of 1-7 years, after which the mortgage interest rate floats with short-term market rates.

FRMs bear significant exposure to both interest rate risk and prepayment risk, relative to ARMs. Interest rate risk is the risk of a change in mortgage value due to shifts in the term structure of interest rates. Since mortgage lenders are typically funded by a mix of deposits and short-term wholesale financing, retaining a large FRM portfolio will expose the lender to losses in a rising interest rate environment. Such maturity mismatch was a primary reason for the wave of US savings and loan failures during the early 1980s (White 1991).

[4]Other work has used regression discontinuity approaches based on credit scores to investigate whether securitization leads to lax screening by mortgage originators (Keys et al. 2010; Bubb and Kaufman 2014).

Although lenders can hedge interest rate risk using swaps, this strategy involves frictions due to counterparty credit risk and liquidity risk (Liu, Longstaff, and Mandell 2006), especially at longer maturities; regulation also limits the ability of some lenders (in particular credit unions) to use derivatives.

Prepayment risk is the risk that the value of the mortgage will change due to shocks to borrower prepayment behavior. FRMs are exposed to this risk because the mortgage is prepaid at par, which may differ substantially from the prior market value. Prepayment rises when market rates fall, since the prepayment option becomes more "in-the-money." The relation between interest rates and prepayment is nonlinear and unstable, however, and prepayment is also affected by nontraded risks such as housing turnover and credit conditions. While prepayment models have become increasingly sophisticated (for academic contributions, see e.g. Schwartz and Torous 1989 or Stanton 1995) this combination of factors makes it difficult to hedge prepayment risk effectively.[5]

In a frictionless setting, mortgage lenders would incur no particular costs in bearing these risks privately (Modigliani and Miller 1958). However, more recent corporate finance research argues that bearing undiversified risks is costly in practice due to the presence of financing frictions (e.g., Froot, Scharfstein, and Stein 1993; Froot and Stein 1998). The exposure of the financial system to interest rate and prepayment risk has recently attracted increased attention from policy makers and academics (e.g. Begenau, Piazzesi, and Schneider 2013), given the current low interest rate environment.

Securitization is an important tool used by lenders to pool and diversify the prepayment and interest rate risk associated with FRMs. The resulting MBS are held by a wide range of international and domestic investors, including mutual funds, pension funds, banks, hedge

[5] Gabaix, Krishnamurthy, and Vigneron (2007) provide evidence that bearing nondiversifiable prepayment risk is costly. These authors show that the marginal MBS investor requires a return premium to hold securities backed by FRMs, and argue that this premium reflects nonsystematic rather than systematic risk from the perspective of the economy as a whole. In related work, Levin and Davidson (2005) emphasize the importance of nondiversifiable refinancing and turnover uncertainty for MBS pricing.

funds, real estate investment trusts, insurers and even sovereign wealth funds. In addition to pass-through bonds, structured securities known as collateralized mortgage obligations are used to concentrate duration and/or prepayment risk into particular classes of securities (see e.g. Fabozzi, Bhattacharya, and Berliner 2009 for details). This tranching allows these risks to be allocated to investors best suited to manage and bear them.

The prevalence of FRMs also has important broader consequences for household risk management, monetary policy transmission, and financial stability. FRMs insulate borrowers against movements in real interest rates, and reduce short-run volatility in disposable income, but leave the borrower unhedged against inflation shocks (Campbell and Cocco 2003). From a macroeconomic perspective, ARMs generate stronger and more immediate transmission of monetary policy via mortgage interest rates (Miles 2004; Calza, Monacelli, and Stracca 2013). From a systemic risk perspective, Campbell and Cocco (2011) argue that FRMs and ARMs default under different circumstances (FRM defaults increase when interest rates decline, while the opposite is true for ARMs), and that FRMs are more likely to lead to "default waves" whereas ARM defaults are more idiosyncratic.

2.2 Mortgage Securitization and the Conforming Loan Limit

The agency MBS market consists of mortgage bonds issued by the government-sponsored enterprises F&F and those guaranteed by the government agency Ginnie Mae. These securities carry a credit guarantee from the relevant agency, effectively eliminating credit risk for the investor. Agency MBS are not insured against interest rate risk or prepayment risk, however; these risks are borne by MBS investors in both the agency and nonagency market.

The CLL is a key determinant of whether a loan is "conforming," that is, whether it is eligible to be purchased and securitized by F&F. Jumbo mortgages larger than the CLL are, by regulation, ineligible for agency securitization, while in contrast, a large majority of non-jumbo mortgages *are* securitized by F&F. (Other loan characteristics can also make a mortgage non-conforming, but these are not as sharply defined as the size limit.)

Table 1 shows how the national CLL for one-unit properties evolved over the sample period. The CLL was raised at the start of each calendar year, often significantly, until it reached its current value of $417,000 in 2006. Note that the CLL applied equally to new originations and loans originated in the past, giving lenders an incentive to be forward-looking and take known future annual increases in the limit (announced at the end of November) into account when originating mortgages. Figure A.1 in the Online Appendix presents evidence suggesting that this indeed affected loans originated in December. For this reason our analysis treats December originations as being subject to the following year's CLL.[6]

Aside from these annual increases, the Economic Stimulus Act (ESA) of 2008 temporarily raised the CLL in counties with high home prices to as much as $729,750. The ESA was passed on February 13, 2008, but was not fully effective until May 2008, in part because of issues regarding the pooling and trading of this new class of "super-conforming" mortgages (see Vickery and Wright 2013). These temporary CLLs were subsequently extended until September 2011, after which permanent high-cost limits established under the Housing and Economic Recovery Act became binding. Our empirical analysis exploits both time-series changes in the national CLL, and cross-sectional variation generated by the ESA.

2.3 The Nonagency Securitization Freeze

Although ineligible for agency securitization, during most of our sample period jumbo mortgages larger than the CLL could be securitized relatively easily through the private nonagency MBS market. However, the nonagency market effectively froze as a source of mortgage funding during the third quarter of 2007, centered in August.[7] Few jumbo MBS have been

[6]As a robustness test, we have also reestimated our main regressions after dropping loans originated in the three month prior to an increase in the national CLL. Our results are very similar under this alternative approach.

[7]See Leitner (2011) or Tirole (2011) for an overview of reasons why markets freeze, including adverse selection, ambiguity aversion, and financial constraints.

issued since the onset of this freeze, and in particular, virtually no jumbo MBS were issued in 2008 and 2009. In contrast, agency MBS securitization activity remained robust during this period, as evidenced by $2.89 trillion of agency MBS issuance in 2008 and 2009 (Vickery and Wright 2013).

Figure 1 shows the mix of loan originations by ownership status in the LPS dataset (described in more detail below) measured six months after origination, split by whether the loan amount exceeds the *national* conforming limit in the origination year.[8] Securitization or sale of jumbo mortgages larger than the national CLL of $417,000 drops rapidly over the course of 2007 (Panel A). Less than one-fifth of jumbos originated near the end of 2007 are securitized or sold, compared to four-fifths at the start of the year. Excluding sales of whole loans (which are included in the private securitization code used by LPS) would bring the fraction of securitized loans close to zero given the lack of jumbo MBS issuance after fall 2007. The fraction of securitized or sold loans then *rises* sharply around May 2008, due entirely to agency securitization. This reflects the implementation of the higher ESA loan limits, which made many loans larger than $417,000 eligible for securitization through the liquid agency market.

The figure also highlights a less extreme but still significant drop in jumbo securitization in 1999 and 2000, a period that follows Russia's sovereign default and the failure of Long Term Capital Management (LTCM) and losses at a number of other private mortgage intermediaries, and which was also associated with an increase in long-term interest rates (see American Banker 1999 for a discussion). Our empirical work makes use of this episode as a second period of jumbo MBS illiquidity; we date it to the period July 1999 to June 2000 based on the jumbo securitization share in the figure.

In contrast to the jumbo market, Panel B of the figure shows that the percentage of securitized loans in the non-jumbo segment remains consistently high over the entire sample

[8]Figure A.2 in the Online Appendix presents loan volumes (rather than shares) by ownership status.

period, reflecting the credit guarantees provided by F&F and the size and uniformity of the agency market.

The jumbo MBS freeze in August 2007 was also associated with a significant rise in jumbo mortgage interest rates. The spread between jumbo and conforming rates, normally around 10–30 basis points, increased to a peak of more than 150 basis points, as documented in Figure A.3 in the Online Appendix. This figure also plots quarterly issuance volume of jumbo MBS, drawn from Inside Mortgage Finance data. Consistent with Figure 1, jumbo MBS issuance falls rapidly to nearly zero from the third quarter of 2007 onwards, and also declines by more than half between 1998:Q3 and 1999:Q3, remaining low until the second half of 2000 when it starts to recover.

3 Data and Descriptive Evidence

3.1 Data

Our primary data source is a large national loan-level mortgage dataset from LPS Applied Analytics. These data have been used extensively by researchers in recent years, in particular to study mortgage delinquency (e.g. Elul et al. 2010; Foote et al. 2010). The LPS data have a particularly high market coverage since 2005, as nine of the top ten servicers contribute their data. Coverage for prior years is less comprehensive, however. The number of first-lien conventional mortgage originations in LPS represents 64% of the origination count reported under the Home Mortgage Disclosure Act (HMDA) over the period 2005–07, but only 60% for 2000–04 and 46% for 1996–99.[9] Early vintages of loans in the LPS dataset are also significantly "seasoned," meaning that only mortgages active (no prepayment or foreclosure)

[9]Prior to 2004, the HMDA data did not record the lien status of a mortgage, so for this calculation we assume the fraction of first-lien mortgages prior to 2004 was equal to the average fraction over 2004–07. Figure A.4 in the Online Appendix compares origination volumes in LPS to those reported by Inside Mortgage Finance (separately for FRMs and ARMs); the resulting market coverage of LPS is similar as when we compare to HMDA.

at the time a servicer begins contributing their data ever appear in the dataset. We find that this problem is concentrated in the period prior to 1996, and consequently set 1996 as the first year of our sample. From this year onwards, median seasoning for any origination vintage never exceeds six months, and is generally equal to zero.

As a robustness test, we have reproduced our main analysis using an alternative loan-level dataset, the Monthly Interest Rate Survey (MIRS), and find similar results (see the Online Appendix). This suggests that any potential non-representativeness of the LPS data in the early part of our sample does not introduce significant selection bias into our analysis.

Our analysis focuses on first-lien conventional mortgages (i.e., we drop FHA/VA and affordable housing loans) on single-family residences, condos or townhouses. We drop observations from Alaska, Hawaii, US Virgin Islands and Guam, which have permanently higher CLLs, and mortgages with origination amounts below 0.25 times or above 2.5 times the CLL. We also exclude mortgages with an initial recorded loan-to-value ratio (LTV) of below 20 or above 100 percent, as these could be a sign of data errors (e.g., second liens recorded as first liens, or a wrong loan amount). Finally, we limit our sample to mortgages used to finance a home purchase rather than to refinance an existing mortgage, since purchase transactions are arguably less endogenous to the availability and pricing of different mortgage contracts. After our restrictions, the remaining sample for the period 1996 to 2009 consists of about 18.5 million loans, 8 million of which were originated between 2004 and 2007. The years with the lowest number of observations are 1996 and 2000, for which we have about 770 thousand loans each.

Our main dependent variable of interest is whether a borrower selects a long-term prepayable FRM, rather than an alternative contract type. We define this variable, "FRM30noPPP," as being equal to 1 if a borrower selects an FRM of maturity 30 years or more, where the prepayment penalty flag is "no" or "unknown."[10] We also examine an alternative vari-

[10]In the early years of our sample, information on prepayment penalties is missing for a large fraction of loans—e.g., more than 50% in 1996 and 1997. The fraction of loans with missing prepayment penalty

able,“FRM,” set equal to 1 if a borrower selects an FRM of any maturity, with or without prepayment penalties.

We also study the securitization status of mortgages post-origination. We classify a loan as non-securitized if the loan is held in portfolio six months after origination, rather than having been securitized or sold as a whole loan. Note that this implies that we can only use this variable, which we denote “Non_sec6,” for loans that are present in the dataset six months after origination.[11]

3.2 Descriptive Evidence

Before turning to our formal analysis, Panel A of Figure 2 plots the market share of long-term prepayable FRMs (that is, FRM30noPPP) over time for loans above and below the national CLL, based on our LPS data. (While not shown, the total FRM market share displays a similar time-series pattern.) The long-term FRM share is consistently higher among conforming loans smaller than the CLL, by 25–30 percentage points on average. This difference could reflect either demand or supply, however, given that jumbo and non-jumbo borrowers have very different characteristics. Our formal analysis focuses on isolating supply shocks, by comparing otherwise similar borrowers that are close to the CLL based on the appraisal value of their home.

Over most of the sample period, the jumbo and conforming FRM shares move together, reflecting their common exposure to aggregate factors (see section 5.3). More important for the present study, however, the jumbo FRM share is unusually low, *by comparison* to the conforming market, during periods of jumbo MBS illiquidity (Panel B). Specifically, the difference between the conforming and jumbo FRM share widens by about 20 percentage

information then rapidly declines, to below 20% by 2000 and to below 3% for 2004–2007.

[11]Securitization status can change multiple times over the life of a loan. We chose an age of six months because we are most interested in the “initial” status after allowing sufficient time for securitization to occur. Using securitization status at 12 months instead does not materially change our findings.

points when the nonagency MBS freezes in the third quarter of 2007, and a similar widening is observed during the earlier illiquidity episode in 1999–2000. Furthermore, the jumbo FRM share increases by around 30 percentage points in the second quarter of 2008, exactly corresponding to the point at which many mortgages above the national CLL became eligible for agency securitization due to the introduction of higher CLLs in high-cost housing areas.[12] Taken together, these observations strongly suggest a link between FRM supply and the ease of securitization: during periods when the nonagency market is illiquid, the FRM share is significantly higher among loans that can be securitized in the still-liquid agency market.

4 Estimation and Results

This section estimates the causal treatment effect of jumbo status on the likelihood of obtaining an FRM during different periods between 1996 and 2009. In particular, we present separate estimates for the two episodes when jumbo MBS liquidity is impaired, and for the remainder of the sample period, during which this market is well-functioning.

One might assume that the effects of jumbo status could be estimated by simply comparing loans on either side of the CLL size cutoff. However, as noted by Kaufman (2012), this strategy is subject to significant endogeneity problems, because the loan amount is a choice variable for borrowers. This is illustrated in Figure 3, which plots FRM share (Panel A) and average borrower FICO credit score (Panel B) against loan size normalized by the CLL for the period December 2003 to July 2007 (the period we use in the RDD in section 4.3). We observe bunching of loans (represented by a large dot) in the loan bin just below the CLL, and few loans in the bins just above the CLL. Furthermore, the FRM share and average FICO score spike upwards just below the CLL, and appear unusually low just above the

[12] It is not clear what drives the short-lived spike in the FRM share among jumbo loans in January 2008. We note however that it is based on low origination volume (see Figure A.2 in the Online Appendix) and is weaker in the MIRS data.

limit. This "overshooting" pattern is suggestive of selection effects, which would bias our estimates. For example, creditworthy borrowers with the ability to increase their downpayment to get below the CLL may have characteristics that correlate with a preference for FRMs, such as higher risk aversion.

For this reason, loan amount is not well suited as the running variable for a regression discontinuity design (RDD), or to assign loans into treatment and control groups in a difference-in-differences (DiD) analysis. For instance, the assumption underlying an RDD is that only one variable, the probability of selecting a jumbo loan, shifts discontinuously at the threshold, while other variables (observed and unobserved) that may affect mortgage choice vary continuously across the threshold. This assumption is clearly violated in Figure 3.

The appraised property value instead provides plausibly exogenous variation in a borrower's probability of selecting a jumbo loan. Throughout our sample, the fraction of jumbos is steeply increasing in the region near an appraisal value of CLL/0.8; it is near zero for loans with appraisal amounts below this cutoff and then rises rapidly above the cutoff (see Panel A of Figure 4). The reason why is that a significant fraction of mortgages involve a loan-to-value (LTV) ratio of exactly 80%. This occurs in part by convention, but also because 80% is the maximum LTV for which F&F will purchase the loan without requiring the borrower to take out private mortgage insurance (PMI).[13] Section B.1 of the Online Appendix presents evidence that using appraisal value instead of loan amount overcomes the selection issues discussed above. In particular, there is no bunching of loans around an appraisal value of CLL/0.8, and average FICO score is smooth through this appraisal threshold.

[13]To illustrate, consider a borrower buying a property with value \$CLL/0.8. She can finance this purchase with an LTV of 80% to receive a mortgage of exactly \$CLL. If instead the property value is \$CLL/0.8 + \$10,000, obtaining an 80% LTV loan puts her above the CLL. To qualify for a conforming loan, she must either pay for PMI, or increase her downpayment by \$10,000. Both strategies may be more expensive than incurring a higher interest rate by selecting a jumbo mortgage. Therefore, her probability of matching with a jumbo loan is discretely higher than if the value of the property was \$10,000 lower.

4.1 Difference-in-Differences Strategy

Our first econometric approach is a difference-in-differences strategy that exploits changes in the CLL over time, similar to Adelino et al. (2012) who study how mortgage interest rates affect home prices. To understand the approach, consider an increase in the CLL at the end of period t. We examine mortgages for which the appraised home value lies within a symmetric band above and below $\text{CLL}_t/0.8$ in the period t prior to the increase, and in the same appraisal band in the period $t+1$ after the increase. Because many mortgage borrowers take out loans with an LTV near 80%, loans with appraisal amounts above $\text{CLL}_t/0.8$ are significantly more likely to fall into the jumbo segment during period t than during $t+1$, i.e. they are "treated" in period t but not in period $t+1$ (because they are smaller than $\text{CLL}_{t+1}/0.8$). Loans in the control group with appraisal amounts below CLL/0.8 in t (and thus also in $t+1$, as CLLs never decrease during our sample period) are untreated in both cases. Our strategy makes use of each annual change in the CLL, as well as the high-balance limits introduced in 2008 (effective in May of that year) which vary by county.

