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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 household risk management, monetary policy, and systemic risk. In this paper, we show that securitization is a key driver of FRM supply. Our analysis compares the agency and nonagency mortgage-backed-securities (MBS) markets, exploiting the freeze in nonagency MBS liquidity in the third quarter of 2007. Using exogenous variation in access to the agency MBS market, we find that when both market segments are liquid they perform similarly in terms of supporting FRM supply. However, after the nonagency market freezes, the share of FRMs is sharply higher among mortgages eligible to be securitized through the still-liquid agency MBS market. Our interpretation is that securitization is particularly important for FRMs because of the prepayment and interest rate risk embedded in these loans. We highlight policy implications for ongoing reform of the U.S. mortgage finance system.

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 Gene Amromin, Andrew Davidson, Chris Foote, Andra Ghent, Aurel Hizmo, Ben Keys, Brian Melzer, Amit Seru, Paul Willen, and seminar participants at the IMF; the Warrington School of Business, University of Florida; the Paul Woolley Centre Conference at the University of Technology, Sydney; the HULM Conference at the Federal Reserve Bank of Chicago; NYU Stern; and the European Summer Symposium in Financial Markets, Gerzensee, for helpful comments and discussions; and 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 U.S. residential mortgage market is dominated by prepayable 30-year fixed-rate mortgages (FRMs), a type of home loan that exists in few other countries (Campbell 2012; Green and Wachter 2005).[1] While experts disagree about the merits of FRMs relative to alternative contract designs, it is widely agreed that the popularity of prepayable FRMs in the U.S. has important consequences for household risk management (Campbell and Cocco 2003; Van Hemert 2010), monetary policy transmission (International Monetary Fund 2004; Miles 2004), and systemic risk (Khandani, Lo, and Merton 2012).

This paper studies how supply-side factors influence equilibrium mortgage choice. In particular, we analyze whether securitization plays an important role in supporting the high share of FRMs in the U.S. mortgage market. Even in the wake of the subprime crisis, most U.S. mortgages are pooled into mortgage-backed securities (MBS), primarily via the government-sponsored enterprises Fannie Mae and Freddie Mac (F&F). FRMs retained in portfolio pose significant interest rate risk and prepayment risk for mortgage lenders, relative to adjustable-rate mortgages (ARMs), the main alternative contract type.[2] We consequently test whether securitization, by allowing these risks to be pooled and diversified, increases the supply of FRMs relative to ARMs.

Exploiting a regulatory cutoff as well as shocks to MBS liquidity, we find that the market share of FRMs is sharply lower amongst mortgages which cannot be easily securitized. This holds most strongly for 30-year FRMs with no prepayment penalties, the loan type with the greatest prepayment and interest rate risk. Data on offered mortgage rates suggests the interest rate charged on FRMs relative to other mortgages is also higher amongst such

[1] FRMs make up 93 percent of U.S. mortgages originated between 2009-11, and 82 percent of the total stock of loans as of December 2011. These are author calculations based on data from LPS Applied Analytics, a dataset covering around two-thirds of the U.S. market. The respective shares for FRMs with a term of at least 30 years and no (or unknown) prepayment penalties are 76 percent and 66 percent. Shares are value-weighted by origination amount (flow) and outstanding balance (stock). Among the sample of countries discussed by Green and Wachter (2005), Denmark and the U.S. are the only cases in which prepayable long-term FRMs predominate.

[2] See section 2 for a detailed discussion of the interest rate and prepayment risk associated with prepayable FRMs. These risks are substantially less important for ARMs, because of their shorter duration.

illiquid loans. Our interpretation of these findings is that lenders are averse to retaining exposure to the risks associated with FRMs in portfolio. Securitization increases lenders' willingness to originate FRMs by transferring these risks to a diverse international pool of MBS investors.

Our second key finding relates to the *form* of securitization, in particular, whether public mortgage credit guarantees like those currently provided by F&F are necessary to support FRM supply. This is a widely debated yet unsettled public policy question.[3] We find that when private MBS markets are liquid and well functioning, as in the period before the onset of the financial crisis in mid-2007, private and government-backed securitization perform similarly in terms of supporting FRM supply. However, public credit guarantees may make securitization less susceptible to market disruptions, thereby improving the *stability* of FRM supply.

As a source of plausibly exogenous variation in access to securitization, we exploit the fact that by regulation, only mortgages up to a size cutoff known as the "conforming loan limit" (henceforth CLL) are eligible to be purchased and securitized by F&F. "Jumbo" mortgages larger than this cutoff may only be securitized through the nonagency MBS market, in which the securities issuer is a private financial institution rather than the quasi-public F&F.[4]

We study variation in mortgage contracts generated by the CLL in periods when both the agency and nonagency markets are liquid, as well as during episodes of illiquidity in the nonagency MBS market. We particularly focus on the period after mid-2007 when the nonagency market freezes and issuance falls to nearly zero, but also study an earlier period

[3]Illustrating the lack of consensus, in a recent U.S. Senate hearing on housing reform, 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?" was held in September 2011. Richard Green (University of Southern California) and Adam Levitin (Georgetown University) argued that government support is likely necessary for continued widespread availability of FRMs, while Dwight Jaffee (UC Berkeley) and Peter Wallison (American Enterprise Institute) argued against this claim. 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.

[4]The agency MBS market consists of securities issued by F&F and those guaranteed by Ginnie Mae, a government agency. Agency MBS carry a credit guarantee, while nonagency MBS generally do not.

of relative illiquidity in 1999–2000. Since the agency MBS market remains liquid throughout our sample (Vickery and Wright 2011), it acts as a stable comparison group, allowing us to isolate the effect of the private securitization freeze on mortgage contract structure. It furthermore enables us to measure the causal effect of agency securitization on contract structure during the "pre-freeze" period when private markets are also liquid.

Our analysis is based on a large national loan-level dataset from LPS Applied Analytics, described in section 2. The raw average FRM share is generally at least 20 percentage points lower in the jumbo market than the non-jumbo market. This statistic is difficult to interpret, however, given that borrowers in these two submarkets have very different characteristics. We use two complementary approaches to control for these demand-side differences, a fuzzy regression discontinuity design (RDD) exploiting cross-sectional variation near the CLL (see section 3), and a difference-in-differences (DiD) analysis exploiting time-series changes in the CLL (section 4). Since loan size itself is endogenous, we use appraised home values as an instrument for mortgage size, 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. This strategy minimizes selection effects due to borrowers adjusting their downpayment in order to qualify for a conforming loan.

We apply these methods over different subperiods between 1996–2009. We find that the *causal* effect of F&F on the FRM share is on average relatively small in the "pre-freeze" period when nonagency securitization is active. Most strikingly, from 2004 to mid-2007, when the nonagency MBS market is most liquid, the effect of F&F is generally indistinguishable from zero, based on either the RDD or DiD approach.

In contrast, the inability of lenders to securitize jumbo mortgages after mid-2007, while affecting the entire jumbo market, *disproportionately* reduces the supply of jumbo FRMs. During this period, the FRM share is 20 to 30 percentage points lower amongst mortgages

which are ineligible to be securitized through the still-liquid agency MBS market. This estimate is obtained by applying a DiD approach to study two events during this period, the onset of the freeze, and the later policy response which involved raising the CLL in high-cost housing areas. These results are actually stronger when we restrict our analysis to the most creditworthy loans (see section 5), suggesting our findings are not driven by credit rationing or borrower selection during the financial crisis period. This differential supply shift is also apparent in mortgage interest rates: the interest rate spread between prime-quality jumbo and conforming FRMs jumps by nearly twice as much as the corresponding spread for ARMs after the jumbo MBS market freezes. Moreover we find a similar decline in the jumbo FRM share during an earlier period of relative nonagency MBS illiquidity in 1999–2000, consistent with our results for the financial crisis period.

While we do not take a normative stance regarding the desirability of FRMs, our findings have several implications for mortgage finance policy. In the debate over reform of F&F, maintaining access to FRMs is one of the key metrics used to compare different policy options, for instance in the U.S. Treasury's recent white paper on housing finance (Department of Treasury 2011). Our results suggest that government backing of the mortgage market may *not* be necessary to maintain a high FRM share, as long as private MBS markets are liquid (notably, this is not the case at the present moment, although private liquidity is returning). Recent U.S. 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. Our results also suggest that financial regulations that discourage or limit securitization (e.g., stringent risk retention rules) may constrain FRM supply, by limiting lenders' ability to transfer risks associated with these loans.

We emphasize that our analysis is partial equilibrium in nature. Our results are identified using local variation in the likelihood of securitization; it is possible they would not translate closely to a large change in market structure. This is an important caveat regarding the policy conclusions derived above. We explore this issue and discuss other caveats in section 6. Our

cautious overall interpretation, however, is that our conclusions are likely robust to general equilibrium effects, and could even be strengthened by them.

2 Institutional Background and Data

Before turning to our analysis, we describe some necessary institutional details, particularly regarding the evolution of the CLL, which is at the core of our identification strategy. We also discuss related literature, describe our data, and present descriptive statistics.

2.1 The Conforming Loan Limit

As described above, our empirical strategy exploits variation in loan contracts generated by the CLL. This limit is a key determinant of whether a loan is "conforming," that is, whether it is eligible to be purchased by F&F. Jumbo mortgages larger than the CLL are ineligible for purchase or securitization by F&F, while in contrast, a large majority of non-jumbo mortgages *are* securitized by F&F.[5] Historically, the CLL adjusted periodically to reflect movements in home prices. Currently, the national CLL for one-unit homes is $417,000. Higher dollar limits apply for mortgages secured by multifamily dwellings, homes located in high-cost housing areas, and homes in Alaska, Hawaii, Guam and the U.S. Virgin Islands. Thus, while we generally refer to a single CLL, there are in fact a set of loan limits that vary by property type and location, with the national CLL being a lower bound.

Table 1 shows how the CLL for one-unit properties evolved over the sample period. During the housing boom, the CLL was raised each calendar year (effective on January 1), often by significant amounts, reflecting rising home prices.[6] The national limit reached

[5]Jumbo mortgages are only a subset of the non-conforming market, because loan characteristics other than size can also make a loan non-conforming. But these other underwriting criteria are not as sharply defined as the size limit.

[6]The CLL during this period applied to new mortgages as well as loans originated in the past. This created an incentive for lenders to be forward looking and take known future annual increases in the limit (usually announced around November) into account when originating mortgages, even before the new limit has taken effect. As a concrete example, the CLL in 2005 was $359,650, and was raised to $417,000 on January 1, 2006. A lender originating a mortgage in late 2005 with a principal balance between these two

$417,000 in 2006. It has subsequently been held at that level, reflecting the fact that home prices have subsequently declined, rather than increased.

In addition to these annual increases, the Economic Stimulus Act of 2008 (ESA) temporarily raised the CLL in designated "high-cost" areas to as much as $729,750 from the national level of $417,000. The ESA was passed on February 13, 2008, but it did not become fully effective until May 2008, in part because of issues regarding the pooling and trading of this new class of "super-conforming" mortgages.[7] These higher temporary CLLs were then extended a number of times, finally expiring on September 30, 2011.[8]

2.2 The Nonagency Securitization Freeze

While ineligible for agency securitization, prior to mid-2007 jumbo mortgages larger than the CLL could be securitized relatively easily through the nonagency MBS market.[9] However, along with some other private securitization markets, the nonagency MBS market froze as a source of mortgage funding during 2007, particularly centered at the onset of the financial crisis in August 2007.[10] Few jumbo MBS have been issued since the third quarter of 2007,

amounts knows that, even though it cannot immediately securitize the loan through the agency MBS market, it will be able to do so after January 1 (as long as it is willing to hold the loan in portfolio until then). Thus, a scheduled increase in the limit is likely to affect contract terms for mortgages originated just prior to the increase. For this reason, in most of our analysis we drop loans originated in the last three months of a calendar year. Our results are similar, however, if these loans are retained in the estimation sample.

[7]Agency MBS are primarily traded in a large liquid forward market known as the "to-be-announced" or TBA market. Initially, SIFMA ruled that MBS backed by super-conforming mortgages would not be eligible for TBA delivery, significantly reducing the liquidity of such loans. In May 2008, Fannie Mae announced that it would temporarily purchase super-conforming mortgages at par to TBA pricing. Later, SIFMA allowed super-conforming mortgages to be included in TBA pools, with some restrictions (see Vickery and Wright 2011 for details). Aside from this issue, the implementation delay likely also reflected the practical logistics of rolling out the new higher limits.

[8]Even today, the CLLs remain above the national limit in high-cost housing areas, because in mid-2008, permanently higher CLLs were established for these areas under the Housing and Economic Recovery Act (HERA). These higher permanent limits were not originally binding, because they lay below the temporary limits. They did however become binding once the temporary limits expired in October 2011.

