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Credit Supply, Prices, and Non-price Mechanisms in the Mortgage Market*

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Abstract

I use an episode of relatively tight credit supply in the jumbo mortgage market to quantify the importance of price and non-price credit supply mechanisms in explaining changes in borrowing. Following market disruptions in March 2020, borrowers with jumbo loans saw significantly tighter credit supply conditions relative to borrowers with conforming loans. As a result, jumbo borrowers were 50 percent less likely to refinance and when they refinanced they borrowed 4-6 percent less than counterfactual borrowers facing looser credit conditions. The reduction in borrowing may have been caused by both an increase in the price and a change in a non-price mechanism, a decline in the availability of cash-out refinances. Decomposing the total effect into a price and cash-out channel, I find that that the cash-out channel accounts for two to three times as much of the decline as the price effect, and together both explain 70-80 percent of the total decline. This suggests that non-price mechanisms can be least as important as prices in clearing credit markets, a fact which is not adequately explained by current models of credit markets.

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1 Introduction

> There is apt to be an unsatisfied fringe of borrowers, the size of which can be expanded or contracted, so that banks can influence the volume of investment by expanding or contracting the volume of their loans, without there being necessarily any change in the level of bank-rate, in the demand-schedule of borrowers, or in the volume of lending otherwise than through the banks. This phenomenon is capable, when it exists, of having great practical importance. – Keynes (1930)

How do lenders use price and non-price mechanisms, such as underwriting criteria or even quantity constraints, to transmit changes in credit supply conditions to borrowers? Inspired in part by Keynes (1930), a line of research emerged which argued that business-cycle movements in credit quantities may be often be caused by changes in non-price mechanisms.[1] More recently, a growing body of work has documented the role of non-price mechanisms in credit markets, but these have generally focused on their use in contract design and not on how they respond to shocks in order to clear markets.[2] Similarly, most financial and macroeconomic studies of credit markets assume that credit markets clear entirely through the adjustment of prices (interest rates) and that changes in non-price mechanisms are not relevant for understanding the response of credit markets to shocks.[3]

Understanding the extent to which lenders use non-price mechanisms to dynamically

[1]See (Baltensperger, 1978; Baltensperger and Devinney, 1985; Jaffee and Stiglitz, 1990). While much of the early work lacked optimizing foundations, Stiglitz and Weiss (1981) and Jaffee and Russell (1976) provided theoretical justifications, based in asymmetric information problems, for why prices might not be sufficient to clear credit markets.

[2]For example, see (Calomiris and Hubbard, 1990; Adams, Einav and Levin, 2009; Einav, Jenkins and Levin, 2012; Veiga and Weyl, 2016; Ambrose, Conklin and Yoshida, 2016; Chodorow-Reich, Darmouni, Luck and Plosser, 2022).

[3]For example, Bernanke, Gertler and Gilchrist (1999); Iacoviello (2005); Iacoviello and Minetti (2008); Curdia and Woodford (2010); He and Krishnamurthy (2013); Gilchrist and Zakrajšek (2012); Buchak, Matvos, Piskorski and Seru (2018); Crawford, Pavanini and Schivardi (2018); Drechsel (2023). While collateral or cash-flow constraints may become more or less binding, this is due to the change in the value of the collateral or cash-flows and not a change in the constraint itself holding fixed the collateral value or cash flows. A bank's discretion in monitoring loan covenant violations is more closely related, but still distinct since prices in this situation are typically already fixed ex ante.

clear markets is important for how we characterize the state of credit markets. If lenders primarily hold non-price mechanisms constant and adjust prices in response to a shock, then credit spreads will sufficiently describe credit supply conditions. However, if changes in non-price mechanisms are important, then empirical measures and models relying only on price clearing may fundamentally mis-characterize credit market conditions.[4] As suggested by Keynes, in a world where lenders rely on non-price mechanisms there may be large changes in credit quantities accompanied by no change or even declines in credit spreads.

In this paper, I quantify the relative importance of price and non-price mechanisms in jumbo mortgage refinancing after the onset of relatively tight credit supply conditions following disruptions in credit markets In February and March 2020. To identify these effects I use the fact that credit risk of loans in the jumbo market is held privately while conforming loan risk is held largely by the GSEs, leading to drastically different credit and liquidity conditions (Fuster, Hizmo, Lambie-Hanson, Vickery and Willen, 2021). By comparing the refinancing behavior of borrowers more dependent on the jumbo market to borrowers less dependent on the jumbo market, I can isolate credit supply conditions and study the transmission of these conditions to borrowers through price and non-price mechanisms.