It is perhaps easiest to think of this DiD analysis as implemented with only one "pre" period (when high appraisal band loans are treated) and one "post" period, although in the main text we present results based on pooling data across different subsets of years. We consider loans that have appraisal amounts within the band $\text{CLL}_t/0.8 \pm (\text{CLL}_{t+1}/0.8 - \text{CLL}_t/0.8)$, subject to a maximum bandwidth of $\pm$ 10% of $\text{CLL}_t/0.8$. We then estimate the following two-stage least squares linear probability model:

$$\begin{aligned} Pr(Y_i = 1) &= \beta_0 + \beta_1 \cdot \widehat{Pr}(jumbo_i) \\ &\quad + \beta_2 \cdot I(period_i = t) + \beta_3 \cdot I(appr_i > CLL_t/0.8) + \gamma' \mathbf{X}_i + u_i \\ Pr(jumbo_i) &= \delta_0 + \delta_1 \cdot I(period_i = t \times appr_i > CLL_t/0.8) \\ &\quad + \delta_2 \cdot I(period_i = t) + \delta_3 \cdot I(appr_i > CLL_t/0.8) + \lambda' \mathbf{X}_i + v_i \end{aligned}$$

where Y is either FRM30noPPP, FRM, or Non_sec6. Identification comes from the fact that δ_1 in the first-stage regression is positive: a loan is more likely to be in the jumbo segment if originated in period t with an appraised property value ($appr_i$) above $\text{CLL}_t/0.8$. We then use predicted jumbo status in the second stage to estimate the effect of jumbo status on contract structure. We also include additional controls, denoted by $\mathbf{X}_i$: month dummies, a cubic function of FICO score (or a dummy for missing FICO score), as well as condo, investor, and subprime dummies.[14] All controls are interacted with calendar year dummies in the pooled regressions, in order to allow for time-variation in their effects. Standard errors are clustered at the state level.[15]

It may be helpful to consider a numerical example (without control variables). In 2004, CLL/0.8 equals \$417,125. Among properties with appraisal amount (417,125, 449,563], about 32% are financed with a jumbo loan in 2004. In 2005, however, jumbos make up only 5% of mortgages in the same property appraisal band, since CLL/0.8 now equals \$449,563. In the "control group," properties appraised between \$384,687 ($= 417,125 - (449,563 - 417,125)$) and \$417,125, the percentage of jumbo mortgages is low in *both* years (6% for 2004 and 3% for 2005). The difference-in-differences, corresponding to δ_1, then equals $(0.32 - 0.05) - (0.06 - 0.03) = 0.24$. Next we consider the outcome variable Pr(FRM30noPPP). Among properties appraised in the band (417,125, 449,563], 39% in 2004 and 43% in 2005 are financed by such a mortgage. For the properties appraised in (384,687, 417,125] the corresponding numbers are 41% and 45%. Thus, although both groups have a somewhat higher share of prepayable 30-year FRMs in 2005 than in 2004, this increase is no larger for the loans in the high appraisal band, despite the large decline in the fraction of jumbo loans in this band. This translates into a treatment effect of jumbo status on the FRM share of close to zero.

[14]The investor dummy equals 1 for declared investment properties or second homes. The subprime dummy is set to 1 if the FICO score is below 620, or if the mortgage is rated as grade B or C in the LPS data.

[15]We have also experimented with two-way clustering by state and calendar month, and obtain similar standard errors and significance levels; for the illiquidity episodes, we cannot cluster along the time dimension, because we have too few clusters.

The exclusion restriction here is that, controlling for other covariates, being in the higher appraisal amount bin above $\text{CLL}_t/0.8$ does not differentially affect a borrower's propensity to select an FRM between the two periods, other than through its effect on the likelihood of obtaining a jumbo loan. This requires that borrowers in that appraisal amount bin do not "time the market" simply in order to obtain a cheaper mortgage in the following year (such market-timing borrowers might have a different propensity to select an FRM due to their unobserved characteristics). To test whether such timing may be quantitatively important, we have reestimated our main results excluding loans originated in the first three months of each post-period, as these loans would be most likely to be affected by such market timing. Our findings are similar using this alternative specification.

4.2 Difference-in-Differences Results

Table 2 presents results from this two-stage DiD regression estimated over different subperiods: the 2007–09 nonagency illiquidity episode, the 1999–2000 episode, and the remainder of the sample. For the 2007–08 episode, we define the "pre" period as August 2007 to April 2008, the period between the nonagency MBS freeze and implementation of higher CLLs in high-housing-cost counties. To measure the CLL applying from May 2008 onward, we identify the county of each loan using the zip code field in LPS and merge in the county-level temporary CLLs implemented under the Economic Stimulus Act. We then apply the DiD strategy for counties for which the CLL was raised above \$417,000, using May 2008 to January 2009 as the "post" period. For the 1999–2000 episode, the two "pre" periods are July–November 1999 and December 1999–June 2000, and the "post" periods are 2000 and 2001 respectively. For the pooled results estimated using the remainder of the sample, the "pre" period is the 12 months prior to the increase in the CLL, and the "post" period is the subsequent calendar year. The CLL increased annually from 1996 to 2006, meaning that we can estimate the treatment effect over 1996–2005. Also, recall from section 2.2 that for the annual CLL changes, December loans are coded as part of the "post" sample.

The table displays the instrumented second stage coefficients, which reflect the causal effect of jumbo status on the outcome variables FRM30noPPP, FRM, and Non_sec6. Our estimates vary substantially with the liquidity of the nonagency MBS market. Focusing initially on FRM30noPPP, we find that over the periods when the nonagency MBS market is liquid, ineligibility for agency securitization has an economically small although statistically significant effect on mortgage choice; jumbo loans are 3 percentage points less likely to be long-term prepayable FRMs. In the "market freeze" period from August 2007 onwards, however, the treatment effect is much larger: jumbos are 29 percentage points less likely to be of the FRM30noPPP type. Similarly, the treatment effect of jumbo status is -27 percentage points for the nonagency illiquidity episode in 1999–2000.

The estimated effects of jumbo status on the fraction of all FRMs (rather than FRM30noPPP) are also economically and statistically significant for the two nonagency illiquidity episodes, although the estimate is somewhat smaller (e.g., for the 2007–08 period, the estimate falls in absolute magnitude from -0.29 to -0.18). This implies that during these periods, when jumbo mortgages cannot be easily securitized, jumbo originations shift both toward ARMs and toward FRMs with shorter duration and less prepayment risk.

Instrumented results for the fraction of loans held in portfolio six months after origination ("Non_sec6") are consistent with our previous discussion about the evolution of jumbo securitization over our sample period. Jumbo loans are 24 and 20 percentage points more likely to be retained in portfolio during the 2007–09 and 1999–2000 jumbo MBS illiquidity episodes than otherwise similar conforming mortgages. These effects would likely be larger if the data allowed us to look at securitization only, rather than also including whole loan sales, given that nonagency securitization falls to nearly zero from late 2007 onwards. Over the remainder of the sample period, however, jumbo loans are only 8 percentage points less likely to be securitized or sold, reflecting the liquid jumbo MBS market.

The bottom part of the table presents the first-stage estimates. Our instrument for jumbo status is strong—in each subperiod, loans originated in period t with appraised property value above $\text{CLL}_t/0.8$ are economically and statistically significantly more likely to be financed by a jumbo loan, compared to loans in this appraisal band originated in period $t + 1$, and normalized relative to loans on properties in the appraisal band just *below* $\text{CLL}_t/0.8$.

Table A.1 in the Online Appendix repeats the same DiD analysis year-by-year up to 2005. The first-stage results show that our instrument is statistically significant in all years, though the relationship becomes stronger over time. The estimated effects of jumbo status on the probability of obtaining an FRM are relatively imprecisely estimated, especially for the early years of the sample, but generally close to zero, consistent with the pooled results. Also consistent with Table 2, the most negative effects on FRM share for a single year is for the year 2000, corresponding to the first illiquidity episode.

4.3 Regression Discontinuity Design

We also use a "fuzzy" regression discontinuity design as an alternative strategy for estimating the effect of jumbo status on the FRM share. We apply this approach using data from December 2003 to July 2007, a period in which a significant fraction of mortgage borrowers financed their homes with an LTV of exactly 80%. Although the RDD approach is still valid outside this period, it is unfortunately much less statistically powerful prior to 2004, since a smaller fraction of loans involved an LTV of exactly 80% (see Figure A.5 of the Online Appendix). Similarly, after the nonagency market freezes in the third quarter of 2007, high jumbo loan interest rates induced many borrowers to make a larger downpayment in order to obtain a conforming loan with a lower interest rate. The DiD approach is more amenable to estimation over the entire sample period, since it does not require a discrete jump in the fraction of jumbo loans at the CLL/0.8 threshold for identification. (On the other hand, the RDD has the advantage that it can be employed in 2006 and the first half of 2007; we cannot estimate a DiD treatment effect over this period because there is no change in the CLL.)

Figure 4 illustrates the identification strategy and the key result of our RDD analysis. Panel A of the figure plots the fraction of borrowers who select a jumbo mortgage against the ratio of the property appraisal amount to CLL/0.8. We observe a sizable discontinuous jump in the probability of selecting a jumbo mortgage at the appraisal cutoff (= CLL/0.8), of about 15 percentage points. However, as shown in the other two panels of the figure, this shift has little or no effect on the market share of 30-year prepayable FRMs (Panel B) or all FRMs (Panel C). By both measures, the FRM share is trending downward with appraisal amount, reflecting that larger mortgages tend to be more likely to feature an adjustable interest rate. But there is no discernible discontinuity around the appraisal cutoff.

To implement this fuzzy RDD formally, we estimate local linear regressions (see e.g. Imbens and Lemieux 2008 for an introduction) on either side of the CLL/0.8 threshold.[16] As shown by Hahn, Todd, and van der Klaauw (2001), the treatment effect τ in a fuzzy RDD can be estimated by the "Wald estimator" in a two-stage least squares setting:

$$\tau = \frac{\lim\limits_{\varepsilon \to 0^+} \mathrm{E}[Y|X = c + \varepsilon] - \lim\limits_{\varepsilon \to 0^+} \mathrm{E}[Y|X = c - \varepsilon]}{\lim\limits_{\varepsilon \to 0^+} \mathrm{E}[D|X = c + \varepsilon] - \lim\limits_{\varepsilon \to 0^+} \mathrm{E}[D|X = c - \varepsilon]} \tag{1}$$

where X is the "running variable" (the appraisal amount in our setting), c is the threshold (CLL/0.8), Y is the outcome of interest (e.g. FRM30noPPP), and D is the treatment indicator (jumbo). Intuitively, the fitted local linear regressions project the expected value of the jumbo loan share or the outcome variable at the CLL/0.8 threshold, both from below and

[16]We include the same set of control variables as in the DiD analysis. To choose the bandwidth for the local linear regressions, we use a cross-validation procedure similar to Almond et al. (2010) (we thank Heidi Williams for sharing their Stata code with us). We estimate local linear regressions of our outcome variable of interest on appraisal value over a window of 0.7 to 1.3 times CLL/0.8 using a variety of bandwidths, and compare the results to a fourth-order polynomial model, estimated separately above and below the threshold. The bandwidths (as a multiple of CLL/0.8) that minimize the sum of squared errors are around 0.08 for Pr(FRM30noPPP) and 0.03 for Pr(jumbo) in the pooled data. For simplicity, we use 0.08 as our baseline bandwidth for all variables, and report the sensitivity of our results to alternative choices in Table A.2 of the Online Appendix, where we also separately estimate the RDD year-by-year (Table A.3).

from above the threshold. The discontinuity at the threshold is measured as the difference between the projection from below and from above.

Results for the pooled data over 2004 to mid-2007 are presented in Table 3. The first row reports the estimated treatment effect of jumbo status, while the rows below show the numerator and denominator of the Wald estimator. The estimated effect of jumbo status on the probability of matching with a prepayable 30-year FRM is 0; given the estimated standard error of 0.025, the effect can be bounded as being no larger than +/- 0.05 with probability 95%. The estimated effect of jumbo status on the share of all FRMs is slightly positive, although also statistically insignificant. Finally, jumbo loans are slightly (2.4%) more likely to be retained in portfolio, statistically significant at the 5% level.

We also compare the estimated effects from the RDD and DiD approaches for the years 2004 and 2005, for which we can use both strategies. The two approaches provide similar results. For Pr(FRM30noPPP), the estimated treatment effect of being in the jumbo segment is 0.004 (s.e. 0.032) using the RDD and -0.022 (s.e. 0.016) using the DiD. For Pr(FRM), the corresponding numbers are 0.023 (s.e. 0.023) using the RDD and -0.024 (s.e. 0.016) using the DiD. None of them are significantly different from zero.

To sum up, these RDD estimates imply that over 2004 to mid-2007, access to agency securitization markets had at most a small causal effect on the relative supply of FRMs, consistent with our DiD estimates for periods when jumbo securitization was well-functioning. This suggests that liquid private securitization markets provided a close substitute for the government-backed agency MBS market as a means of diversifying the prepayment and interest rate risk associated with FRMs.

4.4 Effects on Mortgage Interest Rates

Our interpretation of the evidence presented above is that lenders disproportionately reduce the supply of FRMs when loans are difficult to securitize and generally retained in portfolio.

In practice, this contraction in FRM supply could be implemented through several channels. Lenders could increase mortgage interest rates or points and fees on FRMs, inducing borrowers to substitute toward ARMs. Lenders could also adjust the intensity with which different loans are marketed to borrowers, through advertising or via incentives given to brokers and sales agents. Finally, lenders could simply ration the supply of particular contract types.

In this section we analyze the direct interest rate effects of the 2007–09 nonagency securitization freeze using mortgage interest rate data from HSH Associates. These data are derived from a large weekly survey in which lenders provide pricing data for different types of loans, including both jumbo and non-jumbo mortgages. We obtained national weekly average offered rates and average points for conforming and jumbo 30-year FRMs and 5/1 ARMs.[17] Lenders report a direct (i.e. non-broker) retail interest rate for a loan with zero to one points, to a borrower with good to excellent credit quality, and with a combined LTV of 80%.[18] These data are available from late 2006 onwards for both jumbo and non-jumbo loans. Because the survey does not properly distinguish between jumbo and "super-conforming" loans in high-cost housing areas, however, we focus on the period up to April 2008, before the higher temporary CLLs are implemented.

We are interested in how the interest rate spread between jumbo and conforming FRMs evolves as the market freezes, *relative* to the jumbo-conforming spread for ARMs. Graphical evidence on this point is presented in Figure 5, which plots the jumbo-conforming spread for 30-year FRMs and 5/1 ARMs over the period July 2006 to April 2008. The jumbo-

[17]A 5/1 ARM is a 30-year adjustable-rate mortgage with a fixed interest rate for the first five years; the rate thereafter is set at a spread over a short-term market rate, adjusting once per year.

[18]These survey data have two advantages over interest rates available in LPS. First, LPS does not report points and fees. Second, using interest rates on realized loans may bias estimates of the jumbo-conforming spread, because mortgage choice is an endogenous decision of the borrower, which responds to relative prices. To illustrate, consider a simple example in which there are two banks, A and B, with equally-sized fixed customer bases. Bank A charges no premium on jumbo FRMs (relative to conforming FRMs). Bank B, however, charges a high premium of 100 basis points. Consequently, no jumbo customers of bank B select an FRM, they all select ARMs instead. In this example, the FRM jumbo-conforming spread based on mortgage transaction data would be erroneously measured to be zero, because observed jumbo loans in the data would come only from bank A.

conforming spread rises sharply for both FRMs and ARMs in August 2007, at the same time as securitization activity for jumbo MBS freezes. Importantly, however, the relative increase in jumbo mortgage rates is substantially larger for FRMs than for ARMs.

Formalizing this graphical evidence, we estimate the following regression model:

$$(r_{jumbo} - r_{conforming})_{it} = \beta_0 + \beta_1 \cdot FRM_i + \beta_1 \cdot Freeze_t + \alpha \cdot FRM_i \times Freeze_t + \varepsilon_{it}$$

where the dependent variable is the jumbo-conforming spread for the mortgage type in question (i = FRM or 5/1 ARM), *FRM* is an FRM dummy, and *Freeze* is a dummy equal to 1 from August 2007 onwards. Results are presented in Table 4. Consistent with the graphical evidence, the estimated increase in mortgage interest rates following the August 2007 freeze is nearly twice as large for FRMs as for ARMs, as evidenced by the positive and statistically significant coefficient α of +29bp.

Summing up, consistent with a mortgage supply response, the freeze in access to securitization markets increases mortgage interest rates for all jumbo mortgages, but disproportionately affects rates for jumbo FRMs.[19]

5 Interpretation and Additional Evidence

We interpret our findings as evidence that lenders are averse to retaining the prepayment and interest rate risk associated with FRMs. This section presents additional evidence supporting this interpretation, and considers a number of alternative explanations for our findings.

[19] As can be seen from the table and graph, we also find a jumbo-conforming spread for both FRMs and ARMs prior to the market freeze, consistent with earlier research. While the measured jumbo-conforming spread is somewhat larger for FRMs in 2006 and 2007, our DiD and RDD estimates suggest that borrowers' contract choice was not particularly sensitive to this small difference in relative rates.

5.1 Lender Financial Constraints and Risk-Bearing Capacity

The perfect experiment to test our main hypothesis would be a shock to securitization that has no other effects on the financial system. Although the 2007–09 time period involves a discrete freeze in jumbo securitization activity, this period also differs in other ways from the rest of our sample. Most importantly, it was a period of very significant overall stress for the financial sector, when many lenders were likely financially constrained.

Although this consideration does not invalidate our findings, it raises an important question about external validity, that is, whether our results would be informative about the effects of securitization on mortgage contract design outside of a period when the banking system is in crisis. One hypothesis is that if nonagency securitization activity diminished during a "normal" period, the effect on FRM supply would be much smaller, because lenders would have the risk-bearing capacity to pick up the slack relatively easily, consistent with Froot and Stein (1998). Conversely, risk-shifting incentives à la Jensen and Meckling (1976) may have induced undercapitalized lenders to become *less* risk-averse during the financial crisis period, as modeled in the banking context by Boyd and Hakenes (2014) (see also Acharya et al. 2009; Dam and Koetter 2012). This would lead our results to be attenuated relative to a non-crisis period.