[9]The nonagency MBS market is also known as the "private-label" market, referring to the fact that the issuer pooling the loans and creating the MBS is a private financial institution, rather than a government-sponsored enterprise (GSE) like F&F. While F&F themselves were for-profit corporations during most of our sample period, because of their systemic importance and public charters, these firms were widely viewed as government-backed by market participants. Consistent with this presumption, F&F received significant government support after being taken into public conservatorship in September 2008.

[10]There are several theoretical explanations for this freeze, including adverse selection, ambiguity aversion, neglected risks and financial constraints. See Leitner (2011) and Tirole (2011) for a detailed discussion. For

and in particular, no jumbo MBS backed by newly-originated mortgages were issued in 2008 and 2009. In contrast, agency MBS liquidity remained robust during this period (Vickery and Wright 2011), as evidenced by $2.89 trillion of agency MBS issuance in 2008 and 2009.

Figure 1 shows the securitization status of loans 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. Examining the top half of the figure, securitization of jumbo mortgages larger than the national CLL of $417,000 drops rapidly over the course of 2007. Strikingly, less than one quarter of jumbos originated near the end of 2007 are securitized, compared to four-fifths at the start of the year.[11] The fraction of securitized loans then *rises* sharply around May 2008, due entirely to agency MBS securitization. This reflects the implementation of the higher CLLs in high housing cost counties under the ESA. As a result of the ESA, many loan originations larger than $417,000 became eligible for securitization through the liquid agency MBS market.

In contrast to this tumult in jumbo securitization, there is little change in the total percentage of loans securitized amongst non-jumbo mortgages during the financial crisis period (bottom half of the figure), due to the presence of F&F. If anything, the fraction of loans securitized actually rises slightly from mid-2007 onwards. Notably, nonagency securitization is relatively high prior the crisis, particuarly 2004-07, mainly reflecting securitization of subprime mortages. However, the nonagency share (including sales of whole loans) falls to almost zero after mid-2007, consistent with trends in the jumbo market.

Interestingly, the figure also highlights a smaller but still significant decline in jumbo securitization in 1999-2000, in the wake of Russia's sovereign default and the failure of Long Term Capital Management (LTCM). While not the main focus of this paper, we analyze the effects of this nonagency liquidity shock on FRM supply in section 5.

our purposes we remain agnostic about the relative importance of these different factors.

[11] Moreover, the private securitization code used by LPS includes sales of whole loans. Without the inclusion of this category, the measured fraction of securitized loans in this figure would be even smaller still, reflecting the fact that nonagency MBS issuance falls to almost zero by the end of 2007. We have confirmed this by constructing a similar figure using Home Mortgage Disclosure Act (HMDA) data, which separately identifies private securitizations and whole loan sales.

The nonagency MBS liquidity freeze led to a sharp rise in jumbo mortgage rates, dating to August 2007. The spread between jumbo and conforming mortgage rates, normally around 10–30 basis points, spiked sharply to as much as 150 basis points. Figure A.2 in the Appendix shows the evolution of the jumbo-conforming spread over time.[12]

2.3 Related Empirical Literature

Our identification strategy exploits the CLL in two ways. First, we examine variation in loan size near the limit in a given year using a regression discontinuity design. Second, we use a difference-in-differences approach around time-series *changes* in the CLL, comparing loans that were not conforming in one year to loans in the subsequent year that become conforming due to an intervening change in the limit. In both these approaches we use variation in home values as a source of plausibly exogenous variation in loan amount.

The first strategy is closely related to Kaufman (2012), who uses an RDD to analyze the effect of F&F on a number of mortgage contract features as well as delinquencies and foreclosures.[13] We instead focus on a more in-depth analysis of a particular contract element, namely the FRM feature. In particular, unlike Kaufman, we exploit securitization market shocks and time-series shifts in the CLL. Also related is work by Loutskina and Strahan (2009), who use changes in secondary market liquidity near the CLL to examine the impact of banks' financial conditions on mortgage originations. These authors find that higher MBS liquidity attenuates the relationship between bank financial condition and credit supply. Calem, Covas, and Wu (2011) build on that study to examine the effects of the nonagency market collapse in 2007, as we do, and find that after the collapse, lenders that were previously more dependent on the secondary market exhibit a more pronounced decrease in jumbo lending. Neither Loutskina and Strahan nor Calem et al. distinguish between fixed- and adjustable-rate mortgage supply.[14] Finally, our DiD strategy builds on Adelino, Schoar,

[12]This figure also shows issuance volumes of nonagency MBS since 2002, from Leitner (2011).

[13]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 2011).

[14]Both papers use mortgage-level data from HMDA, which do not contain information about the contract

and Severino (2012), who study how time-series changes in the CLL affect home prices, but do not consider mortgage contract structure.

2.4 Interest Rate and Prepayment Risk

FRMs generate two important types of risk, namely interest rate risk and prepayment risk. Interest rate risk is the risk that the mortgage value may change due to shifts in the term structure of interest rates. This risk affects a lender's net worth if the mortgage asset is not matched by liabilities of similar duration, which generally is not the case for mortgage lenders funded by deposits or short-term wholesale financing. While lenders can hedge interest rate risk using swaps, in practice this strategy involves frictions due to counterparty credit risk and liquidity risk (Liu, Longstaff, and Mandell 2006), especially at longer maturities. Maturity mismatch due to a high portfolio concentration of FRMs was a primary cause of the wave of failures of U.S. savings and loan institutions in the early 1980s (White 1991).

Prepayment risk is the risk that the value of the mortgage will change due to shocks to borrower prepayment behavior. This risk is important for FRMs, particularly those without prepayment penalties, because the mortgage is prepaid at par, which may differ substantially from its market value prior to the prepayment. Borrowers' propensity to prepay increases when mortgage rates fall, causing the prepayment option to become more "in-the-money." The relation between interest rates and prepayment is nonlinear and unstable over time, however. Furthermore, a range of nontraded risks also affect prepayment, such as housing market liquidity, credit conditions, labor mobility and so on. This combination of factors make it difficult for lenders to hedge prepayment risk effectively.[15]

In a frictionless setting, lenders would incur no particular costs in bearing these risks

structure of the loans.

[15] Gabaix, Krishnamurthy, and Vigneron (2007) provide evidence of the costs associated with bearing nondiversifiable prepayment risk. These authors show that the marginal MBS investor requires a return premium to hold securities backed by FRMs. This premium appears to reflect 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 the pricing of MBS. The FRM prepayment option has led to an active industry in modeling prepayment risk (see e.g. Schwartz and Torous 1989 and Stanton 1995 for academic contributions).

privately, consistent with Modigliani and Miller (1958). However, a more recent view in corporate finance is that bearing undiversified risks is costly for firms due to the presence of financing frictions (e.g. Froot, Scharfstein, and Stein 1993; Froot and Stein 1998).

Securitization is the main tool used by lenders to pool and diversify the prepayment and interest rate risk associated with FRMs. MBS backed by U.S. mortgages are held by a wide range of international and domestic investors, including mutual funds, pension funds, banks, hedge funds, REITs, insurers and sovereign wealth funds. In addition to pass-through securities, more sophisticated structures such as collateralized mortgage obligations are widely used to concentrate duration and/or prepayment risk into particular classes of securities, such as z-bonds and PAC support bonds (see e.g. Fabozzi, Bhattacharya, and Berliner 2009 for more details). This tranching allows these risks to be reallocated to classes of investors best suited to manage and bear them. For example, z-bonds are often purchased by life insurers and pension funds with matching long-duration liabilities.

2.5 Data

Our analysis relies on a large national loan-level dataset provided by LPS Applied Analytics (formerly "McDash"). These data have been extensively used by researchers in recent years, in particular to study mortgage delinquency (e.g. Foote et al. 2010; Elul 2011). The LPS data have a high coverage of the overall market since 2005, as nine of the top ten servicers contribute their data. LPS coverage for prior years is somewhat less extensive, however. For instance, while over the period 2005–07, the number of first-lien conventional mortgage originations in LPS represents 64% of the originations in HMDA, the corresponding number is approximately 60% for 2000–04 and 46% for 1996–99.[16]

In some earlier years, mortgages in LPS are highly "seasoned," meaning that only mortgages remaining open (no prepayment or foreclosure) over a number of years ever appear in the dataset. We find that this problem is most severe prior to 1996, and consequently set

[16] Prior to 2004, the HMDA data did not record the lien status of a mortgage. For the reported calculation, we assume the fraction of first lien mortgages prior to 2004 was equal to the average fraction over 2004–07.

1996 as the first year of our sample period.[17]

While we do not expect any potential non-representativeness of the LPS data to introduce systematic bias in our analysis, we note that for our main results we rely on post-2004 data, where coverage of the overall market is better than for the earlier years. We have also reproduced our main empirical results using an alternative loan-level dataset, the Monthly Interest Rate Survey (MIRS), and find very similar patterns (results available on request).

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.[18] We drop observations from Alaska, Hawaii, U.S. Virgin Islands and Guam, which have higher CLLs. We also drop mortgages with origination amounts below 0.25 times or above 2.5 times the CLL. Finally, we drop mortgages with an initial recorded LTV of below 20 or above 100 percent, as these could be signs of data errors (e.g. second liens recorded as first liens, or a wrong loan amount).

We also restrict our sample to purchase-money mortgages, that is, mortgages used to finance a home purchase rather than to refinance an existing mortgage. Purchase transactions are arguably somewhat less endogenous to the availability and pricing of different mortgage contracts than refinancings. Furthermore, the MIRS data only contains purchase transactions. After our restrictions, the total remaining LPS sample consists of about 18.5 million loans, 8 million of which were originated between 2004 and 2007. The years with the lowest number of loans in our sample are 1996 and 2000, where we have about 770 thousand loans each.

Our main dependent variable of interest is whether a borrower selects a long-term pre-

[17]For mortgages originated prior to 1996, the median seasoning is 15 months or higher. After 1996, the annual median seasoning never exceeds 6 months, and is mostly equal to zero. Unlike many researchers that use the LPS data for default and prepayment analysis, where incorporating seasoned loans could lead to significant biases, we do not drop loans based on seasoning for the analysis in this paper. However, in unreported robustness checks we verify that dropping all loans entering the dataset more than six months after origination has only very minor effects on our results.

[18]Retaining FHA and VA loans in our sample leaves our results qualitatively unchanged, however. These loans tended to be smaller than conventional loans over our sample period, so that only a small proportion enter our estimation samples of loans with relatively high appraisal amounts.

payable FRM, rather than an alternative contract type, such as a hybrid or adjustable-rate mortgage (ARM). We define two variables: "FRM30noPPP" equals 1 if a borrower selects a mortgage of maturity 30 years or more, where the prepayment penalty flag is "no" or "unknown."[19] We also examine an alternative variable,"FRM," set equal to 1 if a borrower selects an FRM of any maturity, with or without prepayment penalty.

We also study the securitization status of loans, as reported in the LPS data. In particular, we classify a loan as non-securitized if six months after origination, the loan is held in portfolio, rather than being securitized or sold as a whole loan. Note that this means that we can only use this variable, which we denote "Non_sec6," for loans that are present in the dataset six months after origination.[20]

2.6 Descriptive Evidence

Before turning to our formal analysis, Figure 2 plots the raw FRM share above and below the national CLL (currently $417,000).[21] The FRM share is consistently much higher amongst the loans below the CLL, which were generally eligible to be securitized by F&F—e.g., between 2004 and 2007, the difference in FRM share between the two groups is stable at around 30 percentage points.[22] Notably, however, there is still significant origination of FRMs in the jumbo market even prior to 2008, including the 30-year prepayable FRM. This demonstrates that the absence of F&F does not entirely preclude the availability of long-term fixed-rate contracts.

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

[20]There is a tradeoff in selecting the horizon at which securitization status is measured. Examining securitization status at a higher loan age allows time for loans to be securitized, but drops loans that have already prepaid or defaulted, which may introduce selection. Also, securitization status can change multiple times over the life of a loan, and for our purposes 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.

[21]Like our econometric analysis, we focus on purchase-money mortgages. The graph looks similar if refinancings are included, although there is a level shift, since the FRM share is lower amongst refinancings.

[22]Koijen, Van Hemert, and Van Nieuwerburgh (2009) and Moench, Vickery, and Aragon (2010) study the determinants of time-series variation in the overall FRM share.

The lower FRM share in the jumbo market could of course be due either to demand or supply, given that jumbo and non-jumbo borrowers have very different characteristics. Our formal analysis focuses on isolating supply-driven shocks to mortgage choice. Nevertheless, we highlight two stylized facts from Figure 2 that are relevant for our later analysis. First, while the FRM shares in the jumbo and nonjumbo markets generally move together, the *differential* in the FRM share between the two markets is related to MBS liquidity shocks. Specifically, the differential widens significantly after the nonagency market freezes in mid-2007, and also in the earlier episode of nonagency MBS illiquidity in 1999–2000. For example during 2007 the FRM share rises significantly amongst nonjumbo loans, but falls amongst jumbos. Second, the FRM share differential contracts sharply around May 2008, exactly corresponding to the point at which a large subset of mortgages above the national CLL gained access to securitization, due to the introduction of higher conforming limits in high-cost housing areas. These facts are strongly suggestive that the share of FRMs is related positively to the ease of securitization.