Although it is not clear which of these competing forces dominates, we do expect that the weak financial condition of mortgage lenders during 2007–09 is likely to influence the magnitude of our results from that period. However, we now describe several types of evidence from periods when the banking system is stable that also support the hypothesis that access to securitization is important for the availability of FRMs not just during crisis periods, but more generally.

First, we estimate a large treatment effect of jumbo status on the FRM share during the jumbo MBS illiquidity episode in 1999-2000, even though lenders were not distressed during this earlier time period. To document this, section B.2 of the Online Appendix presents time-series data on mortgage lending standards from the Federal Reserve Senior Loan Officer Opinion Survey, and three measures of financial health for the commercial banking industry: asset growth, return on assets, and the fraction of nonperforming mortgages. The financial condition and risk-bearing capacity of the banking system was deteriorating in 2007-2008 by these measures. But in 1999 and 2000, bank profitability was high and stable, balance sheets were growing, and mortgage lending standards were stable.

Second, we find that the share of FRMs retained in portfolio is much smaller than for ARMs throughout our sample period. For our LPS sample as a whole, only 4.6% of FRMs are retained in lender portfolios after six months; this fraction is almost five times higher for ARMs, at 21.5%. The share of retained loans is lower for FRMs in every calendar year in our sample. This stylized fact shows that lenders consistently rely more heavily on securitization for funding FRMs, and is consistent with relatively lower willingness of lenders to hold FRMs in portfolio, because of their interest and prepayment risk.

Third, the MIRS dataset, unlike LPS, provides some information on lender type; in particular, it allows us to distinguish between savings banks, commercial banks, and mortgage banks. Historically, savings banks specialized in mortgage lending, and unlike other lenders, these firms are obligated by regulation to hold a relatively high percentage of their assets in mortgages or mortgage-related securities.[20] As a consequence, the risk management hypothesis would predict that these firms originate fewer (long-term) FRMs than the other lender types. Indeed, this is what is observed in the data: over 1996–2009, savings banks originated more than twice as many ARMs as a share of overall originations compared to mortgage and commercial banks (40.5% vs. 16.7%, value-weighted). They also originated a larger share of FRMs with a term below 30 years (16.0% vs. 9.1%). Although different explanations could account for these facts, they are consistent with the idea that savings banks originate fewer

[20]Savings banks are subject to the Qualified Thrift Lender test, requiring them to maintain at least 65 percent of assets in a relatively narrow set of assets, the most important of which is mortgages and mortgage-backed securities.

long-term FRMs in order to limit the share of such loans in their large mortgage portfolios.

Finally, anecdotal evidence also supports our risk management interpretation. A Wall Street Journal article from 2013, after the banking system had stabilized, states that: "[W]ith the renewal of the secondary market for jumbo mortgages, more lenders today are willing to offer fixed rates. Packaging the loans into mortgage-backed securities that are sold to investors can lessen the risk to lenders."[21]

5.2 Borrower Selection during Market Freeze Period

A possible alternative explanation for our findings, especially during the 2007–09 nonagency market freeze, is a borrower selection effect in the jumbo market. After the nonagency MBS market becomes illiquid, the overall supply of credit in the jumbo market contracts relative to the conforming market (as illustrated by the sharp increase in the jumbo-conforming spread discussed earlier). If this contraction leads to rationing of borrowers with a preference for FRMs, it could account for the low FRM share above the CLL during this period.

To test for this possibility, we repeat our DiD analysis restricting the regression sample to subsets of the most creditworthy borrowers: (i) non-subprime loans to borrowers with FICO scores above 740 and who provided full documentation (or the documentation status is recorded as "unknown"), or (ii) non-subprime loans to borrowers with FICO scores above 780. Under the selection effects hypothesis, our key coefficient estimate will be attenuated among these subsamples, because they are less likely to be credit rationed in the jumbo market than the average borrower. However, under the risk management hypothesis, the estimated effect of agency MBS access on the FRM share will be similar to our baseline estimates, or may even become larger, to the extent that prepayment risk is more pronounced among more creditworthy borrowers.

Our results, shown in Table 5, are consistent with this second explanation, not the first.

[21] "Fixed-Rate Jumbo Mortgages Make a Comeback," *Wall Street Journal*, May 28, 2013.

Although somewhat less precisely estimated (due to the smaller sample size), our coefficient estimates are substantially larger in magnitude for the FICO>740 subsample than in our baseline sample (e.g. the instrumented second-stage estimate for the share of FRM30noPPP goes from -0.29 to -0.46), and even larger for the FICO>780 subsample. This suggests the low comparative share of FRMs among jumbo loans that are illiquid due to the nonagency MBS freeze is not driven by borrower selection due to rationing.

5.3 Demand-Side Drivers of Mortgage Choice

Our econometric approaches are designed to isolate the effect of funding source on contract structure, holding demand constant. Even so, it is important to consider whether residual demand factors could be influencing our results.

5.3.1 The Role of House Price Growth

A number of papers have studied demand-side drivers of mortgage choice. For instance, Campbell and Cocco (2003) theoretically explore factors that should lead a household to prefer an ARM over an FRM. They argue that ARMs should be particularly attractive to credit-constrained households (who seek to purchase expensive houses relative to their current income, in expectation of higher future income). Other factors that should lead to a preference for ARMs are low risk aversion, stable income, or a high probability of moving. Coulibaly and Li (2009) present empirical evidence consistent with these predictions.

Barlevy and Fisher (2011) argue that speculating homebuyers select mortgages with backloaded payments, such as interest-only ARMs, and present evidence that the use of these types of loans was concentrated in areas that experienced large house price booms. Similarly, Amromin et al. (2011) document that the use of "complex mortgages," which in most cases feature adjustable rates, increases with past house price appreciation.

These findings are relevant for our study, since house prices were rising rapidly in many parts of the country over a large part of the sample period for which we detect no evidence for an economically large effect of jumbo status on contract structure. The housing boom could affect our DiD estimates if either borrowers' affordability constraints or expectations, and therefore their ARM demand, changed *differentially* from year t to $t+1$ in the appraisal bands above and below $\text{CLL}_t/0.8$.[22]

Our regressions include state-by-year fixed effects, meaning that our estimates of the effect of jumbo status are within state-year, where heterogeneity in terms of affordability, mobility, or expected home price growth was presumably much smaller than at the national level. Nevertheless, Table 6 presents the results from additional analyses to assess whether strong house price growth could affect our results. One indication of this would be a strong negative effect of jumbo status on the FRM share in the early part of our sample, when house prices were growing less quickly. Column (1) shows that this is not the case—estimating a pooled DiD analysis for 1996–1999 (prior to the first illiquidity episode) only, we obtain an estimated treatment effect that is in fact slightly positive, though imprecisely estimated.

The remaining columns of the table instead focus on the house price boom period 2002–2005. Column (2) estimates the treatment effect using the same specification as our main analysis, obtaining similar results. In column (3), we add several variables to control for differential affordability and expectations about house price growth: (i) the median local transaction price; (ii) the maximum local house price level relative to January 2002 (to control for the overall magnitude of the boom); and (iii) local house price growth over the 12 months prior to loan origination. The estimated treatment effect is almost unaffected by the inclusion of these controls. Finally, columns (4) and (5) split the 2002–05 sample into counties with above-median and below-median total house price growth over the boom (maximum price appreciation relative to January 2002). Although the estimated effect of jumbo status is more negative for loans in areas with low house price growth, perhaps consistent with

[22]For the RDD, it is unlikely that affordability or expectations would vary discontinuously at the CLL/0.8 threshold, which is what would be required for these factors to affect the treatment effect.

some demand-side effects, the difference in coefficients between the two subsamples is not statistically significant ($p > 0.1$). We also show in the Online Appendix that in the MIRS data, the estimated effect in the low house price growth subsample is positive and larger than for the high growth subsample (i.e., the opposite of what is found for LPS).

Taken together, these results suggest that the finding of little or no effect of jumbo status on contract structure during "normal times" (when the nonagency MBS market is liquid) is at most weakly affected by the extraordinary house price growth, and its effect on affordability and expectations, over part of our sample period.

Demand-side considerations could also be important during the market freeze period. In particular, borrowers who obtain a jumbo loan during the financial crisis might anticipate refinancing quickly because of the elevated jumbo-conforming spread, either to a non-jumbo loan, or into a lower-rate jumbo loan once the spread has normalized. This shorter expected holding period could increase their relative demand for ARMs compared to FRMs, and generate the patterns we observe in the data, even with no change in the relative supply of FRMs versus ARMs.[23] It is difficult to directly test this hypothesis, as there is no (observable) cross-sectional heterogeneity that could be exploited to do so. However, as we have shown in section 4.4, the behavior of mortgage interest rates during the market freeze period is not consistent with this hypothesis. Under this refinancing explanation, there is no reason to expect a larger increase in the jumbo-conforming interest rate spread for FRMs (relative to ARMs) after the market freeze; in fact, if anything the spread should rise less for FRMs, assuming lenders are cognizant of the decline in duration for such loans.

5.3.2 Time-Series Variation in FRM Shares

Koijen et al. (2009) argue that the demand for FRMs (relative to ARMs) should decrease with the term premium on long-term bonds. They then propose that a reasonable way for

[23]We thank Brian Melzer for suggesting this mechanism to us.

households to assess the term premium is to form expectations about future short-term rates from recent average short-term rates. Consistent with this, they find that a simple rule-of-thumb variable, the difference between the current 10-year Treasury yield and the average 1-year Treasury yield over the past three years, explains a large fraction of the substantial time-series variation in the FRM share, shown in Figure 2. Notably, this variable outperforms the contemporaneous spread between FRM and ARM rates in explaining the FRM share.

In Table 7, we build on this work to study how nonagency MBS liquidity affects the FRM share, controlling for the demand-side rule-of-thumb variable of Koijen et al. To do this, we estimate separate time-series models for the conforming and jumbo FRM shares, and for the difference between the two segments. Columns (1) and (3) confirm that the Koijen et al. rule-of-thumb variable has significant explanatory power for the FRM share in both segments, with R^2 values of 0.72 and 0.52 respectively. In columns (2) and (4), we add indicator variables for our two nonagency illiquidity periods, as well as for the period with CLL expansion (May 2008 through the end of our sample). For the conforming sample, the additional explanatory power of these variables is modest, while in the jumbo sample, they have substantial effects: the FRM share is 19 percentage points lower during the market freeze periods than what would be expected based on the demand side alone, and is 23 percentage points higher after the CLL expansion. Also, the R^2 increases by 0.29 when these two indicator variables are added.

Next, column (5) shows that the rule-of-thumb variable has little explanatory power for the time-series evolution of the *difference* in FRM shares between conforming and jumbo loans. However, the two indicator variables explain most of the time variation ($R^2 = 0.70$): during the nonagency illiquidity periods, the FRM share is 24 percentage points lower for jumbos relative to the conforming segment, while during the CLL expansion period (when most jumbo loans effectively become conforming) it is 11 percent higher (column 6).

These results, while not as cleanly identified as our DiD or RDD approaches, confirm the main findings from the cross-sectional analyses. Additionally, column (4) shows that the jumbo FRM share is unusually low during the periods of nonagency MBS illiquidity, even if we benchmark the FRM share relative to the predictions of the Koijen et al. model, rather than to the conforming segment as we do in our main analysis.

5.4 Other Robustness Checks

In the Online Appendix, we present results from additional robustness checks. In addition to qualitatively replicating our main results in the MIRS data, we also use two alternative estimation approaches, which are briefly described here.

Our DiD in section 4 identifies the effect of securitization access during the crisis from the effective introduction of higher CLL in May 2008. One potential confound of this identification is that when F&F introduced the super-conforming loans, they charged an additional 0.5 point upfront fee (called a "loan-level price adjustment") for ARMs.[24] A reasonable hypothesis is that this fee appropriately reflects the additional credit risk of ARMs, in which case it would not tilt mortgage choice toward FRMs (as lenders would have to effectively bear this cost when holding an ARM in portfolio). Nevertheless, to check the robustness of our findings, the Online Appendix presents an alternative DiD which instead relies on the onset of the freeze in August 2007. Since there is no change in the CLL at that time, we compare FRM shares in bands around \$521,250 (=417,000/0.8) in the nine months before and after August 2007, while accounting for the changing likelihood of obtaining a jumbo loan. The estimated effect of jumbo status on Pr(FRM30noPPP) during the market freeze period is -0.27, very close to the estimate from our main DiD. This suggests that institutional factors coupled with the introduction of higher CLL were not driving the earlier result.

The Online Appendix also presents results from an alternative estimation approach using

[24] See Fannie Mae Announcement 08-05, "Temporary Increase to Our Conventional Loan Limits." A 0.5 point upfront fee translates to approximately 0.05-0.1% in interest rate space, if it is financed.

fractional polynomial regressions. There, rather than using appraisal value as an instrument to minimize endogeneity concerns about loan amount, we simply exclude loans with principal amounts close to the CLL, and account for the possibly nonlinear dependence of Pr(FRM) on loan amount in a flexible way. The idea behind this strategy is that the selection effects discussed earlier are likely to be concentrated near the CLL. Results from this approach are also consistent with the findings discussed in the main text.

6 Conclusion and Policy Implications

We interpret our findings from the nonagency MBS freeze that began in 2007, as well as an earlier period of illiquidity in 1999–2000, as evidence that mortgage contract design is sensitive to the ease with which mortgages can be securitized. Reduced access to securitization translates directly into a decline in lenders' willingness to originate freely prepayable long-term FRMs, leading to a significant shift in equilibrium household mortgage choice toward adjustable-rate contracts and FRMs with lower risk. This interpretation is consistent with the predictions of Froot and Stein (1998) and other theoretical models in corporate finance that emphasize so-called "operational hedging" as a channel of risk management.

Our findings suggest a number of policy implications for ongoing reform of the U.S. mortgage finance system. First, regulatory or legislative actions that discourage securitization, such as the implementation of stringent risk retention requirements, may lead to a lower share of FRMs among affected mortgages. Incentives to increase the use of covered bonds, as sometimes proposed, could also potentially reduce the FRM share, since under such a system, prepayment risk is typically retained by the lender.[25]

[25]In a standard covered bond structure (common e.g. in Germany), a noncallable bond is issued backed by a pool of loans known as the "cover pool" that remains on the balance sheet of the originator. Prepayment risk is borne by the originator, just as if the mortgages were funded by deposits. Covered bonds can reduce interest rate risk, however, since the bond is generally of long duration, like the mortgages in the cover pool. In contrast to a standard noncallable covered bond, in Denmark, mortgage banks issue bonds that mimic the cashflows on each mortgage, transferring prepayment risk to bondholders. Our risk management

Second, maintaining the central role of government guarantees and F&F in mortgage finance may not be necessary for FRMs to remain widely available at competitive rates, but only as long as private securitization markets are liquid. This is supported by our finding that prior to the crisis, the FRM share was at most modestly lower among jumbo loans ineligible for agency securitization. Although nonagency MBS market activity has been low since 2007, issuance has increased recently.

Third, recent experience suggests that liquidity in private MBS markets is more volatile than in government-backed markets, correspondingly leading to volatility in FRM supply. Scharfstein and Sunderam (2011) argue in favor of government support for mortgage funding markets only during crises, which could mitigate these effects.

Perhaps the most important caveat associated with these policy conclusions is that we conduct a partial equilibrium analysis based on local variation in access to securitization markets. It is possible that our results would not translate closely into a large change in the mortgage finance system, such as entirely winding down F&F and replacing them with a purely private funding market. For example, eliminating F&F could reduce the liquidity of the TBA ("to-be-announced") market. This market is used to trade agency MBS, but also confers benefits to nonagency originators and investors, such as the ability to hedge short-term price risks for jumbo MBS. Formal modeling of general equilibrium effects would be a useful complement to the partial equilibrium evidence presented here.

Finally, we highlight that our analysis is entirely positive rather than normative in nature. This paper does *not* take a stand on whether or not maintaining the primacy of the 30-year FRM is a desirable policy goal from a social welfare perspective, a question on which experts and policymakers sharply disagree (see e.g. Lea and Sanders 2011). We do emphasize, however, that changes in the FRM share are likely to have significant economic consequences, given the importance of residential mortgages and MBS in household and investor portfolios.

interpretation thus provides an explanation for why Danish lenders originate long-term prepayable FRMs, like the U.S., but unlike other countries in Europe.

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Table 1: Conforming loan limits over sample period

The CLL represents the maximum loan size that Fannie Mae and Freddie Mac are able to purchase and securitize. Table shows national CLL (up to 2008) for single-family homes; higher limits apply for mortgages on multifamily dwellings, and homes in Alaska, Hawaii, Guam and the US Virgin Islands. Under the ESA passed in February 2008, CLLs were raised in counties with high average home prices, as explained in the main text. The CLL/0.8 column presents the threshold for a property's appraisal value such that properties below this threshold can be financed with a conforming loan at 80% loan-to-value ratio.

Year	CLL (1 unit), in $	CLL/0.8
1996	207,000	258,750
1997	214,600	268,250
1998	227,150	283,938
1999	240,000	300,000
2000	252,700	315,875
2001	275,000	343,750
2002	300,700	375,875
2003	322,700	403,375
2004	333,700	417,125
2005	359,650	449,563
2006	417,000	521,250
2007	417,000	521,250
2008	417,000 – 729,750	521,250 – 911,563
2009	417,000 – 729,750	521,250 – 911,563

Table 2: Difference-in-differences analysis

Table shows the estimated treatment effect of being in the jumbo segment of the mortgage market on: the probability of obtaining a freely prepayable fixed-rate mortgage with term of 30 years or higher (FRM30noPPP); the probability of obtaining any type of fixed-rate mortgage (FRM); and the probability of a loan being held in portfolio six months after origination (Non_sec6), for three different periods. The periods listed correspond to the periods for which the treatment effect is estimated; the estimation sample in each case also contains a "post sample" with higher CLLs (for 1996–2005, this is the respective subsequent calendar years; for Jul 1999–Jun 2000, the years 2000 and 2001; and for Aug 2007–Apr 2008, May 2008–Jan 2009). Bottom part of the table shows estimated coefficient on the instrumental variable in the first-stage regression. Sample includes purchase-money conventional mortgages with appraisal amounts in the range [$\mathrm{CLL}_t/0.8 - \min(\mathrm{CLL}_{t+1}/0.8 - \mathrm{CLL}_t/0.8,\ 0.1\cdot\mathrm{CLL}_t/0.8)$, $\mathrm{CLL}_t/0.8 + \min(\mathrm{CLL}_{t+1}/0.8 - \mathrm{CLL}_t/0.8,\ 0.1\cdot\mathrm{CLL}_t/0.8)$] for loans originated between 1996–2006, and [$417000/0.8 - \min(\mathrm{CLL}_{2008}/0.8 - 417000/0.8,\ 0.1\cdot 417000/0.8)$, $417000/0.8 + \min(\mathrm{CLL}_{2008}/0.8 - 417000/0.8,\ 0.1\cdot 417000/0.8)$] for loans originated between August 2007 and January 2009 (where "CLL_{2008}" denotes the higher local loan limits that became effective in May 2008). Controls in each specification include month dummies, state dummies, a cubic function of FICO score at origination (with a dummy for missing FICO), an investor dummy (including second homes), a condo dummy, and a subprime dummy, all interacted with calendar year dummies.

Second Stage:	(1) Pr(FRM30noPPP)	(2) Pr(FRM)	(3) Pr(Non_sec6)
Nonagency market is liquid			
1996–2005 (excluding 7/1999–6/2000):			
Jumbo	-0.031***	-0.033***	0.079***
	(0.010)	(0.011)	(0.010)
N	1622638	1622638	1054360
Nonagency market is illiquid			
Aug 2007–Apr 2008:			
Jumbo	-0.287***	-0.182***	0.241***
	(0.054)	(0.044)	(0.032)
N	64589	64589	57124
Jul 1999–Jun 2000:			
Jumbo	-0.269***	-0.232***	0.195***
	(0.050)	(0.050)	(0.038)
N	154544	154544	107335
First Stage (Pr(Jumbo)):	1996–2005	2007–2008	1999–2000
$(year_i = t)\times$	0.178***	0.062***	0.127***
$(appr_i > CLL_t/0.8)$	(0.034)	(0.008)	(0.017)

Standard errors (clustered at state level) in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3: Fuzzy regression discontinuity design estimates

Table shows the estimated treatment effect ("Wald estimate") of being in the jumbo segment of the mortgage market on: the probability of obtaining a freely prepayable fixed-rate mortgage with term of 30 years or higher (FRM30noPPP); the probability of obtaining any type of fixed-rate mortgage (FRM); and the probability of a loan being held in portfolio six months after origination (Non_sec6). The treatment effect is given by the ratio of the change in Pr(dependent variable) to the change in Pr(jumbo) around the appraisal threshold CLL/0.8 (see equation (1)). Sample includes purchase-money conventional mortgages originated between December 2003 and July 2007. Estimation uses local linear regressions with bandwidth 0.08·(CLL/0.8) and a triangle kernel that gives more weight to observations near the boundary. Controls in each specification include month dummies, state dummies, a cubic function of FICO score at origination (with a dummy for missing FICO), an investor dummy (including second homes), a condo dummy, and a subprime dummy, all interacted with calendar year dummies.

	FRM30noPPP	FRM	Non_sec6
Treatment effect of jumbo	0.000	0.017	0.024**
(Wald estimate)	(0.025)	(0.019)	(0.010)
Change in Pr(dep. var.)	0.000	0.003	0.004*
	(0.004)	(0.003)	(0.002)
Change in Pr(jumbo)	0.154***	0.154***	0.161***
	(0.045)	(0.045)	(0.048)
N	522267	522267	396393

Standard errors (clustered at state level) in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4: Interest rate differential between jumbo and conforming segment

Dependent variable is the interest rate spread between jumbo and conforming loans for either 30 year FRMs or 5/1 ARMs. Sample consists of weekly data of offered mortgage rates from August 2006 through April 2008, collected by HSH Associates. "Market freeze period" is taken to be August 2007 to April 2008. Note that HSH reports average up-front fees and points for each loan type. These are not incorporated in the results presented in the table, although we have estimated an an alternative version of the regression in which we add a fraction of these up-front points and fees to the interest rate. This has very little effect on the results, reflecting the fact that the HSH survey conditions on the fact that fees and points are no larger than 1 percent of the loan balance.

	Jumbo-conforming spread
FRM	0.130***
	(0.007)
Market freeze period	0.390***
	(0.029)
FRM $\times$	0.290***
Market freeze	(0.043)
Constant	0.073***
	(0.005)
N	182

Robust standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Difference-in-differences analysis for nonagency MBS freeze in 2007–2008: Robustness checks

Table shows the estimated treatment effects of jumbo status on the FRM share and fraction of loans retained in portfolio during the "market freeze period" August 2007 to April 2008 under different sample restrictions. Aside from these restrictions, sample and control variables are as in Table 2.

	(1) FRM30noPPP	(2) FRM	(3) Non_sec6
Baseline sample			
Jumbo	-0.287***	-0.182***	0.241***
	(0.054)	(0.044)	(0.032)
N	64589	64589	57124
Non-subprime, FICO>740, not marked as low/no-doc			
Jumbo	-0.458***	-0.239***	0.293***
	(0.082)	(0.063)	(0.064)
N	31062	31062	27729
Non-subprime, FICO>780			
Jumbo	-0.778***	-0.574***	0.326***
	(0.145)	(0.142)	(0.113)
N	17745	17745	15816

Standard errors (clustered at state level) in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Difference-in-differences analysis: investigating the role of house price growth

Table shows the estimated treatment effect of jumbo status on Pr(FRM30noPPP) under different sample restrictions. Sample includes purchase-money conventional mortgages with appraisal amounts in the range [$\text{CLL}_t/0.8 - \min(\text{CLL}_{t+1}/0.8 - \text{CLL}_t/0.8, 0.1 \cdot \text{CLL}_t/0.8)$, $\text{CLL}_t/0.8 + \min(\text{CLL}_{t+1}/0.8 - \text{CLL}_t/0.8, 0.1 \cdot \text{CLL}_t/0.8)$]. Monthly county-level house price indices (HPI) come from CoreLogic. Sample in column (1) excludes July-November 1999 from pre-period. House price controls in column (3) are the 12-month moving average county-level median transaction price (in $); the maximum HPI level after Jan. 2002; and HPI growth over the past 12 month; all interacted with calendar year. In columns (4) and (5), the sample is split according to maximum county-level house price appreciation (HPA) relative to Jan. 2002. Other control variables as in Table 2.

	(1)	(2)	(3)	(4)	(5)
Sample	1996-1999 all	2002-05 all	2002-05 all	2002-05 HPA>median	2002-05 HPA≤median
Jumbo	0.031 (0.090)	-0.036** (0.017)	-0.039* (0.020)	-0.021* (0.012)	-0.058** (0.026)
HP controls	N	N	Y	N	N
N	321415	1037835	1018800	504622	514178
Share FRM30noPPP	0.73	0.47	0.47	0.38	0.55

Standard errors (clustered at state level) in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Explaining time-series variation in FRM shares

Time series regression model of the determinants of the value-weighted share of FRM30noPPP mortgages in the conforming segment (columns 1 and 2), the jumbo segment (columns 3 and 4), and the difference between the two segments (columns 5 and 6). Explanatory variables include the Treasury rates rule-of-thumb variable of Koijen et al. (2009), as well as indicators for market freeze periods (= 1 for July 1999–June 2000 and August 2007–April 2008) and the CLL expansion (May 2008-December 2009). Data period is January 1996–December 2009; data source is LPS.

	(1)	(2)	(3)	(4)	(5)	(6)
	Conforming		Jumbo		Conf.−Jumbo	
Treasury rates rule-of-thumb	-0.107***	-0.094***	-0.141***	-0.129***	0.034**	0.035***
	(0.010)	(0.010)	(0.017)	(0.015)	(0.017)	(0.010)
Market freeze periods		0.051***		-0.187***		0.238***
		(0.017)		(0.027)		(0.023)
CLL expansion		0.122***		0.230***		-0.108**
		(0.030)		(0.074)		(0.049)
Constant	0.812***	0.780***	0.574***	0.560***	0.238***	0.220***
	(0.018)	(0.017)	(0.037)	(0.026)	(0.033)	(0.020)
Adj. R^2	0.72	0.81	0.52	0.81	0.08	0.70
N	168	168	168	168	168	168

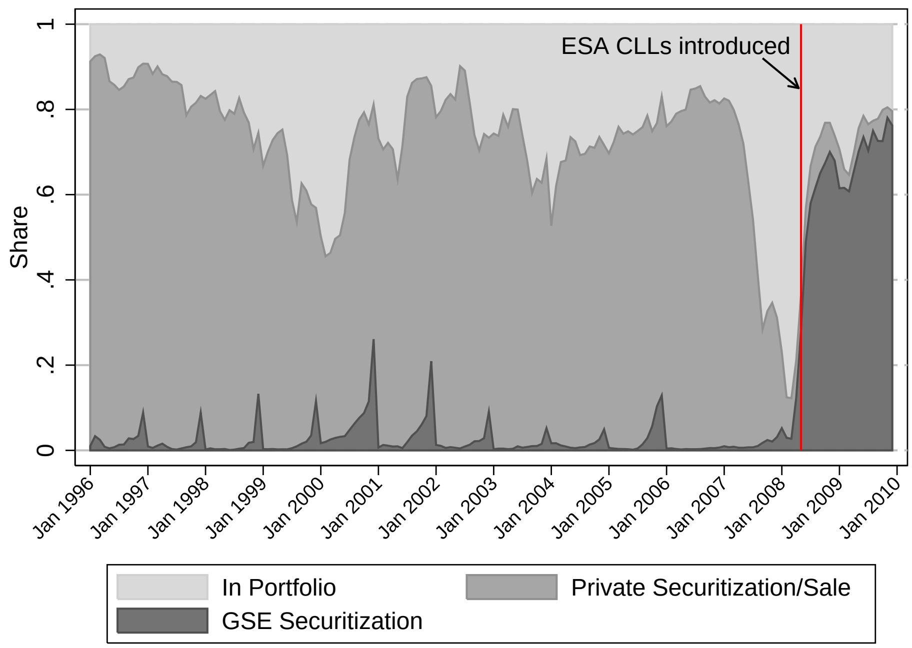
Newey-West (12 lags) standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Figure 1: Securitization activity in jumbo and non-jumbo segment

Author calculations based on LPS data. Purchase-money conventional mortgages only; shares are value-weighted. For graph, jumbo status is defined relative to national conforming limit. Thus, for 2008 and 2009, "super-conforming" mortgages in high-home-price counties are included as part of the jumbo segment. Securitization status is measured six months after origination. Horizontal axis indicates mortgage origination date, not securitization date. Vertical line in May 2008 marks the effective date of the increase in loan limits above the national CLL in high-home-price counties under the ESA.

A. Securitization status six months after origination, jumbo loans



B. Securitization status six months after origination, non-jumbo loans

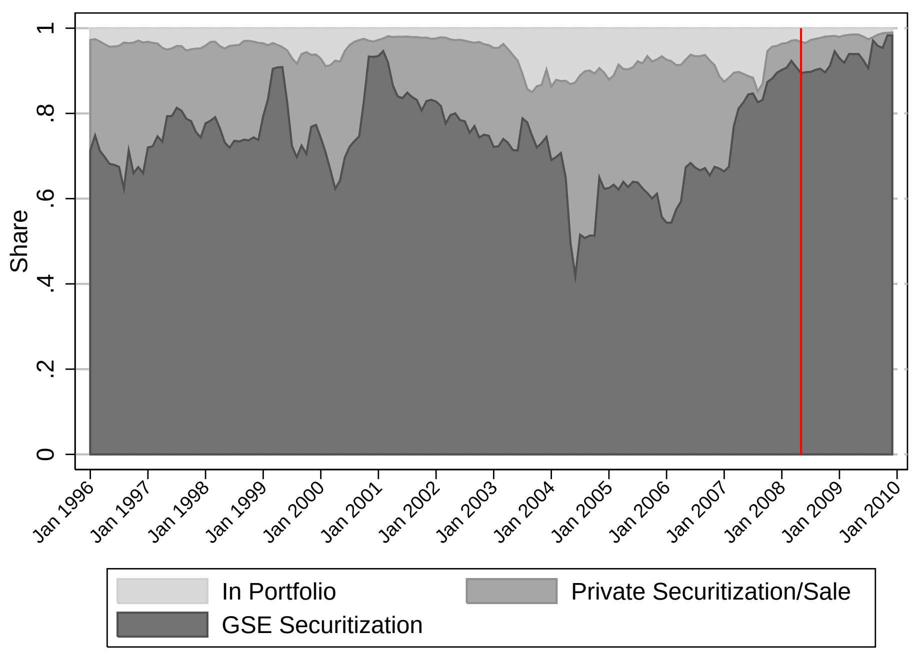
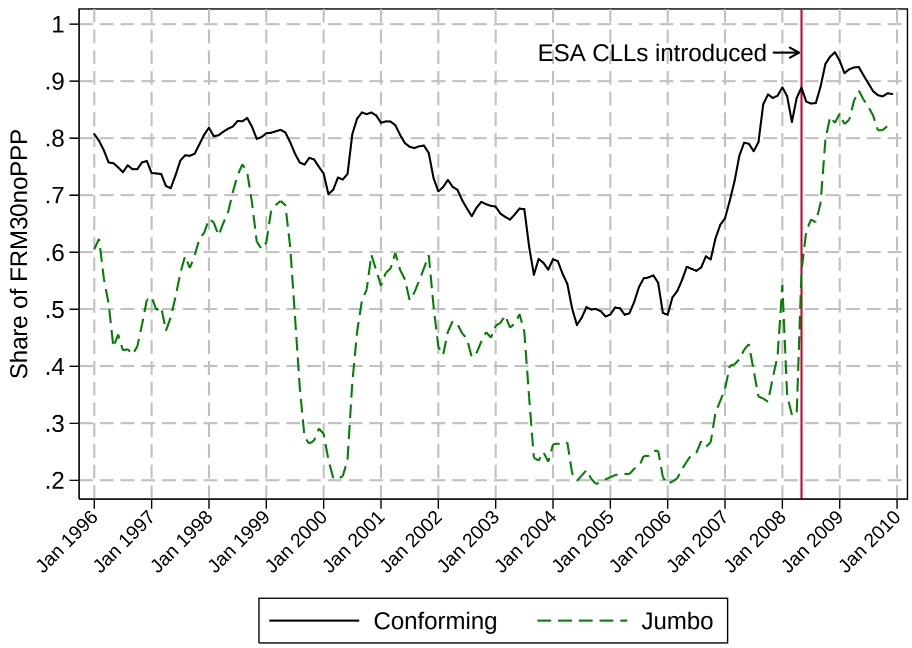


Figure 2: Market share of fixed-rate mortgages in jumbo and non-jumbo segment, 1996–2009

Author calculations based on LPS data. Purchase-money conventional mortgages only; shares are value-weighted. For graph, jumbo status is defined relative to national conforming limit. Thus, for 2008 and 2009, "super-conforming" mortgages in high-home-price counties are included as part of the jumbo segment. Vertical line in May 2008 marks the effective date of the increase in loan limits above the national CLL in high-home-price counties under the ESA.

A. 30-year FRMs without prepayment penalties



B. Difference in FRM shares, conforming minus jumbo

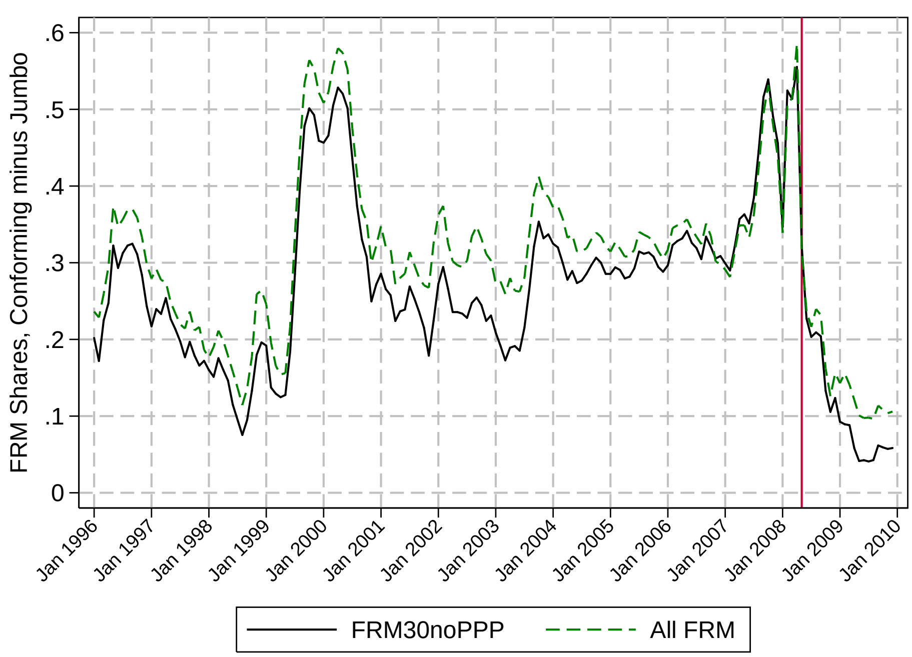
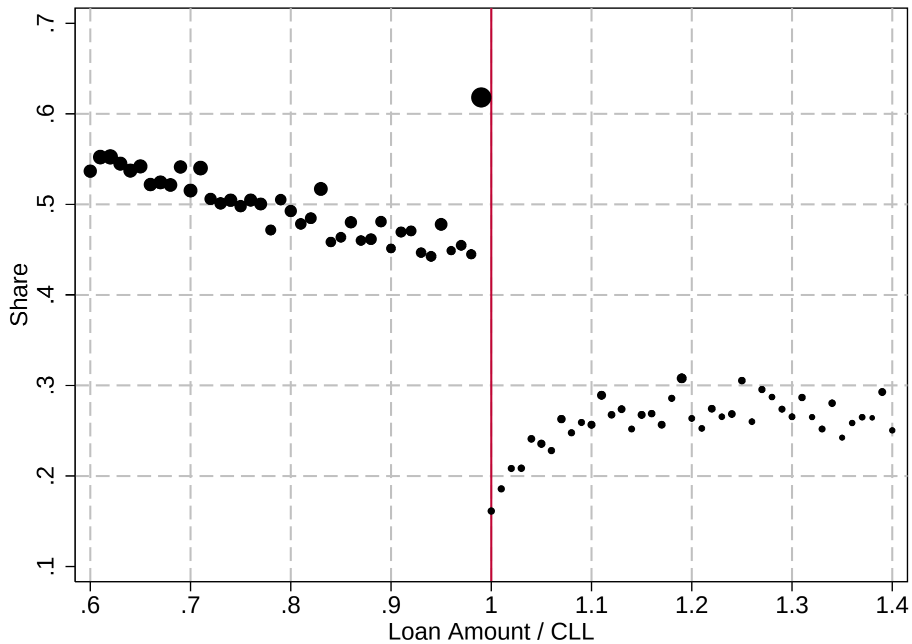


Figure 3: Selection around the conforming loan limit

Based on LPS data for purchase-money conventional mortgages originated between December 2003 and July 2007. Dots represent normalized loan amount bins of size 0.01; 1 means that loan amount is in (CLL, 1.01 · CLL]. Size of dots is proportional to the number of loans in a bin.