3 Securitization and FRMs during the Credit Boom

In this section we estimate the causal treatment effect of jumbo status (i.e. being in the non-conforming segment of the market) on the likelihood of obtaining a (long-term prepayable) FRM during the period 2004–07 when private MBS markets are most liquid. Finding a negative treatment effect even during this period would suggest that F&F's presence in the conforming segment disproportionately facilitates the availability of FRMs at all times. A null (or positive) effect instead suggests that a highly liquid private MBS market performs similarly to the government-backed agency market in terms of supporting FRM supply.

3.1 Regression Discontinuity Design

Our empirical approach in this section is a "fuzzy" regression discontinuity design (RDD). Specifically, we use variation in the property appraisal amount as an instrument for whether or not a borrower takes out a jumbo loan.

One might think that it is straightforward to study the effects of jumbo status by simply comparing mortgages with loan amounts just below the CLL to others with loan amounts just above the CLL. However, as Kaufman (2012) points out, this strategy is subject to significant endogeneity problems, because the loan amount is a choice variable for borrowers. This is illustrated in Figure 3. The figure plots in turn the FRM share (Panel A) and the average FICO score (Panel B) as a function of loan size normalized by the CLL, for the period January 2004 to July 2007. We see that the FRM share drops sharply at the CLL, and in particular that there is an "overshooting" effect at the limit, suggestive of selection effects.[23] Furthermore, there is a sharp shift in the FICO score at the limit. This shows that loan amount is not well suited as the running variable for an RDD, since the assumption underlying this approach 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 appraisal amount instead provides plausibly exogenous variation in a borrower's probability of selecting a jumbo loan. At least in this part of our sample period, this probability discretely jumps upwards at an appraisal amount of CLL/0.8. The reason why is that a significant fraction of U.S. mortgages involve a loan-to-value ratio (LTV) of exactly 80%. This occurs in part by convention, but also because 80% is the maximum LTV such that loans can be purchased by the GSEs without requiring the borrower to take out private

[23]The fact that borrowers who sort just below the CLL have a higher propensity to select FRMs could indicate that F&F's presence disproportionately facilitates FRMs. However, it is also possible that borrowers who have the ability to make a sufficiently large downpayment to get below the CLL have unobserved characteristics that correlate with a preference for FRMs (e.g. high risk aversion).

mortgage insurance (PMI).[24]

Figure 4, again using data from January 2004 to July 2007, 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 property appraisal amount, scaled by CLL/0.8. We observe a sizeable discontinuous jump in the probability of selecting a jumbo mortgage at the appraisal cutoff (= CLL/0.8), of around 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). According to 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. However, there is no discernible discontinuity around the appraisal cutoff.

Unfortunately, this observed discontinuity in the probability of obtaining a jumbo loan is much weaker prior to 2004, since a smaller fraction of borrowers financed their homes with an LTV of exactly 80% in this earlier period. Similarly, after the breakdown of the nonagency market in the third quarter of 2007, jumbo loans became sufficiently expensive so that for a large number of borrowers with houses appraised at more than CLL/0.8, it became attractive to make a larger downpayment in order to obtain a conforming loan with a lower rate instead a jumbo loan. Consequently, we only use this identification strategy for January 2004 to July 2007. Although our identification strategy is in principle still valid outside this time period, it is not statistically powerful.

Below we present results using local linear regression, which formalize the results of Figure 4, and also allow us to attach standard errors to the estimated treatment effect of being in the jumbo segment. Before discussing these results, however, we note that the data

[24] To illustrate, consider a borrower purchasing a property with a value assessed at \$CLL/0.8. She can finance this purchase with an LTV of 80% to get a mortgage of exactly \$CLL. If instead her property were assessed at \$CLL/0.8 + \$10,000, getting an 80% LTV loan puts her above the CLL; if she wants to qualify for a conforming loan, she must either pay for PMI, or increase her downpayment by \$10,000. Both of these strategies may be more expensive than the increase in the interest rate she faces by getting 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.

show no evidence of any "manipulation" or sorting around the appraisal amount CLL/0.8 (which would be a problem for the validity of our RDD). Evidence on this point is provided in the Appendix.

3.1.1 Results

To quantify the treatment effect on contract structure of being in the jumbo segment, we use local linear regressions (see e.g. Imbens and Lemieux 2008 for an introduction) around the CLL/0.8 threshold. 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:

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

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).

To choose the bandwidth for the local linear regressions, we use a cross-validation procedure similar to that in Almond et al. (2010)[25]: 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). For the pooled regressions, 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); for the individual years, the optimal bandwidths are slightly larger. For simplicity, we use 0.08 as our baseline bandwidth for all variables, and report the sensitivity of our results to alternative choices in the Appendix.

For our main estimates, we only use mortgages originated between January and September. As already documented, jumbo mortgages originated late in the calendar year are frequently sold to F&F in the following year (when they become conforming due to the rise

[25] We thank Heidi Williams for sharing their Stata code with us.

in the limit). We do not want this to influence our estimated treatment effects. Additionally, we include a vector of year-month dummies in all regressions in order to control for time-series variation in the overall market share of FRMs relative to ARMs. We have also experimented with adding additional covariates, such as state dummies, FICO scores, and so on, and find that this has little effect on our results.

Results are presented in Table 2. We see that the point estimate of the treatment effect of jumbo status on the probability of matching with a prepayable 30-year fixed-rate mortgage is in fact positive, not negative. The standard errors do not allow rejection of the null hypothesis that the treatment effect is zero, but they do allow us to reject the hypothesis that the effect of jumbo status on Pr(FRM30noPPP) is negative of economically significant magnitude—e.g., -0.1. As shown in the second column, this holds even more strongly if we use FRM (without restrictions on maturity and prepayment penalty) as the dependent variable.[26] The final column of the table examines the effect of jumbo status on the probability of securitization. The estimated treatment effect of 0.02 suggests that the causal effect of jumbo status on the probability of the loan being retained in portfolio (measured six months after origination) is only very slightly, and insignificantly, positive.

These results imply that over 2004 to mid-2007, private securitization 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. This enabled lenders to offer long-term prepayable FRMs to jumbo borrowers to the same extent that those loans were available in the conforming segment.

4 MBS Liquidity Shocks and FRM Supply

While the RDD approach described in the previous section provides a very clean way to test for treatment effects of jumbo status on contract structure, it only allows us to do so for

[26] Also, Table A.1 in the Appendix shows that these results are not very sensitive to the choice of bandwidth, and Table A.2 repeats the exercise year-by-year to show that the previous results are not driven by aggregation across time periods.

years in which the "first stage" is powerful, i.e. from 2004 to mid-2007.

To test for causal effects over a longer period, and in particular during the nonagency market freeze of 2007–08, we implement an alternative identification strategy that makes use of changes in the CLL over time. Consider an increase in the CLL at the end of period t. Similar to Adelino, Schoar, and Severino (2012), we examine mortgages with appraisal amounts 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. Loans with appraisal amounts above $\text{CLL}_t/0.8$ are significantly more likely to be in the jumbo segment during period t, i.e. they are "treated" in period t but not in period $t+1$ (because they are now below $\text{CLL}_{t+1}/0.8$). 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.

It is perhaps easiest to think of this DiD analysis as implemented with only one "pre" and one "post" period, although in the main text we focus on results based on pooling data across different subsets of years.[27] 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

[27] Individual results for each annual change in the CLL are presented in the Appendix. Note also that the increase in the CLL in high-cost areas, which forms part of our analysis, does not occur at the start of a calendar year. We treat the effective date of this increase as being May 1, 2008. We focus on this date, rather than the passage of the act itself, because of implementation lags and the issues around TBA deliverability discussed in section 2. Robustness checks described below indicate however that our results are robust to different treatments of this implementation date.

δ_1 in the first-stage regression is positive: a loan is more likely to be in the jumbo segment if the appraisal amount of the property ($appr_i$) is above CLL/0.8 in the period in question. 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.[28]

It may be helpful to consider a particular example (without control variables). In 2004, CLL/0.8 equals \$417,125. Among properties with appraisal amount (417,125, 449,563], in 2004 about 32% are financed with a jumbo loan. In 2005, the corresponding jumbo percentage for this property appraisal band is only 5%, 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 corresponding percentages are 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, both groups have a somewhat higher share of prepayable 30-year FRMs in 2005 than in 2004, but even though in 2004 a much larger fraction of the loans in the higher appraisal band were financed by a jumbo mortgage, this difference is no larger than for the loans in the lower appraisal band, translating into a treatment effect close to zero.

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. A necessary condition for this exclusion restriction to hold is 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

[28] 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.

might have a different propensity to get an FRM due to their unobserved characteristics). To control for this possibility, we generally drop the first three months of each post-period, as the loans originated during those months would be most likely to be affected by such market timing.[29]

4.1 Results

Table 3 presents results from this two-stage DiD regression estimated over three subperiods: 1996–2002, 2002–2006, and August 2007–January 2009.[30] Our analysis is based on the annual increases in the CLL which occurred at the start of each year 1997–2006, as well as the heterogeneous increase in the CLL in high-cost housing areas, effective May 2008. To identify the relevant temporary high-limit CLL for each mortgage, we identify the county of each loan using the zip codes provided in LPS and a zipcode–county concordance, and then merge this data with the set of temporary county-level CLLs implemented under the Economic Stimulus Act. We then apply the same DiD strategy as above, for the subset of counties for which the CLL was raised above $417,000.

We split the sample in this way in order to separately examine three distinct periods in the liquidity of nonagency MBS securitization: (i) the "pre-boom" period when jumbo MBS liquidity is moderate (1996–2002), (ii) the "boom" period when jumbo MBS liquidity is highest (2002–2006), and (iii) the "market freeze" period when jumbo MBS securitization is entirely frozen.[31]

Column 1 presents the results of the first-stage regression. Our instrument for jumbo status is strong—over 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 fi-

[29]The only exception is the increase in local CLLs in 2008, where we include loans from May 2008, which we consider the effective implementation date. If we drop May to July 2008, and extend the post-period correspondingly, or drop February to April 2008 (when the increase in the CLLs had already been announced but not yet implemented) our estimated effects remain qualitatively unchanged. For the earlier post-periods, we note that not dropping the first three months of the post-periods does not materially alter the results.

[30]We always use pre- and post-periods of identical length (in terms of number of months included).

[31]The year 2002 is part of both the pre-boom sample and the boom sample because it once acts as a post-period (for 2001–2002) and once as a pre-period (for 2002–2003).

nanced by a jumbo loan that is ineligible for agency securitization, relative to loans in this appraisal band originated in period $t+1$, normalized in both periods relative to loans with property value in the band just *below* $\text{CLL}_t/0.8$.

The main coefficients of interest, however, are the instrumented effects of jumbo status on the FRM market share, shown in columns 2 and 3. The dependent variable in Column 2 is equal to 1 if the borrower obtains a 30-year FRM with no prepayment penalties. In column 3 a value of 1 indicates that the borrower obtained *any* type of FRM.

We find strikingly different results across the three subperiods. In the "pre-boom" period, the FRM share is moderately (around 10 percentage points) lower amongst jumbos loan ineligibile for agency securitization. During the nonagency MBS boom period, ineligibility for agency securitization has an economically small effect on the FRM share, consistent with our RDD results, which cover a similar time period.[32] Most starkly, however, during the market freeze period, the causal effect of jumbo loan status on the FRM share is economically large, minus 29 and 18 percentage points in columns 2 and 3 respectively, and statistically significant. In other words, consistent with the time-series evidence in Figure 2, there is a much higher share of FRMs amongst the segment of mortgages that "becomes" conforming due to the higher CLLs in high-cost areas implemented under the ESA.

Our key conclusion from these results is that access to securitization has important effects not just on mortgage supply per se, but particularly on the *relative* supply of FRMs. At one extreme, during the market freeze period when jumbo loans cannot be securitized privately, access to the agency MBS market sharply raises the FRM share, concentrated in particular amongst 30-year FRMs with no prepayment penalties, the category of loans with the greatest prepayment and interest rate risk. Our interpretation is that lenders are averse to retaining in portfolio the risks associated with FRMs, and respond by disproportionately contracting the supply of FRMs, leading to substitution towards ARMs by jumbo borrowers. At the other

[32] As shown in the Appendix, for the period 2004–06 for which there is a direct overlap between the sample used for the DiD analysis and our previous RDD results, the results of the analysis are very similar: the effect of jumbo status on the probability of selecting an FRM is very close to zero, tightly estimated, and not statistically significant.

extreme, in the period when jumbo securitization is most liquid, eligibility for securitization in the agency market has essentially no impact on the FRM share.