A. Share of 30-year FRMs without prepayment penalties (FRM30noPPP) by loan amount relative to CLL



B. Mean FICO score by loan amount relative to CLL

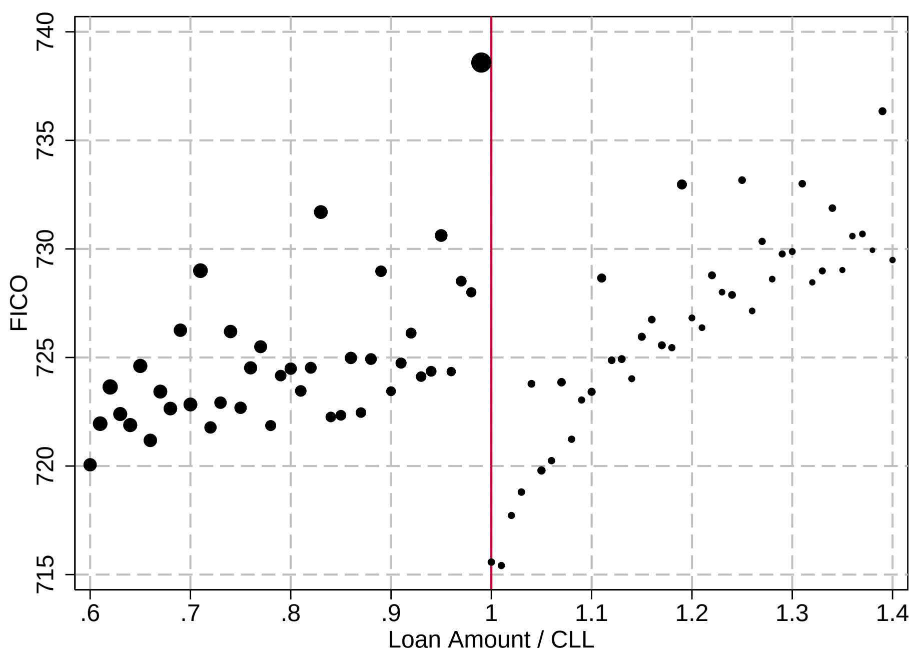
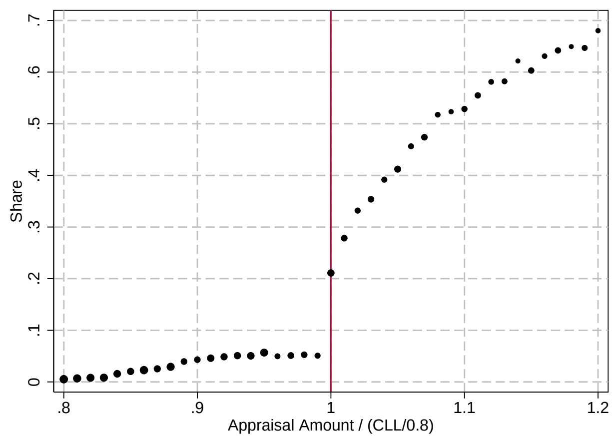


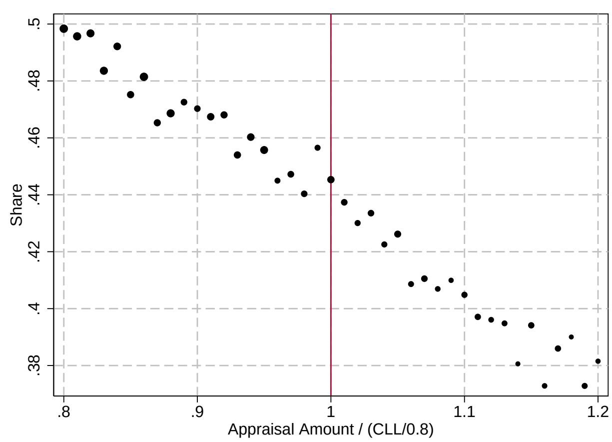
Figure 4: Regression discontinuity analysis

Based on LPS data for purchase-money conventional mortgages originated between December 2003 and July 2007. Dots represent normalized appraisal amount bins of size 0.01; 1 means that appraisal amount is in (CLL/0.8, 1.01 · CLL/0.8]. Size of dots is proportional to the number of loans in a bin.

A. Probability of selecting a jumbo mortgage



B. Probability of selecting a 30-year prepayable FRM



C. Probability of selecting any FRM

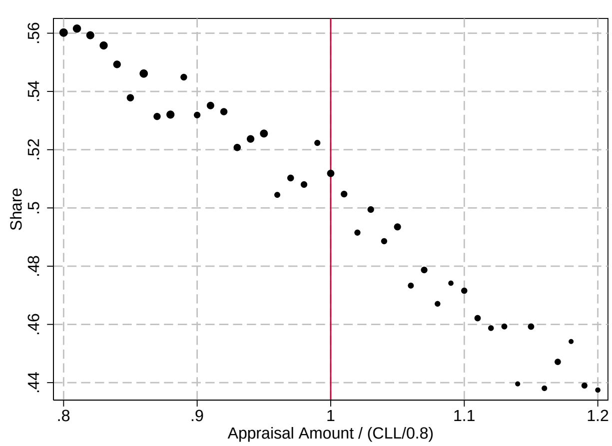


Figure 5: Jumbo-conforming interest rate spread for FRMs and ARMs

Figure shows the jumbo-conforming interest rate spread (i.e. the difference between offered rates to jumbo borrowers and conforming borrowers), separately for fixed-rate and adjustable-rate mortgages. Vertical line denotes onset of the "market freeze" period. Based on data from HSH Associates.

Online Appendix (not for publication)

A Additional Figures and Tables

Figure A.1: Jumbo share among mortgages on properties with appraisal amount in the band $(CLL_t/0.8, CLL_{t+1}/0.8]$, by calendar month

Chart shows residuals, averaged by calendar month, from regression of jumbo share on calendar year dummies, where the jumbo definition is according to year-t CLL. Sample covers 1996–2006. The overall average monthly jumbo share for the appraisal bin $(CLL_t/0.8, CLL_{t+1}/0.8]$ is 24.2%.

This figure shows that loans on properties with appraisal amount in $(CLL_t/0.8, CLL_{t+1}/0.8]$ originated in December of year t are substantially more likely to feature a loan amount above CLL_t (i.e. have jumbo status according to the year t definition) than similar loans originated in November or earlier months. This suggests that lenders take CLL increases into account after they are announced (at the end of November) but before they are in effect. However, there is little evidence that this occurs earlier than December.

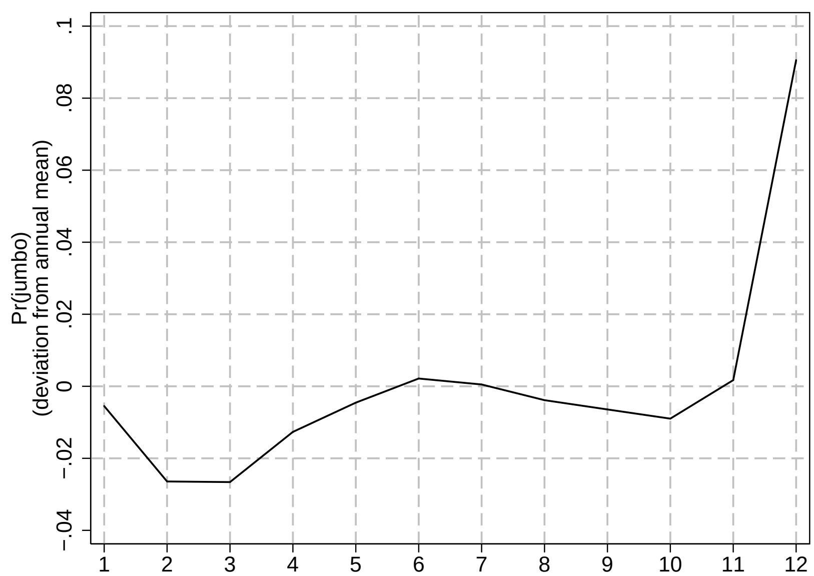
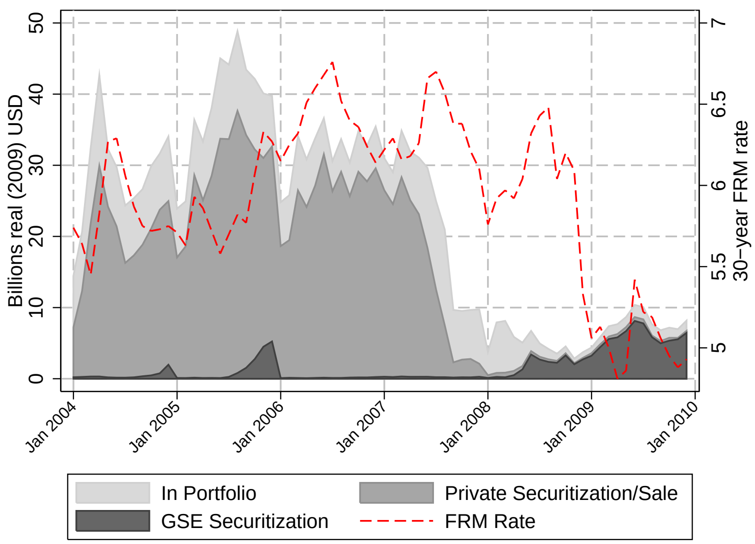


Figure A.2: LPS origination volumes in jumbo and non-jumbo segment, by subsequent securitization status

Author calculations based on LPS data. Conventional first-lien mortgages (purchase and refinance) only. Jumbo status is determined relative to national conforming limit; in particular, for 2008 and 2009 this includes "super-conforming" mortgages in high-cost areas. Volumes of loans with different securitization statuses are calculated by multiplying total loan volume in the segment (jumbo or non-jumbo) by the securitization shares of loans in that segment that are present in the data six months after origination. Horizontal axis indicates mortgage origination date, not securitization date. Dashed line shows 30-year FRM interest rate from Freddie Mac.

A. Origination volume by securitization status six months after origination, jumbo loans



B. Origination volume by securitization status six months after origination, non-jumbo loans

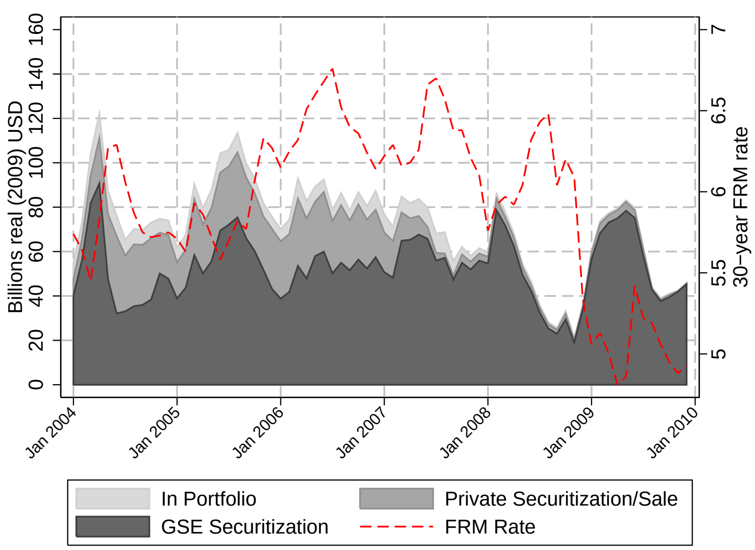
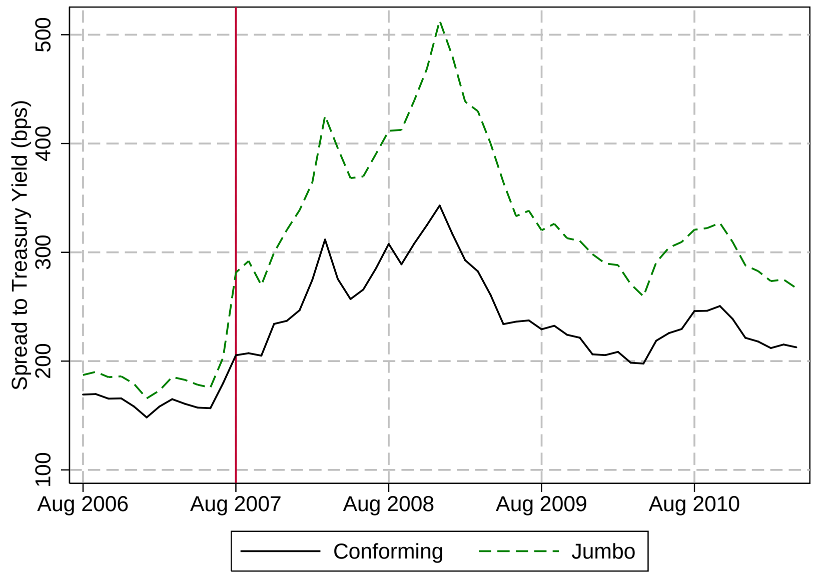


Figure A.3: The freeze in the jumbo MBS market

A. Jumbo and conforming mortgage rates. Figure presents interest rates on 30-year fixed-rate jumbo and conforming mortgages, based on survey data collected by HSH Associates. Mortgage rates are expressed as a spread to the average of the 5-year and 10-year Treasury yield. Market freeze onset is marked at August 2007, the month that BNP Paribas suspends convertibility for two hedge funds, reflecting problems in subprime MBS markets.



B. Quarterly prime jumbo MBS issuance since 1996. Author calculations based on data from Inside Mortgage Finance.

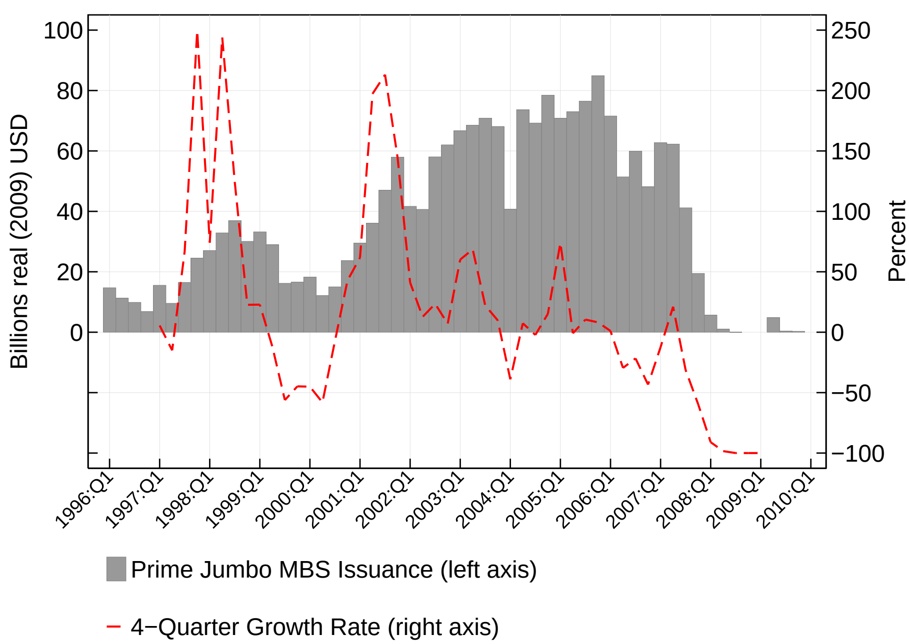
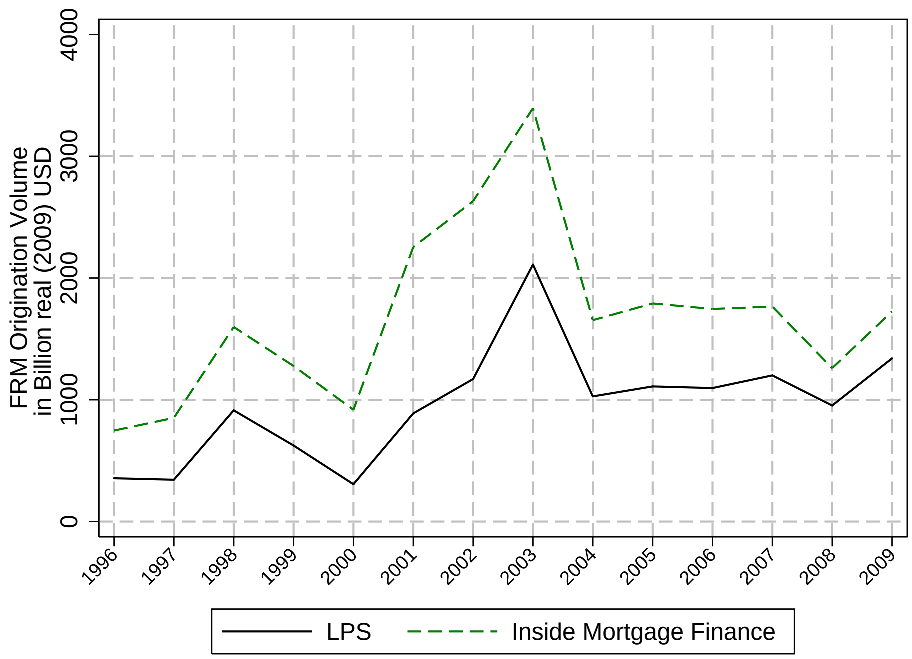


Figure A.4: Origination Volumes, 1996-2009

Author calculations based on data from LPS and Inside Mortgage Finance. Includes all mortgage types (purchase and refinances; conventional and FHA/VA).

A. Annual origination volumes of FRM loans



B. Annual origination volumes of ARM loans

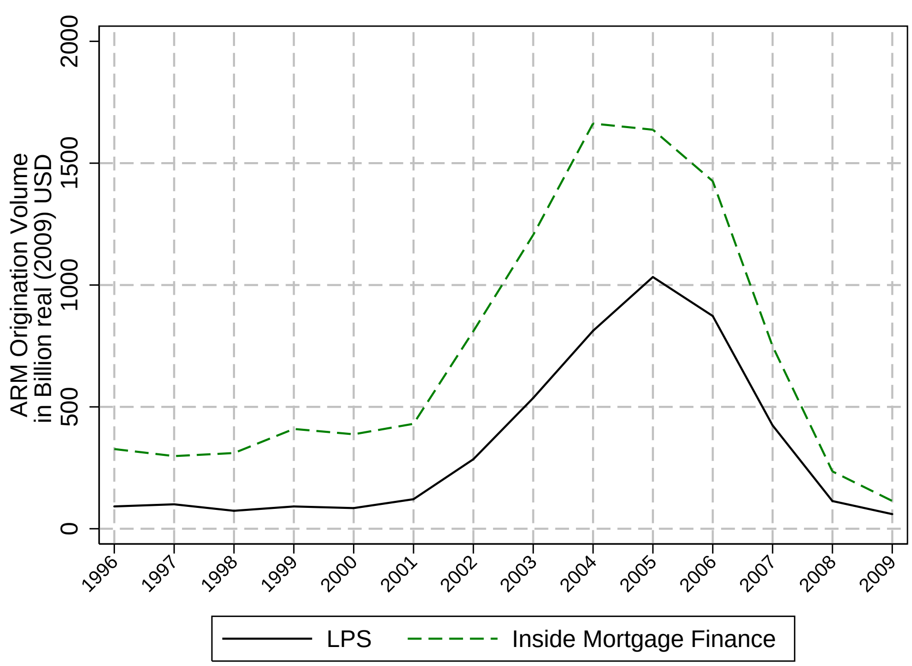
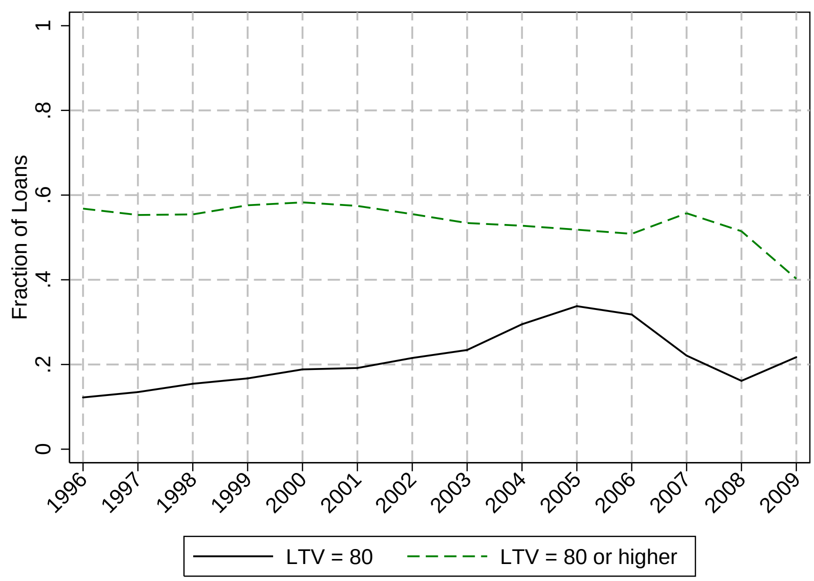


Figure A.5: Time-variation in the share of loans with origination LTV of exactly 80

Charts show that the share of loans with an origination LTV of exactly 80 is highest in 2004-2006. The share of loans with LTV of 80 or higher (dashed line) remains mostly flat over time (with more fluctuations in MIRS than in LPS), indicating that in earlier parts of the sample a larger share of loans had an LTV above 80, while in the 2004-2006 period it was presumably more common to get a first lien with LTV of 80 while taking out a second ("piggyback") lien to finance part of the purchase. Author calculations based on data from LPS and MIRS. Includes conventional purchase loans only (conforming and jumbo).

A. LPS data



B. MIRS data

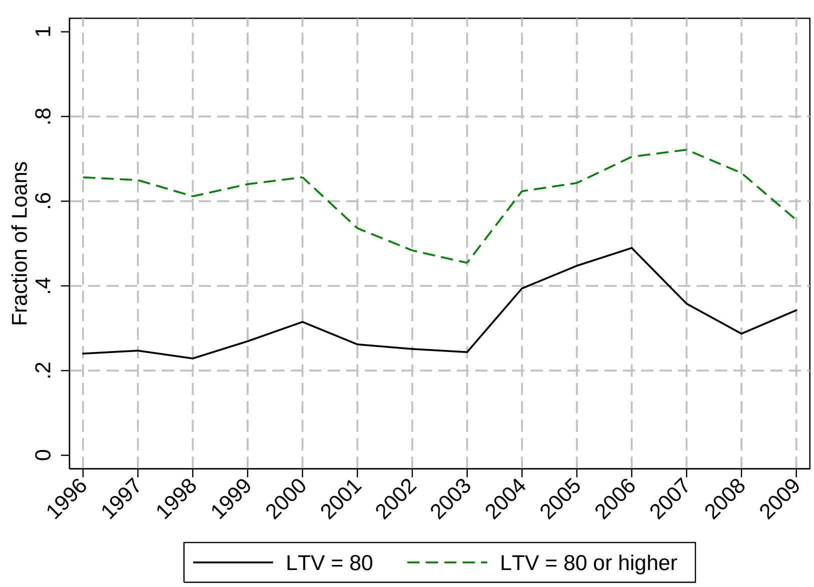


Table A.1: Difference-in-differences estimates: Year-by-year results

Sample includes purchase-money conventional mortgages with appraisal amounts in [$\mathrm{CLL}_t/0.8 - \min(\mathrm{CLL}_{t+1}/0.8 - \mathrm{CLL}_t/0.8,\ 0.1\cdot\mathrm{CLL}_t/0.8)$, $\mathrm{CLL}_t/0.8 + \min(\mathrm{CLL}_{t+1}/0.8 - \mathrm{CLL}_t/0.8,\ 0.1\cdot\mathrm{CLL}_t/0.8)$] originated in years t and $t+1$. Year listed at the top of a panel indicates the year t for which the treatment effect is estimated. Controls in each specification include month dummies, state dummies, a cubic function of FICO score at origination (with a dummy for missing FICO), an investor dummy (including second homes), a condo dummy, and a subprime dummy.

	t =**1996**				t =**1997**			
	Jumbo	FRM30noPPP	FRM	Non_sec6	Jumbo	FRM30noPPP	FRM	Non_sec6
$(year_i = t)\times$ $(appr_i > CLL_t/0.8)$	0.032*** (0.009)				0.082*** (0.008)			
Jumbo		0.059 (0.267)	0.229 (0.262)	0.054 (0.178)		-0.027 (0.092)	-0.093* (0.048)	0.029 (0.045)
N	44172	44172	44172	23246	94340	94340	94340	52041
Adj. R^2	0.026	0.036	< 0	0.137	0.067	0.046	0.086	0.060
	t =**1998**				t =**1999**			
	Jumbo	FRM30noPPP	FRM	Non_sec6	Jumbo	FRM30noPPP	FRM	Non_sec6
$(year_i = t)\times$ $(appr_i > CLL_t/0.8)$	0.057*** (0.011)				0.066*** (0.014)			
Jumbo		-0.057 (0.102)	-0.010 (0.064)	0.056 (0.053)		0.061 (0.141)	0.053 (0.096)	0.109* (0.056)
N	118953	118953	118953	64331	80657	80657	80657	50966
Adj. R^2	0.056	0.031	0.051	0.057	0.043	0.042	0.071	0.128
	t =**2000**				t =**2001**			
	Jumbo	FRM30noPPP	FRM	Non_sec6	Jumbo	FRM30noPPP	FRM	Non_sec6
$(year_i = t)\times$ $(appr_i > CLL_t/0.8)$	0.143*** (0.017)				0.075*** (0.011)			
Jumbo		-0.255*** (0.033)	-0.224*** (0.033)	0.187*** (0.032)		0.092 (0.069)	0.058 (0.045)	0.140*** (0.022)
N	127158	127158	127158	90066	163921	163921	163921	100622
Adj. R^2	0.109	0.085	0.159	0.168	0.060	0.034	0.044	0.059

	t =**2002**				t =**2003**			
	Jumbo	FRM30noPPP	FRM	Non_sec6	Jumbo	FRM30noPPP	FRM	Non_sec6
$(year_i = t) \times$ $(appr_i > CLL_t/0.8)$	0.113*** (0.016)				0.091*** (0.017)			
Jumbo		-0.165*** (0.037)	-0.122*** (0.030)	0.147*** (0.029)		-0.032 (0.059)	-0.117** (0.048)	0.072 (0.065)
N	194312	194312	194312	90653	118067	118067	118067	64970
Adj. R^2	0.064	0.043	0.096	0.078	0.041	0.082	0.167	0.046

	t =**2004**				t =**2005**			
	Jumbo	FRM30noPPP	FRM	Non_sec6	Jumbo	FRM30noPPP	FRM	Non_sec6
$(year_i = t) \times$ $(appr_i > CLL_t/0.8)$	0.232*** (0.053)				0.331*** (0.055)			
Jumbo		-0.008 (0.021)	-0.023 (0.022)	0.061*** (0.007)		-0.014 (0.017)	-0.012 (0.015)	0.078*** (0.020)
N	319506	319506	319506	228833	405950	405950	405950	318428
Adj. R^2	0.144	0.115	0.146	0.040	0.269	0.153	0.175	0.038

Standard errors (clustered by state) in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.2: Fuzzy regression discontinuity design: Robustness checks for pooled data, December 2003–July 2007

A. FRM30noPPP

	bandwidth=0.04	0.06	0.10	0.12
Change in Pr(dep. var.)	0.000	-0.000	0.001	0.001
	(0.004)	(0.004)	(0.004)	(0.003)
Change in Pr(jumbo)	0.135***	0.147***	0.160***	0.165***
	(0.040)	(0.043)	(0.046)	(0.048)
Treatment effect	0.002	-0.000	0.004	0.005
	(0.032)	(0.031)	(0.022)	(0.018)
N	238435	390871	632666	769236

B. FRM

	bandwidth=0.04	0.06	0.10	0.12
Change in Pr(dep. var.)	0.004	0.004	0.003	0.003
	(0.004)	(0.004)	(0.003)	(0.003)
Change in Pr(jumbo)	0.135***	0.147***	0.160***	0.165***
	(0.040)	(0.043)	(0.046)	(0.048)
Treatment effect	0.033	0.026	0.018	0.017
	(0.025)	(0.022)	(0.017)	(0.015)
N	238435	390871	632666	769236

C. Non_sec6

	bandwidth=0.04	0.06	0.10	0.12
Change in Pr(dep. var.)	0.003	0.004*	0.004**	0.004**
	(0.002)	(0.002)	(0.002)	(0.002)
Change in Pr(jumbo)	0.141***	0.154***	0.167***	0.173***
	(0.044)	(0.047)	(0.049)	(0.051)
Treatment effect	0.021	0.025**	0.024***	0.026***
	(0.015)	(0.012)	(0.008)	(0.008)
N	181191	297306	481158	584509

Standard errors (clustered at the state level) in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.3: Fuzzy regression discontinuity design: Robustness checks, year-by-year 2004–2007

Reporting estimated treatment effect only, for bandwidths 0.05, 0.08, 0.11

A. FRM30noPPP

	2004	2005	2006	2007
Bandwidth = 0.05	-0.085	0.055*	-0.015	-0.034
	(0.090)	(0.029)	(0.044)	(0.079)
N	86905	104523	77570	43062
Bandwidth = 0.08	-0.042	0.027	0.013	-0.032
	(0.064)	(0.024)	(0.030)	(0.052)
N	146682	172583	130700	72302
Bandwidth = 0.11	-0.014	0.015	0.017	-0.023
	(0.050)	(0.021)	(0.026)	(0.040)
N	193040	222022	177536	97928

B. FRM

	2004	2005	2006	2007
Bandwidth = 0.05	-0.011	0.079***	0.023	-0.103
	(0.057)	(0.028)	(0.039)	(0.106)
N	86905	104523	77570	43062
Bandwidth = 0.08	-0.018	0.046**	0.040	-0.074
	(0.046)	(0.019)	(0.028)	(0.078)
N	146682	172583	130700	72302
Bandwidth = 0.11	-0.002	0.030*	0.036	-0.038
	(0.040)	(0.018)	(0.022)	(0.058)
N	193040	222022	177536	97928

C. Non_sec6

	2004	2005	2006	2007
Bandwidth = 0.05	0.028	0.028	0.027	0.032
	(0.049)	(0.026)	(0.032)	(0.066)
N	57131	79683	62690	37259
Bandwidth = 0.08	0.035	0.033	0.019	-0.028
	(0.034)	(0.024)	(0.030)	(0.052)
N	96539	131538	105647	62669
Bandwidth = 0.11	0.041*	0.038*	0.020	-0.042
	(0.024)	(0.022)	(0.026)	(0.048)
N	127076	169281	143636	84884

Standard errors (clustered at state level) in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

B Supporting Analyses

B.1 Borrower Sorting around CLL/0.8

In this section we document that there is no evidence of discontinuities in borrower characteristics or loan volume around the appraisal cutoff CLL/0.8, suggesting that appraisal amount relative to this cutoff can be used as a source of plausibly exogenous variation in jumbo loan status.

Panel A of Figure B.1 shows that, using all loans in our sample over 1996–2009, there are no conspicuous spikes in loan volumes right below or above the appraisal cutoff CLL/0.8.We have also verified this for each year separately. While there are frequently spikes at multiples of $5,000 due to rounding of appraisals, there is no pattern of these spikes being larger or smaller to the left or right of the cutoff.

Panel B of the figure shows the mean FICO scores around the CLL/0.8 cutoff, again using all data over 1996–2009, and demonstrates that there does not seem to be significant sorting of borrowers with different credit quality around the threshold. In the figure, one can see a slight spike below the cutoff, which however appears to be random noise rather than indicative of a change in the underlying relationship around CLL/0.8. Consistent with this interpretation, formal local linear regressions do not yield significant estimates of the discontinuity when appropriate bandwidths (as determined by a cross-validation procedure) are used. Similarly, none of the other characteristics we use as controls in our regressions (condo, investor, and subprime dummies) change significantly around the threshold. Kaufman (2012) discusses the institutional details of the appraisal process in more detail.

B.2 Bank Financial Health and Lending Standards

We compile time-series data on mortgage credit conditions and the financial position of bank lenders during the sample period. These series are described below, and are plotted in Figures B.2 and B.3. These statistics document that lending conditions and the financial position of bank lenders were weak in 2008 and 2009, but quite robust during the 1999–2000 jumbo MBS illiquidity episode. During this earlier period, bank lender profitability and asset growth was at or above its historical average and stable, and mortgage lending standards were stable.

Mortgage lending standards. We measure lending standards by the net fraction of domestic respondents tightening standards for residential mortgage loans in the Federal Reserve's Senior Loan Officer Opinion Survey. This quarterly survey asks senior loan officers at a sample of commercial banks to report changes in lending standards and loan demand for different types of loans, as well as other information about credit conditions. The survey is used by the Federal Reserve in policy formation, and has also been used in academic research to measure the credit cycle.[1]

Asset growth. We measure the four-quarter asset growth rate of banking firms from two sources: i) the Federal Reserve Flow of Funds table L.219 (which covers depository institutions), and ii) the Federal Reserve Bank of New York Quarterly Trends for Consolidated Banking Organizations (which covers commercial banks and bank holding companies, and is based on quarterly regulatory data).

Profitability and loan performance. Data are taken from the Federal Reserve Quarterly Trends report mentioned above, and reflect information about the commercial banking industry. We plot accounting return on assets (annualized net income as a percentage of total assets) as a measure of banking sector profitability, and the percentage of residential real estate loans that are nonperforming as a measure of loan performance.

B.3 DiD Analysis of the Onset of the Nonagency Freeze

As a further test of the effect of the nonagency MBS freeze in 2007, we estimate an additional DiD model which exploits the onset of the freeze in the jumbo market as a source of variation in securitization liquidity. We compare the predicted effect of jumbo status on contract structure during the nonagency "market freeze" period of August 2007 to April 2008 to the effect over the preceding nine-month period (November 2006 to July 2007). We consider loans with appraisal amounts in a window of size $\pm 10\%$ around \$521,250 (=417,000/0.8) and use an appraisal amount above \$521,250 as an instrument for obtaining a jumbo loan.

Table B.1 presents the results of this analysis. Column (1) presents the first stage regression. Columns (2)–(4) present the key second stage instrumental variable regressions.