Instrumented results for the fraction of loans held in portfolio six months after origination ("Non_sec6"), presented in column 4, confirm this ordering of the relative ease of jumbo securitization across the three periods. Jumbo loans ineligible for agency securitization are moderately (15 percentage points) more likely to be retained in portfolio during the pre-boom period, only slightly more likely to be retained in the boom period, and much more likely to be retained, rather than securitized or sold as a whole loan, during the market freeze period (24 percentage points). These effects would be likely to be even stronger if we considered securitization only, rather than whole loan sales, given that nonagency securitization falls to nearly zero from late 2007 onwards.

Table A.3 in the Appendix repeats the same DiD analysis year-by-year up to 2006. The first-stage results show that our instrument is valid in all years, though it becomes stronger over time.[33] The estimated effects of jumbo status on the probability of obtaining an FRM vary considerably over time, although the effects are often imprecisely estimated. Despite this imprecision, one notable feature of the year-by-year results is that the effect of jumbo status on Pr(FRM30noPPP) is estimated to be very significantly negative (economically and statistically) for one period, namely the year 2000. This result is discussed in more detail in section 5.

Also in the Appendix, we present year-by-year results from an alternative estimation approach in which, rather than using appraisal value as an instrument to minimize endogeneity concerns about loan amount, we simply drop loans that are close to the CLL. The idea behind this approach is that the selection effects discussed earlier are likely to be concentrated near the CLL. While omitted from the main text because of space constraints, results from this approach are also consistent with the findings discussed here.

[33]The F-statistics from the first-stage regression are above 50 for all years except 1996, where it equals approximately 7, potentially explaining why the estimated treatment effect for that year is so imprecisely estimated.

4.2 DiD Analysis: Onset of the Nonagency Freeze

As a further test of the effect of the nonagency MBS freeze, we estimate an additional DiD model which can also be seen as a "coarse" version of the regression discontinuity design presented earlier. 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 ±10% around \$521,250 (=417,000/0.8) and use having an appraisal amount above \$521,250 as an instrument for obtaining a jumbo loan.

Importantly, one should not interpret the estimated effect of being in the jumbo segment on the likelihood of obtaining an FRM as an unbiased causal effect estimate. As we saw in Figure 4, 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]. We argue that comparing the estimated effect across the two subperiods is nevertheless informative, as this interaction effect "nets out" the bias.

Table 4 presents the results of this analysis. The first two lines show that the effect of being in the appraisal band above \$521,250 has a much 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 strongly significant positive effect of about +6.6 percentage points ($= 0.278 - 0.212$) on the probability of obtaining a jumbo loan.

Our main coefficients of interest is the interaction effect "Jumbo × 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 somewhat smaller yet still highly statistically significant. Column (4) shows that the probability of a jumbo loan

remaining in portfolio is significantly larger than before the crisis, which as in our earlier results, reflects the freeze in issuance of nonagency MBS. Thus, these results are consistent with the ones from the previous subsection, both qualitatively and quantitatively.

5 Additional Evidence and Interpretation

5.1 Borrower Selection during Market Freeze Period

A possible alternative explanation for the findings presented above is a borrower selection effect in the jumbo market during the nonagency market freeze. After the nonagency MBS market becomes illiquid, it is clear that 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 amongst these subsamples, because they are less likely to be credit rationed in the jumbo market during the financial crisis than the average borrower. However, under the "risk management" interpretation posited earlier, 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 pronouced amongst more creditworthy borrowers.

Our results, shown in Table 5, are consistent with this second explanation, not the first. Although somewhat imprecisely estimated (due to the smaller sample size), our coefficient estimates are significantly larger in magnitude for the FICO>740 subsample (e.g. the in-

strumented 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 amongst jumbo loans that are illiquid due to the nonagency MBS freeze is not driven by borrower selection due rationing.

A different possible selection effect may relate to refinancing behavior.[34] Perhaps borrowers who obtain a jumbo loan during the financial crisis anticipate refinancing quickly because of the elevated jumbo-conforming spread, either to a nonjumbo 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. Under such a scenario, demand for FRMs might be reduced even among a borrower population with constant characteristics and underlying preferences, raising the possibility that our results reflect temporary changes in demand, rather than supply. However, as we show below, the behavior of mortgage interest rates during the market freeze period is not consistent with this hypothesis. Under this refinancing explanation, we would not expect to observe a larger increase in the jumbo-nonjumbo 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 drop in duration for such loans. In contrast, we now present evidence that lenders raised jumbo rates (relative to conforming rates) significantly *more* for FRMs than for ARMs from August 2007 onwards.

5.2 Effects on Mortgage Interest Rates

The analysis presented above finds that access to securitization significantly influences equilibrium mortgage choice. Our interpretation is that lenders disproportionately reduce the supply of FRMs when loans are difficult to securitize. In practice, this contraction in supply could be implemented through a number of channels. Lenders could adjust mortgage interest rates on FRMs upwards (relative to ARMs) when the loan is ineligible for securitization,

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

inducing borrowers to substitute across loan products. Related, lenders could adjust the points or fees charged on FRMs relative to other mortgage types. 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 types of credit.

In this section we analyze the direct interest rate effects of the nonagency securitization freeze using loan interest rate data collected by 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, to prime borrowers.[35] These data are available from late 2006 onwards, and separately examine interest rates on 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.

From HSH Associates we obtained national weekly average offered rates and average points for conforming and jumbo 30-year FRMs and 5/1 ARMs.[36] The other conditioning information used by HSH in their survey is that the lender provides a direct (i.e. non-broker) non-rebate 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%.

Our key parameter of interest is the *differential* in the interest rate spread between jumbo and conforming loans between FRMs and ARMs, and the change in this differential after the

[35] HSH directly surveys loan officers regarding actual "street" mortgage rates available to borrowers, taking into account any discounts or other differences relative to posted or advertised rates. Note that we focus on these survey data, rather than interest rate data available in LPS; the main reason why is that we cannot directly apply our DiD or RDD approach to interest rates of a particular product type (e.g. prepayable 30-year FRMs) because mortgage choice is an endogenous decision made by the borrower, partially in response to relative prices. To illustrate how this can bias estimates of the jumbo-conforming spread, 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. A second limitation of LPS is that it does not report points and fees.

[36] 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.

nonagency market freeze. Graphical evidence on this spread is presented in Figure 5, which plots the jumbo-conforming spread (that is, the interest rate differential between jumbo and conforming mortgages) for 30-year FRMs and 5/1 ARMs over the period July 2006 to April 2008. We emphasize two main stylized facts from this graph. First, the jumbo-conforming spread rises sharply for both loan types in August 2007, at the same time as the freeze in securitization activity for jumbo MBS and in asset-backed commercial paper. Second, the increase in mortgage rates is substantially larger for FRMs than for ARMs.

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

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

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, *freeze* is a dummy equal to 1 from August 2007 onwards. Results are presented in Table 6.[37] 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 5/1 ARMs, as evidenced by the positive and statistically significant coefficient α of +29bp.

Summing up, consistent with a mortgage supply response, a freeze in access to securitization markets increases mortgage interest rates for all loan types, but disproportionately affects rates for jumbo FRMs. This closely matches our earlier evidence showing a drop in the market share of long-term prepayable FRMs amongst jumbo loans in the wake of the collapse of jumbo MBS issuance.[38]

[37] Note that HSH reports average up-front fees and points for each loan type. This is excluded from the table, although we have estimated an an alternative version of the regression in which we add a fraction of these up front points to the interest rate. This has very little effect on the results, reflecting the fact that the HSH results condition on the fact that fees and points are no larger than 1 percent of the loan balance.

[38] 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 a large previous literature. While the measured jumbo-conforming spread is somewhat larger for FRMs in 2006 and 2007, our earlier findings above suggest that borrowers' contract choice was not particularly sensitive to this small difference in relative rates.

5.3 MBS Liquidity and Mortgage Choice in 1999–2000

As shown in Figure 1, apart from the 2007–08 market freeze there is one earlier period in which the fraction of securitized jumbo loans declines substantially, dating approximately from mid-1999 to mid-2000. This period corresponds to the aftermath of the LTCM collapse, as well as a sharp decline in MBS issuance due to rising interest rates.[39] Our interpretation, supported by the patterns in Figure 1, is that MBS liquidity of jumbo loans declined during this period, reflecting the smaller pipeline of new securities, although not as dramatically as during the financial crisis. We posit that the agency MBS market was less affected by these events because of its larger overall size and the much greater liquidity of the TBA market.

Figure 6 plots the market share of FRMs against the mortgage amount, in a band around the CLL during both this period of MBS illiquidity and the period after August 2007. Notably, in both these periods there is a sharp and very large drop in the FRM share exactly at the limit. While the endogeneity of loan size is a concern, as discussed earlier, it is notable that in both cases, this drop in the FRM share persists even for mortgage amounts significantly larger than the loan limit. Compared to Panel A of Figure 3, which shows the same plot for 2004 to mid-2007, the drop-off in FRM share around the CLL is much larger.[40]

Drilling down more carefully, in the year-by-year DiD regressions presented in Appendix Table A.3, there is a large and statistically significant second-stage effect of jumbo status on the FRM share for the year 2000, corresponding to this period of illiquidity. Quantitatively, ineligiblity for agency securitization reduces the FRM share by 23 to 30 percentage points during this period, strikingly similar to our estimate for the later market freeze period. The

[39]Mortgage interest rates, as measured by the Freddie Mac conventional interest rate series on 30-year FRMs, rose from 6.79% in January 1999 to 8.52% by May 2000, reflecting rising Treasury yields. This led to a sharp decline in mortgage origination volumes, particularly for refinancings. The trade publication "Mortgage Banking" writes in December 1999 that "The refi market has dried up—so far there hasn't been carnage in the overall origination marketplace, [but] there's no doubt that the impact of interest rates has been great, with every company affected by excess capacity." Pointing to volatility in MBS markets during this period, the "American Banker" writes in September 1999 that "The market is 'getting crushed,' he [a market participant] said. Mortgage spreads are 'at or near the spreads of fall 1998, and still there's not that much buying,' he said, referring to the liquidity crisis that hit the capital markets last fall."

[40]The time-series plot in Figure 2 also shows that the FRM share in the jumbo segment drops sharply relative to that in the conforming segment during those two episodes.

estimated effect for the year 1999, on the other hand, is zero as shown in the table; this changes if we estimate it using the data for July 1999 to July 2000 only (corresponding approximately to the period with low securitization activity), yielding an estimated effect of -0.24 ($p = 0.04$).

6 Discussion

The evidence from the 2007 nonagency MBS freeze, as well an earlier period of apparent illiquidity in nonagency securitization in 1999–2000, suggests that mortgage lenders are sensitive to changes in the ease with which jumbo mortgages can be securitized. Lack of access to securitization translates directly into a decline in lenders' willingness to originate FRMs, in particular freely prepayable long-term FRMs, and a significant shift in equilibrium household mortgage choice towards adjustable-rate contracts.[41]

We interpret these findings to suggest that quantity and price decisions by mortgage originators in significant part reflect risk management concerns regarding interest rate risk and prepayment risk. This interpretation is consistent with the predictions of Froot and Stein (1998) and a number of other theoretical models in corporate finance that emphasize so-called "operational hedging" as a channel of risk management.

[41] A historical fact that may seem at odds with the arguments in this paper is that FRMs have been popular in the U.S. for many decades, while securitization only became widespread more recently, in the 1980s. Our reading of the evidence, however, is that historical events prior to our sample period are entirely supportive of our key findings. Until the 1990s, residential mortgages were predominately originated by savings and loans (S&Ls). Prior to the passage of the St. Germain Depository Institutions Act of 1982, S&Ls were in fact by law *only* permitted to originate FRMs. While this left S&Ls exposed to interest rate and prepayment risk, in the postwar period prior to the late 1970s the term structure of interest rates was generally fairly stable and upward sloping (with the exception of an episode in 1966), and borrower prepayment was relatively less sensitive to interest rates than is the case today. S&Ls were however highly exposed to the inflation and high short-term interest rates of the late 1970s and early 1980s; these events led to widespread S&L losses and failures. An important driver of the rapid growth in MBS issuance in the 1980s was the need to reduce the exposure of S&Ls to the risks of FRMs, in the wake of this crisis. Origination of ARMs provided an alternative way to reduce these exposures. For further details, we refer readers to Green and Wachter (2005); these authors provide a detailed description of the emergence of FRMs in the U.S., beginning with their first issuance in the 1930s by the Home Owners Loan Corporation.