Our main coefficient of interest is the interaction effect "Jumbo $\times$ Market freeze period" which measures the differential effect of being in the jumbo market during the market freeze period. Column (2) shows that the estimated effect of being in the jumbo segment on the probability of obtaining a FRM30noPPP is 27 percentage points lower during the market freeze than before. The effect for all FRMs, shown in column (3), is smaller yet still highly statistically significant. Column (4) shows that the probability of a jumbo loan remaining in portfolio is significantly larger during the market freeze. Thus, these results are consistent with the ones from the DiD in the main text, both qualitatively and quantitatively (for

[1]See e.g. Basset, W. F., M. B. Chosak, J. C. Driscoll, and E. Zakrajsek (2014), "Changes in Bank Lending Standards and the Macroeconomy," *Journal of Monetary Economics*, 62:23–40; Lown, C., and D. P. Morgan (2006), "The Credit Cycle and the Business Cycle: New Findings Using the Loan Officer Opinion Survey," *Journal of Money, Credit and Banking*, 38:1575–1597.

instance, the estimated effect of jumbo status on FRM30noPPP during the market freeze is -28.7 percent in Table 2).

Importantly, one should not interpret the estimated effect of being in the jumbo segment on the likelihood of obtaining an FRM ("Jumbo" in the table) as an unbiased causal effect estimate. As Figure 4 in the main text shows, the probability of selecting an FRM varies continuously with the appraisal amount, while here we implicitly assume it to be constant (but potentially different) over the appraisal amount ranges [469,125, 521,250] and (521,250, 573,375]. The interaction effect that compares the estimated effect across the two subperiods is nevertheless informative, since the interaction effect (Jumbo × Market freeze period) "nets out" the bias.

Examining the first stage estimates, the effect of being in the appraisal band above $521,250 has a significantly stronger effect on the probability of obtaining a jumbo over late 2006 to mid-2007 than during the market freeze period (when jumbo loans became much less common). However, even during the market freeze period, being in the higher appraisal band has a significant positive effect of about +6.6 percentage points ($= 0.278 - 0.212$; significant at $p < 0.01$) on the probability of obtaining a jumbo loan, suggesting that the instrument is still powerful, even after the onset of the freeze.

Summing up, this alternative approach, which exploits the onset of the freeze, yields very similar estimates for the market freeze period compared to our main DiD strategy, which is based on the increase in the CLL in high-housing-cost counties under the ESA.

B.4 Fractional Polynomial Regressions

As discussed at the beginning of section 4, directly linking mortgage contract structure to whether the borrower selects a jumbo mortgage would likely lead to significantly biased estimates of the effects of agency securitization, due to sorting of borrowers into the conforming market. However, Figure 3 suggests that these selection effects are concentrated relatively close to the CLL, within approximately 20 percent of the limit. Consequently, we now consider an additional estimation approach in which we control for endogenous selection into jumbo or conforming mortgages simply by excluding loans with principal amounts close to the CLL.

We estimate linear probability models, where the dependent variable is equal to one if the borrower selects a 30-year prepayable FRM and zero otherwise. This choice is modeled as a fractional polynomial function of the loan amount, which provides a flexible way to account for the possibly nonlinear relationship between loan size and demand for an FRM.[2]

[2]For an introduction to fractional polynomial (FP) models, see Royston, P., and D. G. Altman (1994), "Regression using fractional polynomials of continuous covariates: Parsimonious parametric modelling,"

We add a dummy variable for whether the loan amount exceeds the CLL, with the goal of picking up discrete jumps in Pr(FRM30noPPP) as a result of being in the jumbo segment. The coefficient on this jumbo dummy is the main variable of interest.

Under the presumption that selection effects are most severe close to the CLL, we exclude mortgages with loan amounts between 95% and 120% of the CLL.[3] We estimate separate regressions by origination year between 1996 and 2007, as well as a separate regression for the market freeze period (August 2007 to April 2008). We also control for the same borrower covariates as in the main text.[4]

Results are presented in Table B.2. The results show that, controlling for other observable borrower characteristics and dropping loans near the CLL, the difference in the FRM share between the jumbo and conforming markets in "normal times," while not zero, is relatively small, generally of the order of around 10 percentage points. However, the estimated effects are larger during times of nonagency MBS illiquidity; over 1999/2000, the coefficient on the jumbo dummy increases in magnitude to 20 and 30 percentage points respectively, and in the market freeze period, it increases to 34 percentage points.

Note that the estimated coefficient on the jumbo dummy may be an upper bound of the effects of being in the conforming segment on contract structure, since borrowers in the conforming and jumbo segment may still differ in terms of unobservables that influence mortgage choice, such as expected mortgage tenure, expected income, risk aversion, etc. Given this potential omitted variable bias, we rely on the estimated coefficients mainly to study variation over time, rather than interpret the magnitude of the coefficient directly.

Graphical evidence supporting these findings is presented in Figure B.4, which plots the market share of FRMs against the mortgage amount, in a band around the CLL, during both periods of nonagency MBS illiquidity. Notably, in both these periods there is a sharp and very large drop in the FRM share exactly at the limit; this drop persists even for mortgage amounts significantly larger than the loan limit. Compared to Panel A of Figure 3 in the main text, which shows the same plot for 2004 to mid-2007, the drop-off in FRM share around the CLL is much larger.

Journal of the Royal Statistical Society, Series C (Applied Statistics), 43:429–467. In our analysis, we consider FP functions up to degree 2, meaning that we find the powers (p_1, p_2) from the pre-defined set $S = \{-2, -1, -0.5, 0, 0.5, 1, 2, 3\}$ (where 0 means $log(x)$, with x denoting the loan amount) in order to obtain the best fit of our dependent variable on $\beta_1 x^{p_1} + \beta_2 x^{p_2}$ and the other covariates. Going beyond degree 2 is too costly computationally in our application.

[3] In other unreported specifications we have experimented with dropping a larger band around the limit, up to 140% or 160% of the CLL; this generally produces similar results, with the coefficient on the jumbo dummy moving somewhat closer to zero.

[4] That is, controls include calendar month dummies, state dummies, a cubic function of FICO score at origination, a dummy for missing FICO, an investor dummy (inclusive of a second home), a condo dummy, and a subprime dummy.

Table B.1: Differential effect of nonagency MBS freeze on contract choice in jumbo segment

Sample includes purchase-money conventional mortgages with appraisal amounts in $[0.9 \cdot 417000/0.8, 1.1 \cdot 417000/0.8]$ originated between November 2006 and April 2008. "Market freeze period" is taken to be August 2007 to April 2008. Controls include month dummies, state dummies, a cubic function of FICO score at origination (with a dummy for missing FICO), an investor dummy (including second homes), a condo dummy, and a subprime dummy.

	(1) Jumbo	(2) FRM30noPPP	(3) FRM	(4) Non_sec6
($appr_i > 417$k/0.8)	0.278*** (0.0536)			
($appr_i > 417$k/0.8) $\times$ Market freeze period	-0.212*** (0.0460)			
Jumbo		-0.101*** (0.0155)	-0.0923*** (0.0193)	0.0533*** (0.0176)
Jumbo $\times$ Market freeze period		-0.270*** (0.0447)	-0.159*** (0.0453)	0.270*** (0.0697)
N	162225	162225	162225	141542

Standard errors (clustered at state level) in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table B.2: Fractional polynomial regressions, excluding loans near conforming loan limit

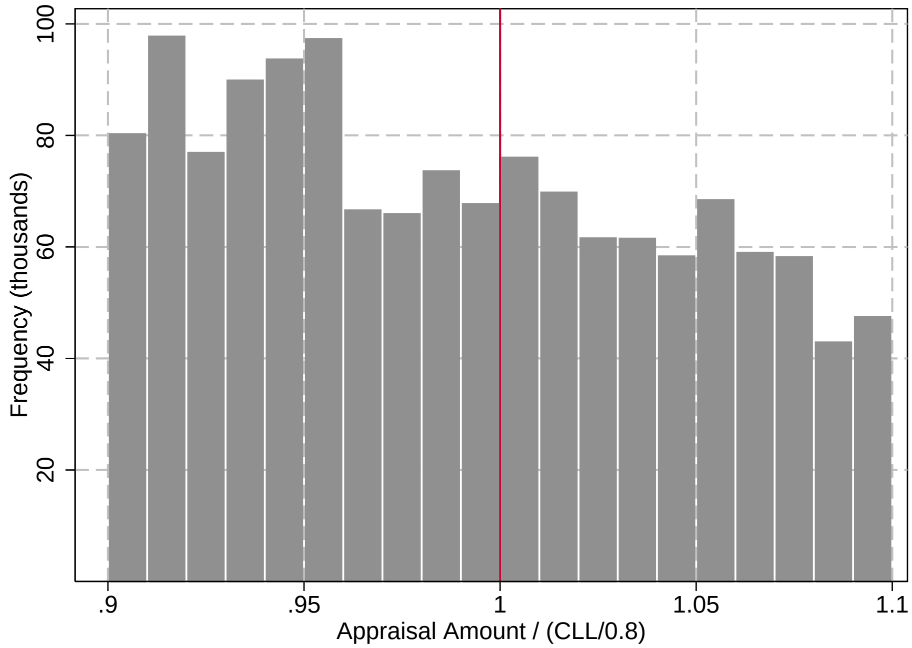
Dependent variable = 1 if borrower selects a 30-year FRM without prepayment penalties, = 0 otherwise. Sample includes purchase-money conventional mortgages from LPS. Controls in each regression include month dummies, state dummies, a cubic function of FICO score at origination (with a dummy for missing FICO), an investor dummy (including second homes), a condo dummy, and a subprime dummy. Each regression excludes mortgages between 95% and 120% of the conforming loan limit.

	(1) 1996	(2) 1997	(3) 1998	(4) 1999	(5) 2000	(6) 2001	(7) 2002	(8) 2003	(9) 2004	(10) 2005	(11) 2006	(12) 2007 (to July)	(13) Crisis
Jumbo	-0.208***	-0.104**	-0.118***	-0.205***	-0.300***	-0.166***	-0.103**	-0.101***	-0.083***	-0.114***	-0.098**	-0.116***	-0.341***
	(0.014)	(0.033)	(0.018)	(0.033)	(0.035)	(0.040)	(0.031)	(0.014)	(0.010)	(0.024)	(0.030)	(0.009)	(0.007)
N	729324	720098	1218808	1163019	726749	981151	1144103	1762311	1809432	2156366	1917161	947540	759295
Adj. R^2	0.046	0.040	0.034	0.050	0.114	0.042	0.039	0.046	0.098	0.163	0.200	0.151	0.134
FP Deviance	811933.9	829651.6	1196293.0	1234061.0	767469.1	1015513.8	1442762.2	2343902.7	2439670.3	2746921.0	2327311.3	959344.7	469982.2
FP Powers	-2 1	-.5 0	-2 2	-2 2	-.5 .5	.5 .5	0 .5	-.5 1	1 2	-1 -1	-1 -1	-1 0	-.5 0

Standard errors (clustered at state level) in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Figure B.1: No evidence for selection around appraisal amount CLL/0.8

A. Histogram of appraisal amounts. Based on LPS data for purchase-money conventional mortgages originated between 1996 and 2009. Bins of normalized appraisal amounts defined such that values on the boundary are included in the bar to the left.



B. FICO score distribution. Based on LPS data for purchase-money conventional mortgages originated between 1996 and 2009. Dots represent normalized appraisal amount bins of size 0.01; 1 means that appraisal amount is in (CLL/0.8, 1.01 · CLL/0.8]. Size of dots is proportional to the number of loans in a bin.

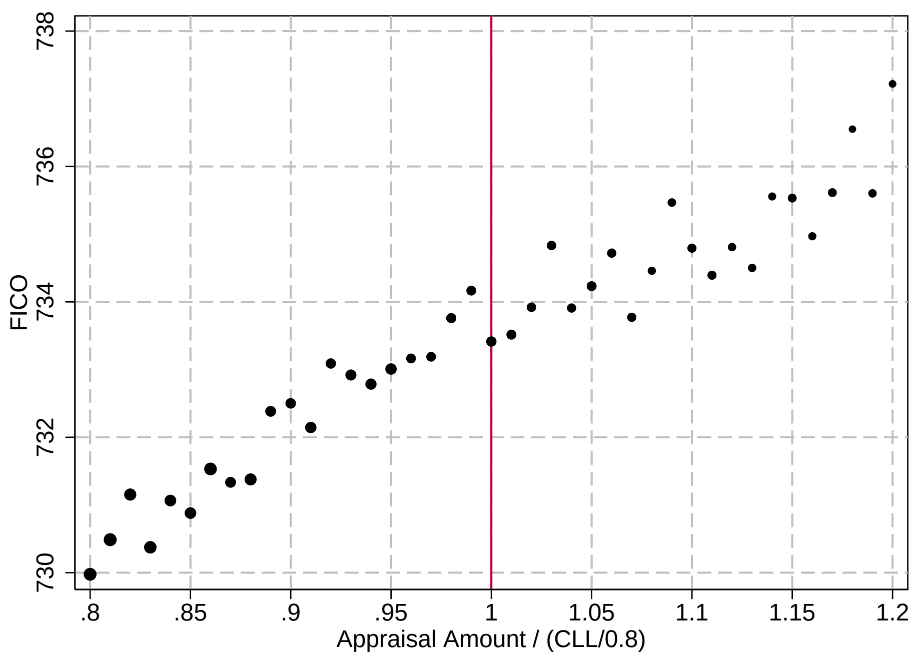


Figure B.2: Mortgage lending standards from the Federal Reserve's Senior Loan Officer Opinion Survey

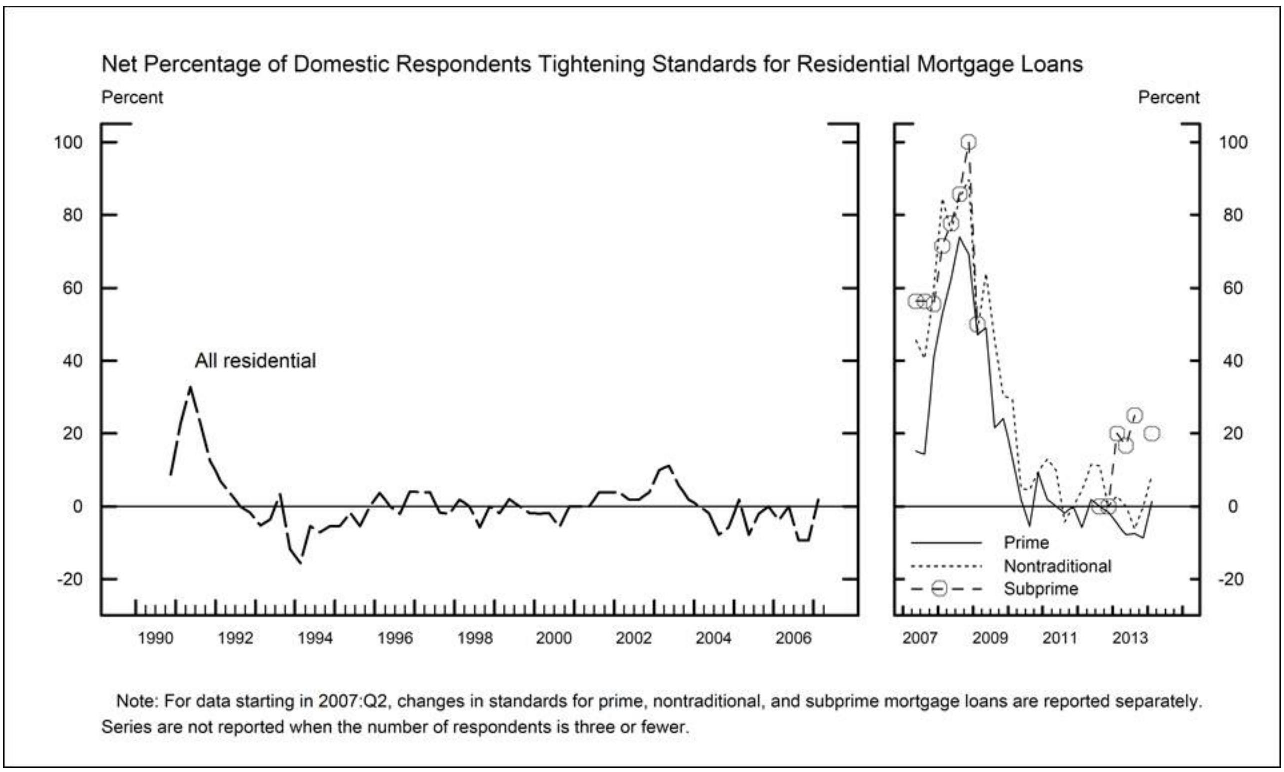
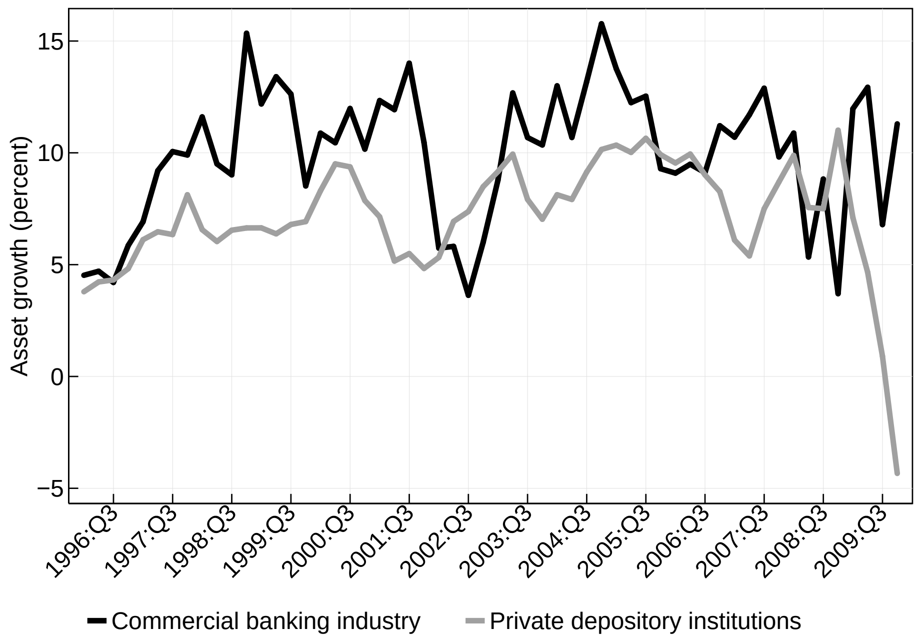