6.1 Policy Implications and Caveats

Subject to some important caveats, discussed below, our findings suggest a number of policy implications for ongoing reform of the U.S. mortgage finance system. First, our results suggest that regulatory or legislative actions that discourage securitization, such as the implementation of stringent risk retention requirements, may lead to a lower share of FRMs amongst 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, some risks associated with the mortgage are retained by the lender.[42]

Second, our results imply that maintaining the current GSE-centered mortgage finance system may not be necessary for FRMs to remain widely available at competitive rates, but only as long as private securitization markets are liquid.[43] Prior to the financial crisis, our results suggest that the FRM share was at most modestly lower amongst jumbo loans ineligible for securitization by F&F, once we control carefully for differences in borrower characteristics between these two submarkets.

Third, recent experience suggests that private MBS markets are likely to be subject to more volatility in liquidity than government-backed markets, leading to relatively lower FRM supply in periods when MBS liquidity freezes, as we document in the jumbo market during the recent financial crisis. Scharfstein and Sunderam (2011), for example, argue in favor of government intervention in mortgage funding markets only during crisis periods, which

[42] In a standard covered bond structure, 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. Covered bonds are popular in some continental European countries, such as Germany. In contrast to a standard noncallable covered bond, in Denmark, mortgage banks issue bonds that mimic the cashflows on each mortgage origination, transferring prepayment risk to bondholders. For this reason, lenders in Denmark are willing to originate a high share of long-term prepayable FRMs, like the U.S., but unlike other countries in Europe (see Green and Wachter 2005 for a further discussion). Our empirical results suggest that shifting to a Danish-style system would not significantly affect the FRM share, but shifting to a system based on standard covered bonds would likely reduce the relative supply of FRMs. This is because the latter approach would require lenders to retain prepayment risk, which, as suggested by our results, lenders seem reluctant to do.

[43] At the time of this writing, liquidity in the nonagency MBS market is low but slowly improving, reflected in a small number of recent jumbo MBS deals sponsored by the issuer Redwood Trust Inc.

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 to a large change in the mortgage finance system, such as winding down F&F and replacing them with a purely private funding market.

Our interpretation is that general equilibrium effects could either strengthen or weaken the policy conclusions drawn above. One possible reason why private markets might be unable to provide 30-year FRMs at competitive rates for the whole market, rather than just the jumbo market, is that an elimination of F&F, or a significant shrinkage in their activities, would be likely to reduce market liquidity of the TBA ("to-be-announced") MBS market. This market is used to trade agency MBS, but confers benefits to nonagency originators and investors also. For example, investors in nonagency MBS often use TBA forward contracts to hedge short-term price risks for jumbo MBS. A deterioration or collapse in TBA liquidity could thus have spillovers on the private nonagency MBS market, which are not captured in our partial equilibrium analysis. On the other hand, it seems possible that some kind of TBA-like market structure could emerge organically from a private market in response to a winding-down of F&F.[44] Indeed, a shift towards a larger private, nonagency MBS market could further increase the liquidity of MBS backed by non-conforming FRMs and thus have a positive effect on their supply.

A further reason why private markets might be unable to provide 30-year FRMs at competitive rates for the whole market, rather than just the jumbo market, is that without a government guarantee against default risk, many institutional investors and foreign entities may no longer be able or willing to invest in MBS. As a higher fraction of FRMs is securitized relative to ARMs, this might cause a larger increase in FRM rates.

[44] Amongst other issues, some legal hurdles would need to be overcome for TBA trading to be possible in the nonagency MBS market; in particular, the market would need to be exempt from the registration requirements of the Securities Act of 1933 (see Vickery and Wright 2011 and Dechario et al. 2011 for a more detailed discussion).

Overall, our tentative and somewhat speculative conclusion is that the policy implications of our findings are likely to be robust to general equilibrium considerations. At least, we believe the ability of the nonagency MBS market to fund and securitize large volumes of FRMs prior to the financial crisis suggests that it would be possible to substantially reduce the footprint of government credit guarantees without significantly affecting the FRM share, so long as private MBS liquidity was at least similar to the "pre-boom" period from 1996–2002.

We note that, while we find no causal effect of F&F on mortgage structure in recent history prior to the financial crisis, these agencies almost certainly played a causal role in establishing the long-term FRM historically. In fact, it is possible that there is path-dependence in the type of mortgages that are offered and popular: if a country begins from an equilibrium in which FRMs are rare, then the secondary market for such mortgages is likely to be small and illiquid, and there will also be less product market competition for these instruments. These factors in turn make FRMs more expensive, keeping their market share low, and reinforce the illiquidity of the MBS market. On the other hand, government intervention that leads to coordination on FRMs as the dominant product may create a self-reinforcing cycle, enabling FRMs to remain the dominant contract type even if government support is subsequently removed.[45]

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 important consequences, given the importance of residential mortgages and MBS in household and investor portfolios.

[45]One implication of this path-dependency argument: one should not infer that prepayable FRMs would disappear in the U.S. in the absence of government sponsorship just because FRMs are generally rare in other countries which do not feature this support.

7 Conclusions

A significant and growing literature in financial economics studies household mortgage choice and its consequences. Our results suggest that supply-side factors play an important role for equilibrium mortgage choice. In particular, we find that the liquidity of securitization markets is a key driver of the availability and popularity of fixed-rate mortgages, and thus has important effects on U.S. household portfolios. Quantitatively, our estimates based on recent experience indicate that the share of FRMs is 20 to 30 percentage points higher when lenders are able to easily securitize newly-originated mortgages.

We highlight a number of implications of our findings for the ongoing debate around U.S. mortgage finance reform, which is among the most pressing financial policy issues facing the U.S. today. In particular, our results suggest that government credit guarantees for securitized mortgages may not be necessary for maintaining a high FRM share, but only as long as private securitization markets are liquid and well functioning. From a broader perspective, our findings provide a striking illustration of how the institutional features of the financial system can shape financial contracting and the allocation of risk amongst households, financial intermediaries and investors.

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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 in general able to purchase for single-family homes. Since February 2008, CLLs have been higher 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: Fuzzy regression discontinuity design: Results

Table shows 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 January 2004 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. All regressions include year-month dummies. We use the "rd" Stata command by Nichols (2011) to perform the estimation.

	FRM30noPPP	FRM	Non_sec6
Change in Pr(dep. var.)	0.00552	0.00973***	0.00346
	(0.00340)	(0.00341)	(0.00257)
Change in Pr(jumbo)	0.145***	0.145***	0.152***
	(0.00227)	(0.00227)	(0.00261)
Treatment effect	0.0381	0.0672***	0.0227
(Wald estimate)	(0.0236)	(0.0238)	(0.0168)
N	407443	407443	310280

Robust standard errors in parentheses

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

Table 3: Difference-in-differences analysis

Sample includes purchase-money conventional mortgages with appraisal amounts in the range [$\text{CLL}_t/0.8 - \min(\text{CLL}_{t+1}/0.8 - \text{CLL}_t/0.8,\ 0.1{\cdot}\text{CLL}_t/0.8)$, $\text{CLL}_t/0.8 + \min(\text{CLL}_{t+1}/0.8 - \text{CLL}_t/0.8,\ 0.1{\cdot}\text{CLL}_t/0.8)$] for loans originated between April and September of 1996–2006, and [$417000/0.8 - \min(\text{CLL}_{2008}/0.8 - 417000/0.8,\ 0.1{\cdot}417000/0.8)$, $417000/0.8 + \min(\text{CLL}_{2008}/0.8 - 417000/0.8,\ 0.1{\cdot}417000/0.8)$] for loans originated between August 2007 and January 2009. "Market freeze period" is taken to be August 2007 to April 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. Standard errors are clustered at the individual loan level, as the same loan can be part of the "high appraisal" band in period t and the "low appraisal" band in period $t+1$.

A. 1996–2002: Pre-boom period

	(1) Jumbo	(2) FRM30noPPP	(3) FRM	(4) Non_sec6
$(year_i = t)\times$ $(appr_i > CLL_t/0.8)$	0.0774*** (0.00282)			
Jumbo		-0.116** (0.0490)	-0.0970*** (0.0359)	0.153*** (0.0326)
N	345867	345867	345867	218475

B. 2002–2006: Nonagency MBS boom

	Jumbo	FRM30noPPP	FRM	Non_sec6
$(year_i = t)\times$ $(appr_i > CLL_t/0.8)$	0.249*** (0.00194)			
Jumbo		-0.0372*** (0.0128)	-0.0374*** (0.0123)	0.0676*** (0.00974)
N	596814	596814	596814	407687

C. August 2007 - January 2009: Nonagency MBS market freeze

	Jumbo	FRM30noPPP	FRM	Non_sec6
Market freeze period $\times$ $(appr_i > 417\text{k}/0.8)$	0.0619*** (0.00278)			
Jumbo		-0.287*** (0.0939)	-0.182** (0.0827)	0.241*** (0.0608)
N	64589	64589	64589	57124

Clustered standard errors in parentheses

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

Table 4: 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
$(appr_i > 417\text{k}/0.8)$	0.278***			
	(0.00234)			
$(appr_i > 417\text{k}/0.8)$ × Market freeze period	-0.212***			
	(0.00319)			
Jumbo		-0.101***	-0.0923***	0.0533***
		(0.0104)	(0.00992)	(0.00771)
Jumbo × Market freeze period		-0.270***	-0.159***	0.270***
		(0.0525)	(0.0473)	(0.0349)
N	162225	162225	162225	141542

Robust standard errors in parentheses

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

Table 5: Difference-in-differences for nonagency MBS freeze vs. period with increased CLLs: Robustness checks

"Market freeze period" is taken to be August 2007 to April 2008. Comparison period with higher CLLs ("CLL_{2008}") is May 2008 (when issuance of high-balance MBS started) to January 2009. Sample includes purchase-money conventional mortgages with appraisal amounts in [417000/0.8 − min(CLL_{2008}/0.8 − 417000/0.8, 0.1·417000/0.8), 417000/0.8 + min(CLL_{2008}/0.8 − 417000/0.8, 0.1·417000/0.8)].

A. Only non-subprime loans with (non-missing) FICO score above 740 and not marked as low/no-documentation

	(1) Jumbo	(2) FRM30noPPP	(3) FRM	(4) Non_sec6
Market freeze period × ($appr_i$ > 417k/0.8)	0.0466***			
	(0.00337)			
Jumbo		-0.458**	-0.239	0.293***
		(0.179)	(0.155)	(0.105)
N	31062	31062	31062	27729

B. Only non-subprime loans with (non-missing) FICO score above 780

	Jumbo	FRM30noPPP	FRM	Non_sec6
Market freeze period × ($appr_i$ > 417k/0.8)	0.0456***			
	(0.00403)			
Jumbo		-0.778***	-0.574***	0.326**
		(0.244)	(0.204)	(0.136)
N	17745	17745	17745	15816

Robust standard errors in parentheses

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

Table 6: Interest rate differential between jumbo and conforming segment

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.

	Jumbo-conforming spread
FRM	0.130***
	(0.00724)
Market freeze period	0.390***
	(0.0286)
FRM ×	0.290***
Market freeze	(0.0429)
Constant	0.0725***
	(0.00470)
N	182

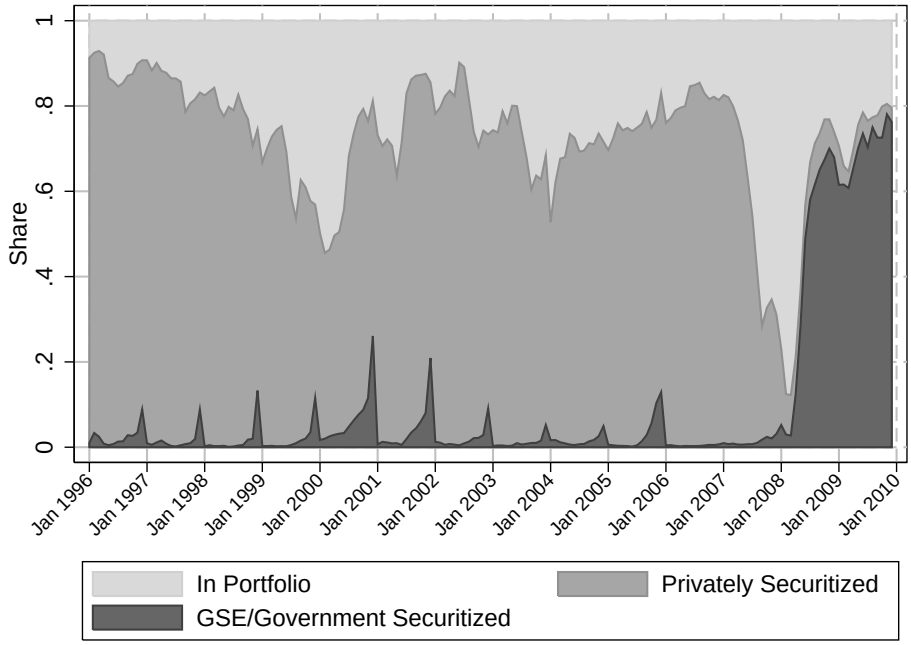
Robust standard errors in parentheses

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

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. Jumbo status is determined relative to national conforming limit; in particular, for 2008 this includes "super-conforming" mortgages in high-cost areas. Securitization status is measured six months after origination of a loan, so that only mortgages that are in the dataset by that point (and have not yet prepaid) are included in this calculation. Horizontal axis indicates mortgage origination date, not securitization date.

A. Securitization status six months after origination, jumbo loans



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

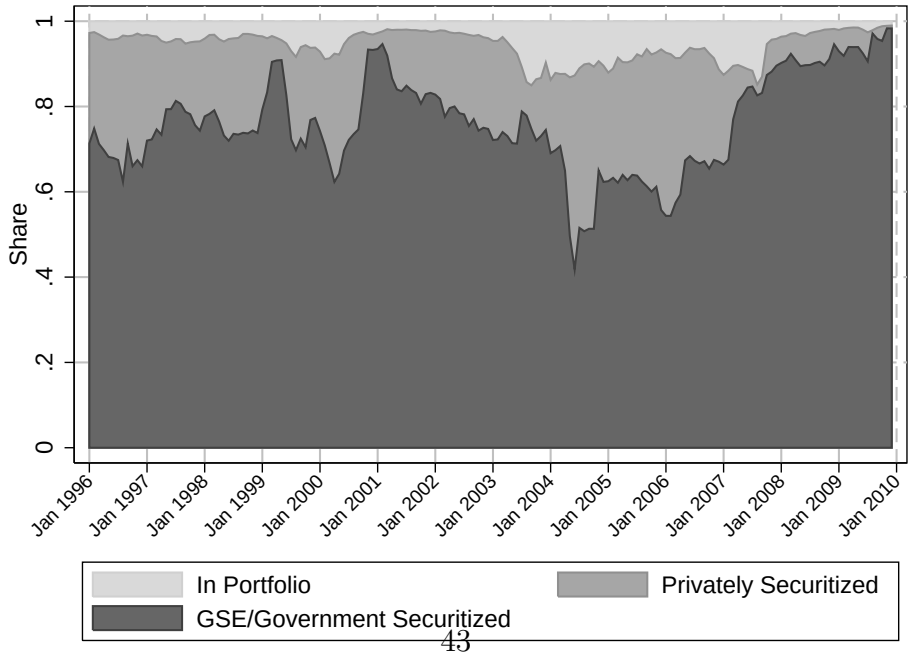
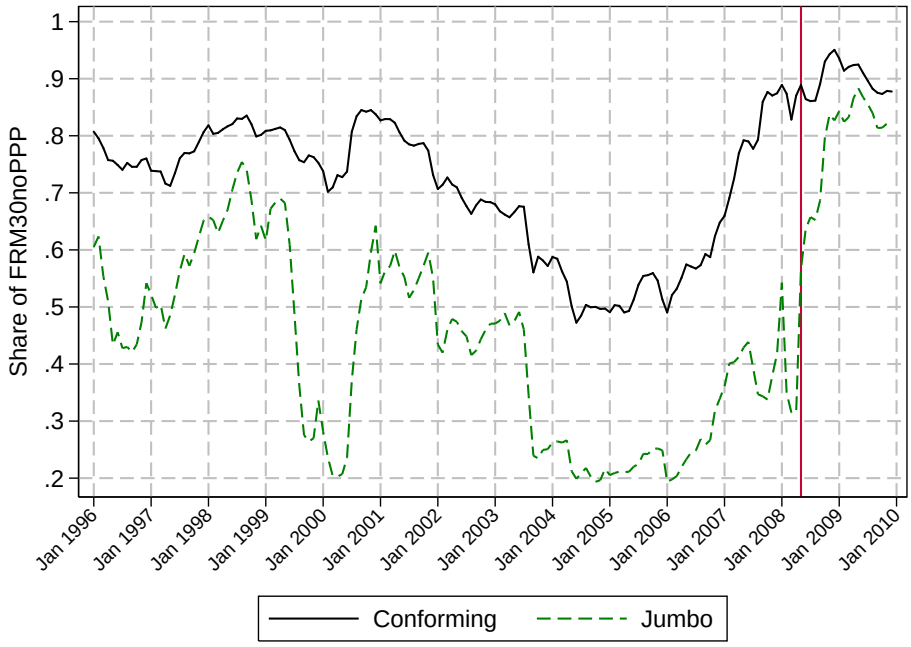


Figure 2: Market share of fixed-rate mortgages in jumbo and non-jumbo segment, 1996–2009

Author calculations based on LPS data. Purchase-money conventional mortgages only; shares are value-weighted. For 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 without prepayment penalties



B. All FRMs

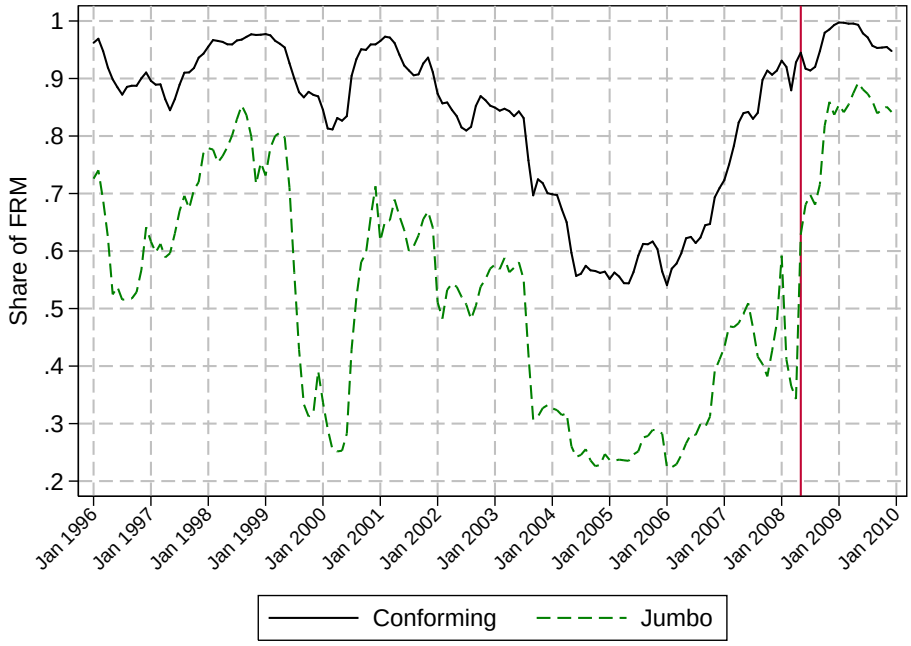
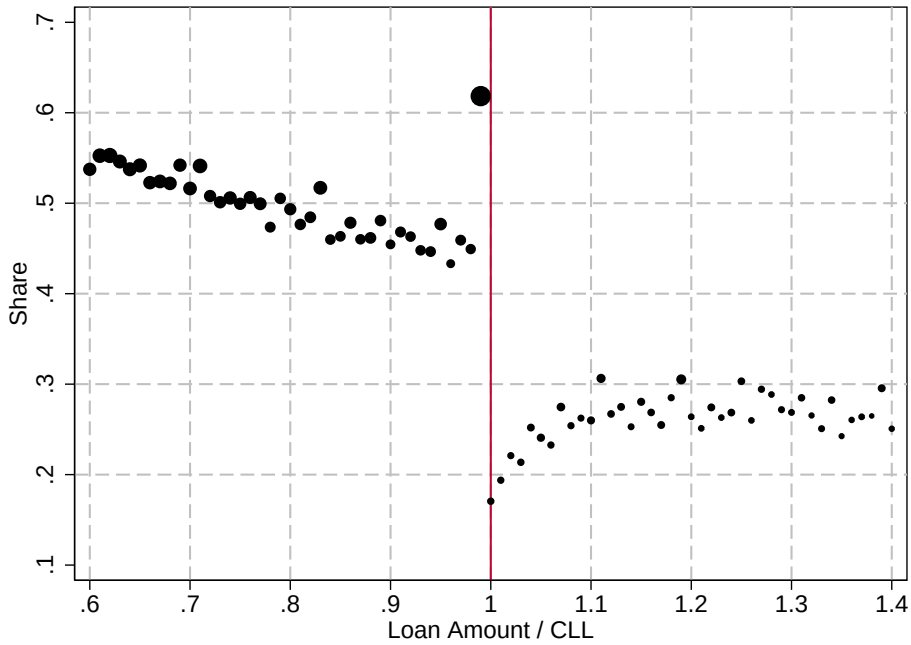


Figure 3: Selection around the conforming loan limit

Based on LPS data for purchase-money conventional mortgages originated between January 2004 and July 2007. Dots represent 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

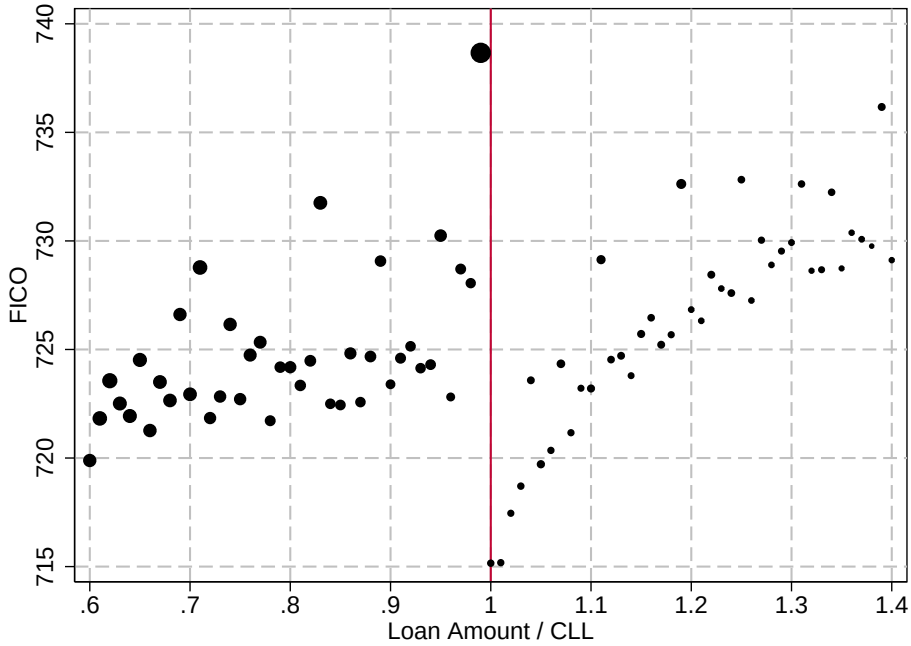
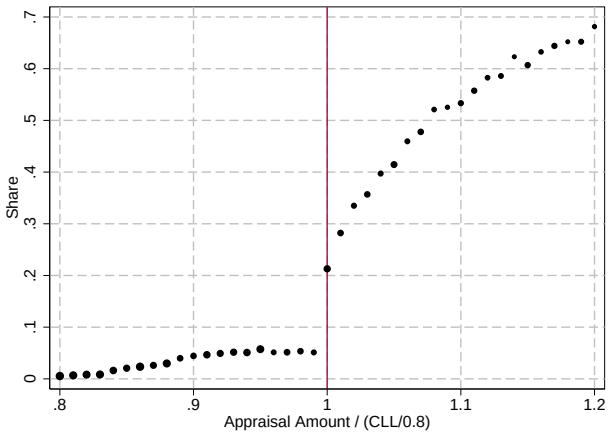


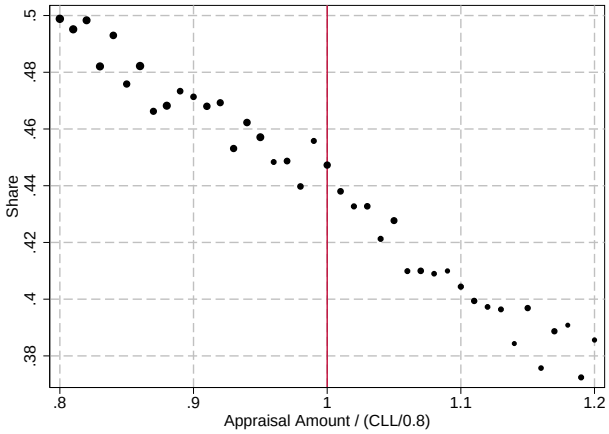
Figure 4: Regression discontinuity analysis

Based on LPS data for purchase-money conventional mortgages originated between January 2004 and July 2007. Dots represent 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

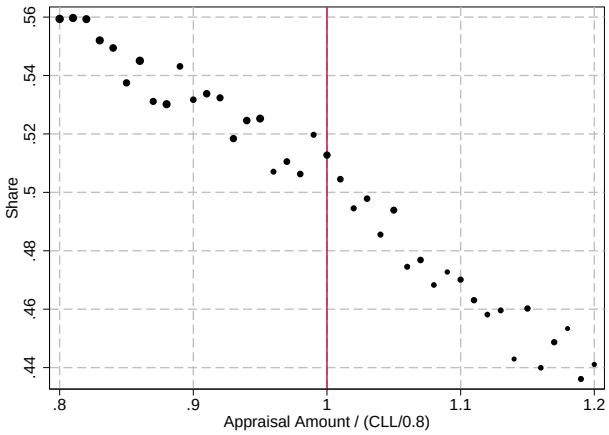


Figure 5: Jumbo-conforming interest rate spread for FRMs and ARMs

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.