Figure B.3: Banking sector financial conditions over 1996–2009

Sources: Federal Reserve Flow of Funds; Quarterly Trends for Consolidated Banking Organizations

A. 4-quarter asset growth



B. Return on assets and nonperforming loans

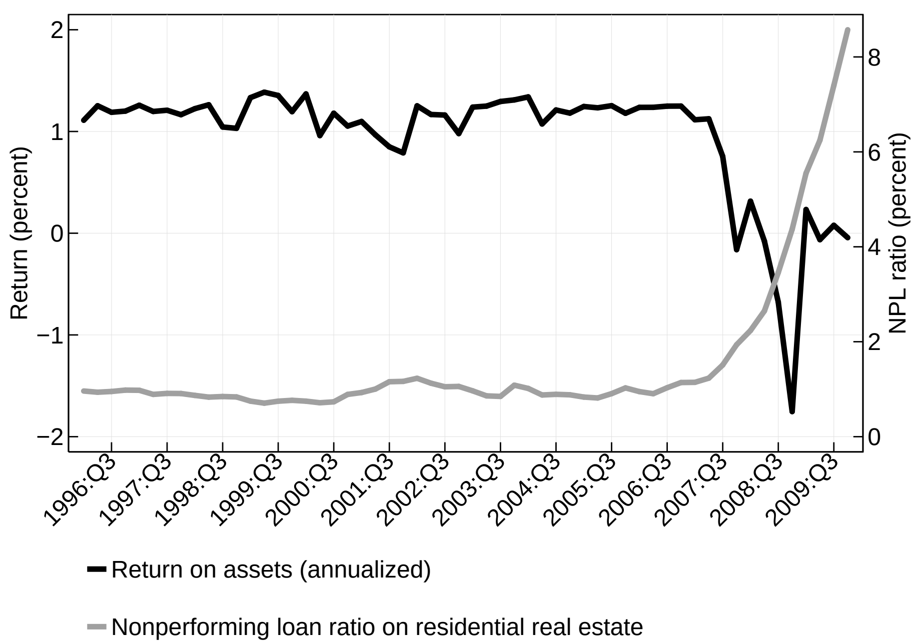
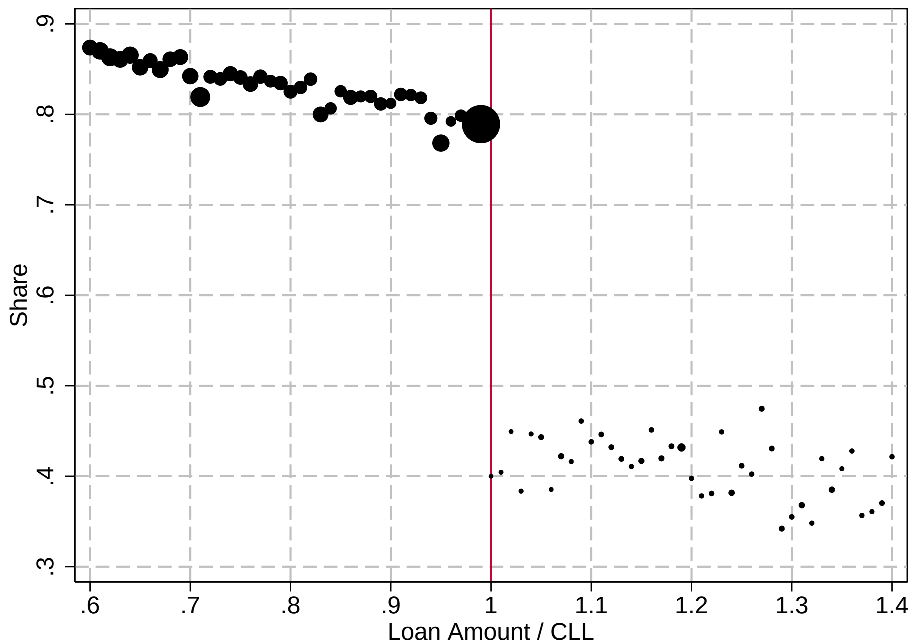


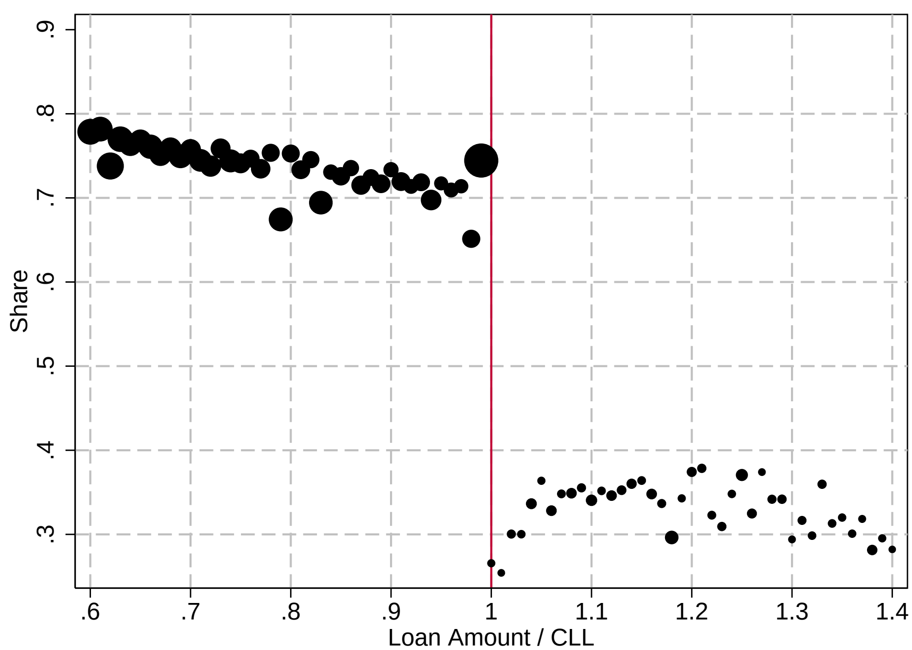
Figure B.4: Share of 30-year FRMs without prepayment penalties (FRM30noPPP) by loan amount relative to CLL during times with low jumbo securitization

Based on LPS data for purchase-money conventional mortgages. Dots represent normalized loan amount bins of size 0.01; 1 means that loan amount is in (CLL, 1.01 · CLL]. Size of dots is proportional to the number of loans in a bin.

A. August 2007 – April 2008



B. July 1999 – June 2000



C Results using the MIRS data

As a further robustness check, we replicate our main results using an alternative dataset, the Monthly Interest Rate Survey (MIRS). MIRS is a loan-level lender survey of home mortgage terms collected and maintained by the Federal Home Financing Agency (and formerly the Federal Home Financing Board). Each month, the MIRS surveys a sample of bank and non-bank lenders, which report account-level terms and conditions on first-lien mortgages closed during the last five business days of the previous month. MIRS includes only single-family, fully amortizing, purchase-money, nonfarm loans, and also excludes FHA-insured and VA-guaranteed loans, multifamily loans, and mobile home loans. Although data is available from the 1970s onwards, an improved survey methodology was implemented in 1992; MIRS also began reporting more detailed information on ARM repricing from this year onwards.

Overall, MIRS is less useful than LPS as a source of data on mortgage choice: (i) it has significantly lower overall sample size, (ii) the survey samples only a subset of lenders, selected in a non-random way (e.g., it oversamples thrifts relative to their overall market share), (iii) it includes less information on borrower and loan characteristics (for example, it does not include information on the borrower's credit score, or prepayment penalties), and (iv) it does not track the loan post-origination (e.g., it does not include information on when or if the loan is securitized or sold). Despite these disadvantages, analysis of MIRS is still useful as a robustness check, given that it is collected independently using a different methodology than LPS (i.e., a lender survey, rather than a data feed from servicers). MIRS also has two advantages relative to LPS: first, it reports the type of lender that originated the mortgage (thrift, commercial bank or mortgage company), and second, it does not suffer from a relative decline in coverage prior to 2005.

Table C.1: Difference-in-differences analysis on MIRS data

Table shows the estimated treatment effect of being in the jumbo segment of the mortgage market on the probability of obtaining a fixed-rate mortgage with term of 30 years or higher (FRM30) and on the probability of obtaining any type of fixed-rate mortgage (FRM), for three different periods. Periods and sample restrictions are the same as in Table 2. Controls in each specification include month dummies and state dummies interacted with calendar year indicators.

Second Stage:	(1) Pr(FRM30)	(2) Pr(FRM)	
Nonagency market is liquid			
1996–2005 (excluding 7/1999–6/2000):			
Jumbo	-0.036	-0.050**	
	(0.031)	(0.022)	
N	274970	274970	
Nonagency market is illiquid			
Aug 2007–Apr 2008:			
Jumbo	-0.696***	-0.441***	
	(0.210)	(0.139)	
N	6122	6122	
Jul 1999–Jun 2000:			
Jumbo	-0.084**	-0.096**	
	(0.035)	(0.038)	
N	43195	43195	
First Stage (Pr(Jumbo)):	1996–2006	2007–2008	1999–2000
$(year_i = t)\times$	0.156***	0.064***	0.224***
$(appr_i > CLL_t/0.8)$	(0.015)	(0.013)	(0.031)

Standard errors (clustered at state level) in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table C.2: Fuzzy regression discontinuity design on MIRS data: Results for pooled data, December 2003–July 2007

Table shows estimated treatment effect of being in the jumbo segment of the mortgage market on the probability of obtaining a fixed-rate mortgage with term of 30 years or higher, and on the probability of obtaining any type of fixed-rate mortgage. Sample includes purchase-money conventional mortgages originated between December 2003 and July 2007. Estimation uses local linear regressions with bandwidth $x \cdot (\text{CLL}/0.8)$ for different x around our baseline of 0.08, and a triangle kernel that gives more weight to observations near the boundary. All regressions include year-month dummies, as well as state dummies interacted with calendar year indicators.

A. 30-year FRM

	bandwidth=0.04	0.06	0.08	0.10	0.12
Treatment effect	0.031	0.063	0.065	0.065	0.055
	(0.071)	(0.060)	(0.056)	(0.049)	(0.042)
Change in Pr(dep. var.)	0.005	0.010	0.011	0.011	0.010
	(0.011)	(0.009)	(0.008)	(0.007)	(0.007)
Change in Pr(jumbo)	0.158***	0.164***	0.166***	0.171***	0.174***
	(0.023)	(0.026)	(0.027)	(0.028)	(0.028)
N	21338	34813	46763	56451	68941

B. FRM

	bandwidth=0.04	0.06	0.08	0.10	0.12
Treatment effect	0.078	0.099*	0.084*	0.069*	0.057*
	(0.068)	(0.051)	(0.046)	(0.036)	(0.031)
Change in Pr(dep. var.)	0.012	0.016*	0.014*	0.012**	0.010*
	(0.011)	(0.008)	(0.007)	(0.006)	(0.005)
Change in Pr(jumbo)	0.158***	0.164***	0.166***	0.171***	0.174***
	(0.023)	(0.026)	(0.027)	(0.028)	(0.028)
N	21338	34813	46763	56451	68941

Standard errors (clustered at state level) in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table C.3: Difference-in-differences estimates on MIRS data: Year-by-year results

Sample includes purchase-money conventional mortgages with appraisal amounts in $[\text{CLL}_t/0.8 - \min(\text{CLL}_{t+1}/0.8 - \text{CLL}_t/0.8,\ 0.1{\cdot}\text{CLL}_t/0.8),\ \text{CLL}_t/0.8 + \min(\text{CLL}_{t+1}/0.8 - \text{CLL}_t/0.8,\ 0.1{\cdot}\text{CLL}_t/0.8)]$ originated in years t and $t+1$. Controls in each specification include month dummies and state dummies.

	$t =$**1996**			$t =$**1997**		
	Jumbo	FRM30	FRM	Jumbo	FRM30noPPP	FRM
$(year_i = t)\times$ $(appr_i > CLL_t/0.8)$	0.154*** (0.023)			0.169*** (0.024)		
Jumbo		0.166 (0.174)	0.190 (0.154)		0.152* (0.087)	0.094 (0.065)
N	8492	8492	8492	18326	18326	18326
	$t =$**1998**			$t =$**1999**		
	Jumbo	FRM30	FRM	Jumbo	FRM30noPPP	FRM
$(year_i = t)\times$ $(appr_i > CLL_t/0.8)$	0.116*** (0.020)			0.168*** (0.017)		
Jumbo		-0.020 (0.090)	0.034 (0.065)		-0.103** (0.052)	-0.097* (0.050)
N	22404	22404	22404	19480	19480	19480
	$t =$**2000**			$t =$**2001**		
	Jumbo	FRM30	FRM	Jumbo	FRM30noPPP	FRM
$(year_i = t)\times$ $(appr_i > CLL_t/0.8)$	0.214*** (0.025)			0.100*** (0.015)		
Jumbo		-0.176*** (0.042)	-0.160*** (0.033)		-0.095 (0.129)	-0.196*** (0.071)
N	36954	36954	36954	48129	48129	48129
	$t =$**2002**			$t =$**2003**		
	Jumbo	FRM30	FRM	Jumbo	FRM30noPPP	FRM
$(year_i = t)\times$ $(appr_i > CLL_t/0.8)$	0.113*** (0.015)			0.072*** (0.014)		
Jumbo		0.012 (0.071)	0.001 (0.065)		0.240 (0.169)	0.047 (0.160)
N	48705	48705	48705	19337	19337	19337
	$t =$**2004**			$t =$**2005**		
	Jumbo	FRM30	FRM	Jumbo	FRM30noPPP	FRM
$(year_i = t)\times$ $(appr_i > CLL_t/0.8)$	0.232*** (0.039)			0.278*** (0.022)		
Jumbo		-0.031 (0.041)	-0.024 (0.040)		-0.046 (0.033)	-0.059** (0.030)
N	31384	31384	31384	33463	33463	33463

Standard errors (clustered at state level) in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table C.4: Difference-in-differences analysis on MIRS data: investigating the role of house price growth

Table shows the estimated treatment effect of jumbo status on Pr(FRM30) under different sample restrictions. Sample includes purchase-money conventional mortgages with appraisal amounts in the range $[\text{CLL}_t/0.8 - \min(\text{CLL}_{t+1}/0.8 - \text{CLL}_t/0.8,\ 0.1{\cdot}\text{CLL}_t/0.8),\ \text{CLL}_t/0.8 + \min(\text{CLL}_{t+1}/0.8 - \text{CLL}_t/0.8,\ 0.1{\cdot}\text{CLL}_t/0.8)]$. Monthly county-level house price indices (HPI) come from CoreLogic. Sample in column (1) excludes July-November 1999 from pre-period. House price controls in column (3) are the 12-month moving average county-level median transaction price (in $); the maximum HPI level after Jan. 2002; and HPI growth over the past 12 month; all interacted with calendar year. In columns (4) and (5), the sample is split according to maximum county-level house price appreciation (HPA) relative to Jan. 2002. Regressions also include month dummies, and state dummies interacted with calendar year.

	(1)	(2)	(3)	(4)	(5)
Sample	1996-1999 all	2002-05 all	2002-05 all	2002-05 HPA>median	2002-05 HPA≤median
Jumbo	0.021 (0.048)	-0.015 (0.028)	-0.016 (0.029)	-0.048* (0.028)	0.039 (0.052)
HP controls	N	N	Y	N	N
N	65153	132889	130642	63725	66917

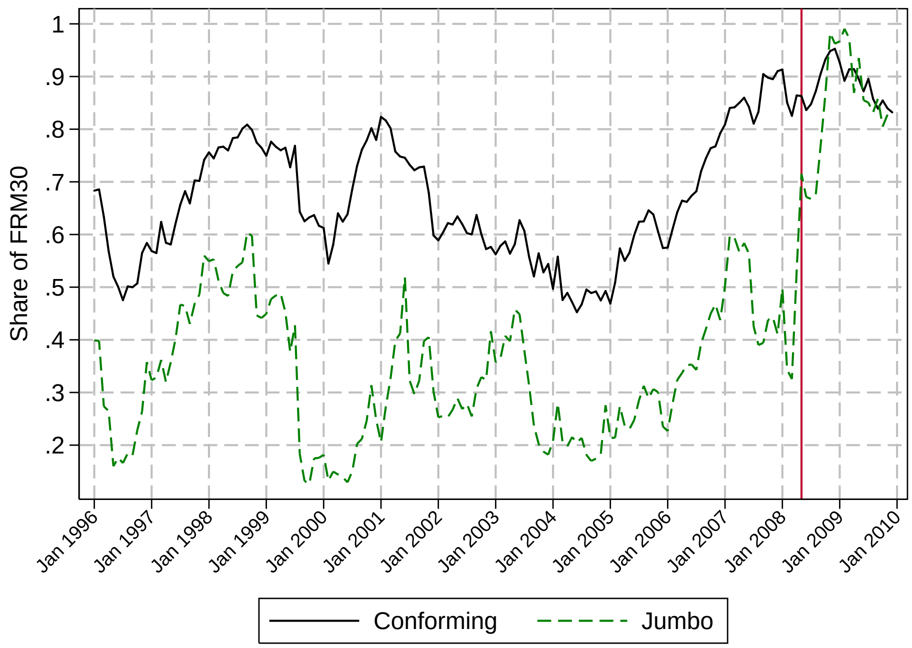
Standard errors (clustered at state level) in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Figure C.1: Market share of fixed-rate mortgages in jumbo and non-jumbo segment, 1996–2009

Author calculations based on MIRS data. Purchase-money conventional mortgages only; shares are value-weighted. For purposes of the graphs "Conforming" refers to mortgages with an initial principal balance below the national conforming limit. The vertical line in May 2008 marks the effective introduction of "super-conforming" mortgages (jumbo mortgages that F&F were allowed to purchase).

A. 30-year FRMs



B. Difference in FRM shares, conforming minus jumbo