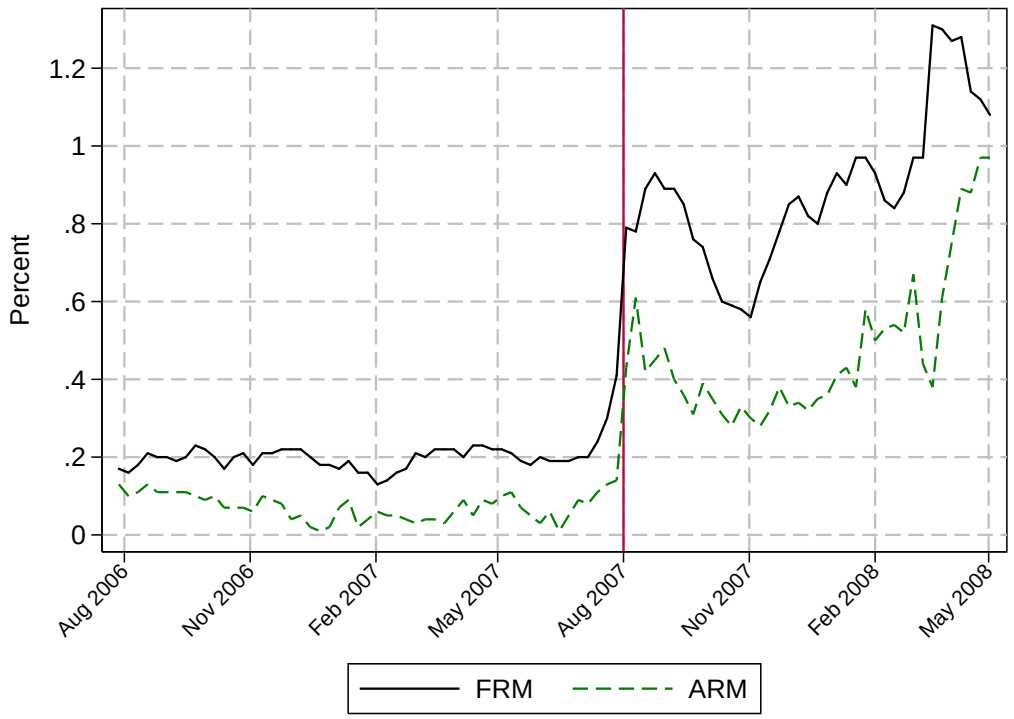
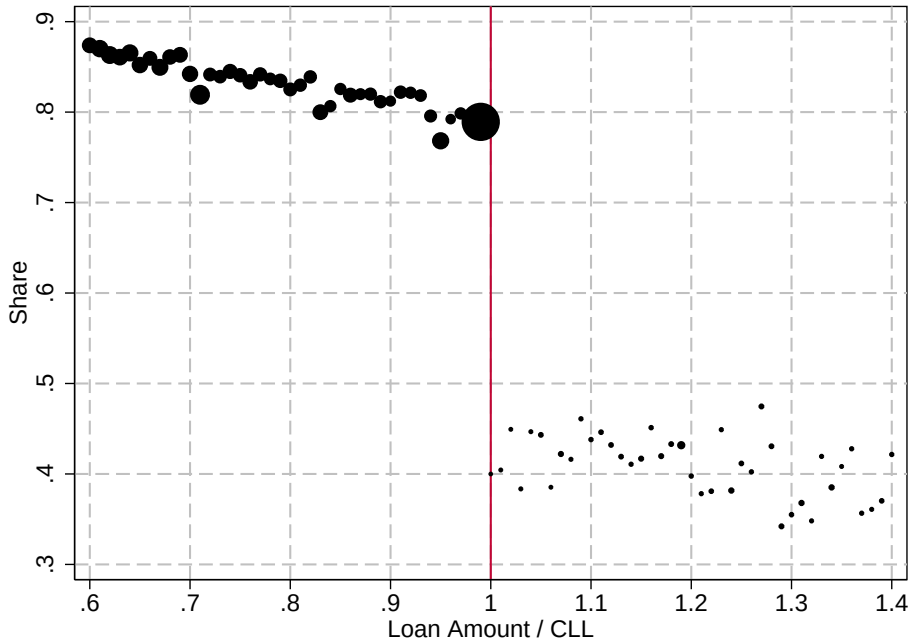


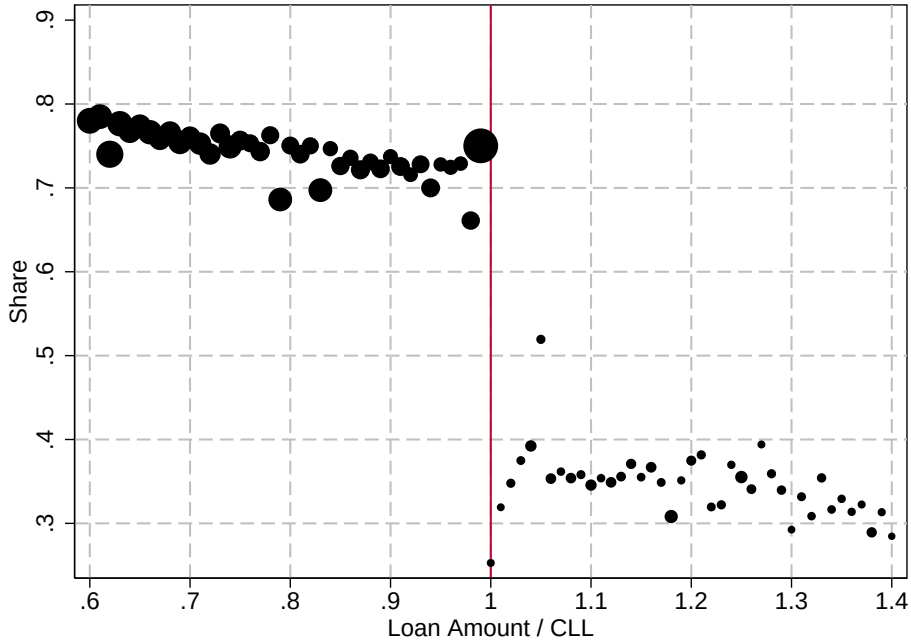
Figure 6: Share of 30-year FRMs without prepayment penalties (FRM30noPPP) by loan amount relative to CLL during times with low nonagency securitization

Based on LPS data for purchase-money conventional mortgages. Dots represent 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 – July 2000



A Appendix

In this Appendix, we begin by presenting robustness checks of our regression discontinuity design. In particular, we check the sensitivity of the results presented in Table 2 to different choices of the estimation bandwidth, both for the pooled data (Table A.1) and year-by-year (Table A.2). We also present some evidence supporting the identifying assumption that there is no borrower sorting around the CLL/0.8 appraisal threshold (section A.1).

Next, Table A.3 shows the results from estimating our DiD regressions year-by-year, rather than pooled across years as shown in the main text.

Section A.2 then discusses an alternative estimation strategy, based on modeling contract choice as polynomial functions of loan amount on both sides of the CLL threshold (instead of local linear regressions around CLL/0.8 as in the RDD results presented in the main text).

Finally, Figure A.2 presents some additional descriptive graphs about the freeze of the nonagency MBS market in the third quarter of 2007.

A.1 Borrower Sorting around CLL/0.8

Panel A of Figure A.1 shows that, for 2006 and 2007, where CLL/0.8 equals $521,250, there are no conspicuous spikes in loan volumes right below or above the cutoff. There is a spike in the histogram at $520,000; however this is to be expected due to rounding of appraisals (as the figure shows, these spikes in the frequency of appraisals also occur at other multiples of $5,000). Panel B of the figure shows the mean FICO scores around the CLL/0.8 cutoff, 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 looks more like random noise 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 some of 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.

A.2 Fractional Polynomial Regressions

As discussed at the beginning of section 3.1, 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, amenable to estimation both before and after the onset of the financial crisis, 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 non-linear relationship between loan size and demand for an FRM.[46] 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. We also control for the same borrower covariates as in section 4.[47]

Our analysis includes purchase mortgages originated between January and September of each calendar year. Under the presumption that selection effects are most severe close to

[46]See Royston and Altman (1994) for an introduction to fractional polynomial (FP) models. In our analysis, we consider FP functions up to degree 2, meaning that we find the powers (p_1, p_2) from the predefined 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.

[47]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.

the CLL, we exclude mortgages with loan amounts between 95% and 120% of the CLL.[48] 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).

Results are presented in Table A.4. 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 the years preceding the crisis, while not zero, is relatively small, consistently of the order of around 10 percentage points. However, in the market freeze period, this difference sharply increases, to 34 percentage points.

Note that the estimated coefficient on the jumbo dummy may be an upper bound of the effects of F&F intervention and higher MBS liquidity 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.

[48] 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.

Table A.1: Fuzzy regression discontinuity design: Robustness checks for pooled data, January 2004–July 2007

A. FRM30noPPP

	bandwidth=0.04	0.06	0.10	0.12
Change in Pr(dep. var.)	0.00737	0.00567	0.00636**	0.00599**
	(0.00483)	(0.00389)	(0.00305)	(0.00277)
Change in Pr(jumbo)	0.127***	0.138***	0.150***	0.156***
	(0.00307)	(0.00255)	(0.00207)	(0.00192)
Treatment effect	0.0583	0.0411	0.0424**	0.0385**
	(0.0384)	(0.0284)	(0.0204)	(0.0179)
N	186368	305142	493886	600056

B. FRM

	bandwidth=0.04	0.06	0.10	0.12
Change in Pr(dep. var.)	0.0137***	0.0114***	0.0100***	0.00908***
	(0.00484)	(0.00390)	(0.00305)	(0.00278)
Change in Pr(jumbo)	0.127***	0.138***	0.150***	0.156***
	(0.00307)	(0.00255)	(0.00207)	(0.00192)
Treatment effect	0.108***	0.0825***	0.0667***	0.0583***
	(0.0389)	(0.0287)	(0.0206)	(0.0181)
N	186368	305142	493886	600056

C. Non_sec6

	bandwidth=0.04	0.06	0.10	0.12
Change in Pr(dep. var.)	0.00290	0.00358	0.00361	0.00397*
	(0.00362)	(0.00293)	(0.00231)	(0.00211)
Change in Pr(jumbo)	0.133***	0.145***	0.158***	0.164***
	(0.00353)	(0.00293)	(0.00238)	(0.00220)
Treatment effect	0.0219	0.0247	0.0228	0.0242*
	(0.0272)	(0.0201)	(0.0145)	(0.0128)
N	142084	232977	376842	457661

Robust standard errors in parentheses

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

Table A.2: Fuzzy regression discontinuity design: Robustness checks for pooled data, 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	-0.0320	0.116**	0.0247	0.000123
	(0.0680)	(0.0520)	(0.0567)	(0.126)
N	66047	80301	59675	37512
Bandwidth = 0.08	-0.00241	0.0583	0.0538	0.0253
	(0.0523)	(0.0365)	(0.0395)	(0.0947)
N	111348	132695	100526	62874
Bandwidth = 0.11	0.0257	0.0388	0.0579*	0.0305
	(0.0427)	(0.0296)	(0.0321)	(0.0780)
N	146563	170658	136625	85174

B. FRM

	2004	2005	2006	2007
Bandwidth = 0.05	0.0559	0.150***	0.0991*	-0.0699
	(0.0698)	(0.0530)	(0.0580)	(0.119)
N	66047	80301	59675	37512
Bandwidth = 0.08	0.0458	0.0799**	0.103**	-0.0186
	(0.0535)	(0.0371)	(0.0403)	(0.0895)
N	111348	132695	100526	62874
Bandwidth = 0.11	0.0559	0.0531*	0.0951***	0.0195
	(0.0436)	(0.0301)	(0.0327)	(0.0741)
N	146563	170658	136625	85174

C. Non_sec6

	2004	2005	2006	2007
Bandwidth = 0.05	0.0262	0.0296	0.0217	0.0617
	(0.0627)	(0.0356)	(0.0338)	(0.0841)
N	42876	61270	48519	32769
Bandwidth = 0.08	0.0238	0.0377	0.0191	-0.0135
	(0.0476)	(0.0252)	(0.0239)	(0.0644)
N	72370	101161	81755	54994
Bandwidth = 0.08	0.0277	0.0388*	0.0233	-0.0285
	(0.0383)	(0.0205)	(0.0195)	(0.0535)
N	95268	130196	111213	74463

Robust standard errors in parentheses

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

Table A.3: Difference-in-differences estimates: Results (year by year)

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 between April and September of years t and $t+1$. 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
$(year_i = t)\times$ $(appr_i > CLL_t/0.8)$	0.0291***				0.0844***			
	(0.00951)				(0.00710)			
Jumbo		-0.497	-0.295	-0.0494		0.111	-0.0423	-0.0271
		(0.441)	(0.342)	(0.340)		(0.100)	(0.0763)	(0.0926)
N	23028	23028	23028	13424	51863	51863	51863	29622
Adj. R^2	0.0248	< 0	0.0555	0.146	0.0706	0.0347	0.0787	0.0277

	t =**1998**				t =**1999**			
	Jumbo	FRM30noPPP	FRM	Non_sec6	Jumbo	FRM30noPPP	FRM	Non_sec6
$(year_i = t)\times$ $(appr_i > CLL_t/0.8)$	0.0502***				0.0690***			
	(0.00516)				(0.00650)			
Jumbo		-0.0704	-0.0234	0.00746		0.0151	-0.00119	0.154*
		(0.131)	(0.0891)	(0.108)		(0.126)	(0.105)	(0.0835)
N	65277	65277	65277	36293	44373	44373	44373	28728
Adj. R^2	0.0526	0.0314	0.0509	0.0320	0.0450	0.0521	0.0814	0.131

	t =**2000**				t =**2001**			
	Jumbo	FRM30noPPP	FRM	Non_sec6	Jumbo	FRM30noPPP	FRM	Non_sec6
$(year_i = t)\times$ $(appr_i > CLL_t/0.8)$	0.130***				0.0654***			
	(0.00504)				(0.00380)			
Jumbo		-0.298***	-0.230***	0.186***		0.177*	0.147*	0.206***
		(0.0510)	(0.04415)	(0.0359)		(0.0948)	(0.0777)	(0.0496)
N	71613	71613	71613	52733	89713	89713	89713	57675
Adj. R^2	0.103	0.0810	0.145	0.155	0.0548	0.0245	0.0189	0.0538

	t =**2002**				t =**2003**			
	Jumbo	FRM30noPPP	FRM	Non_sec6	Jumbo	FRM30noPPP	FRM	Non_sec6
$(year_i = t)\times$	0.125***				0.0849***			
$(appr_i > CLL_t/0.8)$	(0.00403)				(0.00417)			
Jumbo		-0.146***	-0.141***	0.148***		-0.0575	-0.115*	0.0325
		(0.0497)	(0.0431)	(0.0349)		(0.0867)	(0.0800)	(0.101)
N	112982	112982	112982	53738	69473	69473	69473	39070
Adj. R^2	0.0697	0.0431	0.0935	0.0693	0.0390	0.0899	0.174	0.0359

	t =**2004**				t =**2005**			
	Jumbo	FRM30noPPP	FRM	Non_sec6	Jumbo	FRM30noPPP	FRM	Non_sec6
$(year_i = t)\times$	0.237***				0.316***			
$(appr_i > CLL_t/0.8)$	(0.00298)				(0.00235)			
Jumbo		0.0102	-0.00916	0.0627***		-0.00958	-0.00570	0.0752***
		(0.0186)	(0.0186)	(0.0155)		(0.0122)	(0.0121)	(0.00830)
N	185897	185897	185897	134795	228462	228462	228462	180084
Adj. R^2	0.147	0.117	0.145	0.0367	0.258	0.155	0.175	0.0367

Robust standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.4: 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 originated between January and September of each calendar year. 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. Each regression excludes mortgages between 95% and 120% of the conforming loan limit.

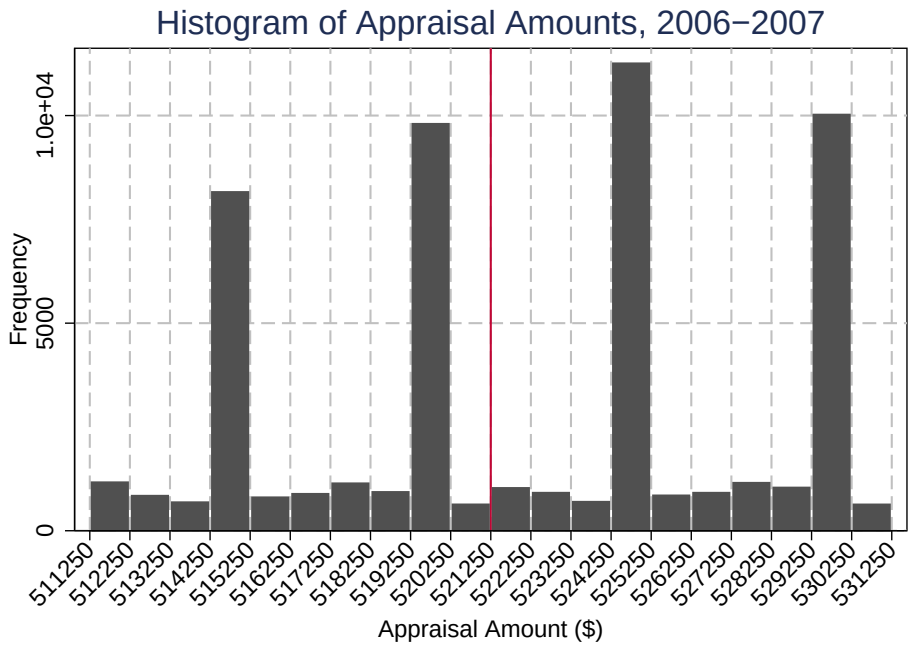
	(1) 1996	(2) 1997	(3) 1998	(4) 1999	(5) 2000	(6) 2001	(7) 2002	(8) 2003	(9) 2004	(10) 2005	(11) 2006	(12) 2007 (to July)	(13) Crisis
Jumbo	-0.216***	-0.113***	-0.111***	-0.178***	-0.314***	-0.173***	-0.0965***	-0.0819***	-0.0763***	-0.110***	-0.0975***	-0.116***	-0.341***
	(0.00576)	(0.00523)	(0.00384)	(0.00400)	(0.00518)	(0.00511)	(0.00479)	(0.00362)	(0.00258)	(0.00220)	(0.00245)	(0.00361)	(0.00458)
N	555328	524742	905651	903218	542403	727018	823613	1379699	1382666	1656286	1470872	947540	759295
Adj. R^2	0.0462	0.0406	0.0325	0.0440	0.121	0.0430	0.0431	0.0392	0.0936	0.159	0.201	0.151	0.134
FP Deviance	621277.9	613370.9	878152.7	952085.3	584888.1	746228.2	1034558.8	1831277.7	1870272.5	2116727.9	1786786.6	959344.7	469982.2
FP Powers	-2 1	-1 0	-2 2	-2 2	0 0	.5 .5	0 .5	.5 .5	1 2	-1 -1	-1 -1	-1 0	-.5 0

Robust standard errors in parentheses

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

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

A. Histogram of appraisal amount: Figure shows the distribution of loan volumes for different property appraisal values around the "conforming property price" threshold. There is no evidence of a distortion in the distribution, suggesting borrowers do not materially adjust their home buying patterns in order to qualify for a conforming mortgage with LTV of 80%.



B. FICO score distribution

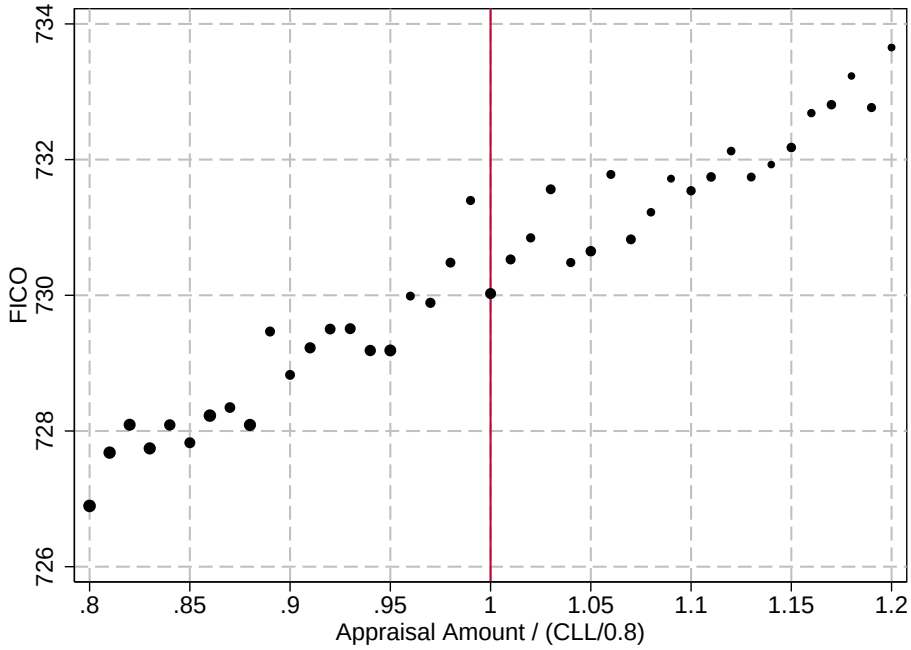
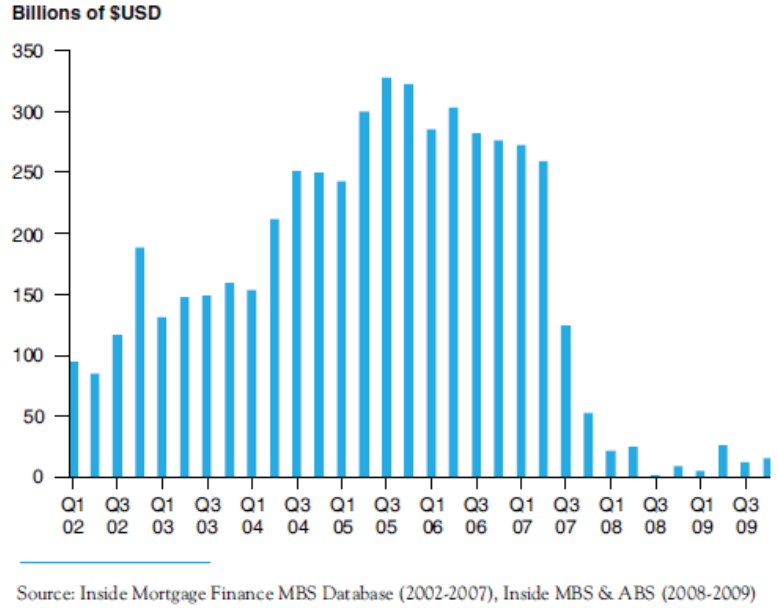
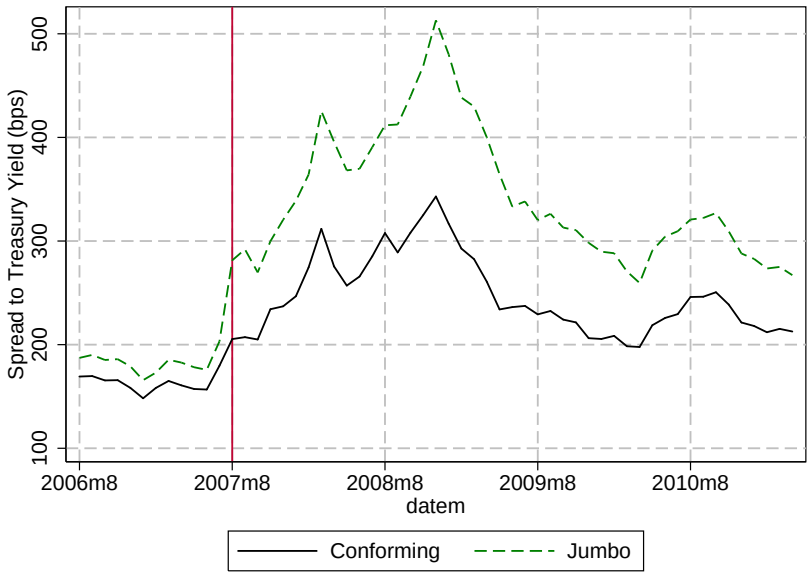


Figure A.2: The freeze in the jumbo MBS market

A. Quarterly nonagency MBS issuance since 2002. Source: Leitner (2011).



B. 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. Crisis onset is marked at August 2007, the month that BNP Paribas suspends convertibility for two hedge funds, reflecting problems in subprime MBS markets.