I make three specific contributions. First, I show that tight credit supply in the jumbo market significantly reduced refinancing rates throughout the refinancing boom. Refinancing rates between jumbo and conforming borrowers track each other extremely closely leading up to the pandemic, consistent with the assumption that refinancing demand follows parallel trends across these market segments. However, a large gap in refinancing rates between jumbo and conforming market borrowers emerges in March 2020 and persists through September 2021. Borrowers refinancing jumbo loans were 25 to 50 percent less likely to refinance between March 2020 and September 2021, even as there was an overall increase in the likelihood of refinancing. So while demand for refinancing increased with declining interest rates, credit supply conditions in the jumbo market were relatively tighter.

[4] For example, Iacoviello and Minetti (2008) mention the possibility that non-price rationing may pollute the interpretation of the external finance premium in their analysis, but the problem is left unresolved.

Second, I document a large decline in the intensive margin of borrowing by jumbo borrowers who do refinance and show that this decline is unlikely to be explained by changes in prices. By tracking refinancing borrowers into their new loans, I observe both the price they paid and the size of their new loan. Conditional on refinancing, tight credit supply caused jumbo refinancers to borrow four to six percent less than conforming borrowers. This is an economically large shift since the average change in debt conditional on refinancing is about five percent over this period. At the same time, I estimate that borrowers with loans in the jumbo market faced a premium of 15-20 basis points. Together, these numbers give estimates of the semi-elasticity of mortgage debt of about -0.29 to -0.37, at least a 29 percent reduction in borrowing if rates increased by 100 basis points. This is an order of magnitude larger than existing estimates in the literature (DeFusco and Paciorek, 2017) and implausibly large. Moreover, the estimated effect on borrowing is essentially constant between March 2020 and September 2021, while the price premium varies and even disappears. This fact, along with the extremely high semi-elasticity estimate, suggests that the price of borrowing cannot explain much of the adjustment in quantities.

Finally, I show that the decline in the intensive margin of borrowing is largely explained by a non-price mechanism, a reduction in the supply of cash-out refinances to jumbo borrowers. Cash-out refinances allow borrowers to borrow at a new rate as well as extract equity from their home and they typically have different underwriting rules than rate refinances. I estimate that tight credit supply reduced the probability a borrower refinanced a jumbo loan with a cash-out loan by 13-19 percentage points, a decline of at least 50 percent from the pre-pandemic rates. This shift took place despite the fact that home equity surged with house prices throughout this period, further distinguishing this mechanism from more traditional collateral value channels. Holding the cash-out margin fixed, I re-estimate the elasticity of mortgage demand and get more plausible estimates, suggesting that the non-price mechanism was confounding the price effect. I then use a simple linear decomposition to show that the price premium faced by jumbo borrowers explains only about 25 percent of the total decline in leverage, while the fall in cash-out refinancing explains two to three times as much of the decline.

To summarize, tight credit supply in the jumbo market caused large relative declines in borrowing and this was largely implemented through a non-price mechanism, while the role played by prices was modest. In fact, looking only at the rate premium would have suggested incorrectly there was very little difference in credit supply across the conforming and jumbo markets. These results imply that non-price mechanisms may play a central role in how lenders manage changes in the credit environment. This has implications for tracking business and credit cycle dynamics and brings up important questions of what pins down the use of prices relative to non-price mechanisms.

One interesting question is why credit conditions remained so tight in the jumbo market given that house prices eventually started booming and labor markets recovered very quickly. While concerns about defaults may have shifted credit supply initially in early 2020, credit risk is unlikely to explain the persistence of tight conditions in the jumbo market given the strong fundamentals. It was not until the overall volume of refinancing began to slow that jumbo market credit supply began to ease, suggesting that capacity constraints as in Fuster et al. (2021) may have been important. This could mean that lenders rely on non-price mechanisms not only to respond to changes in risk, as might be expected in a credit rationing model (Jaffee and Russell, 1976; Stiglitz and Weiss, 1981), but also to manage capacity constraints. Broadly, these results suggest an interesting kind of nominal rigidity since interest rates were changing daily, but the spread between these jumbo and conforming loan products was inflexible relative to differences in non-price mechanisms.

Turning to the empirical work in more detail, the exercise hinges on credibly identifying variation in credit supply and then tracing its effects across prices, the extensive margin of refinancing probabilities, and the intensive margin of borrowing conditional on refinancing. To identify differences in credit supply, I leverage the requirement that conforming loans must be at or below the "conforming" loan limit and compare refinancing behavior of borrowers with loans above and below these limits. These limits are set annually at the county level by the FHFA with loans above these limits ineligible for sale to a GSE and so ending up in the jumbo market.[5]

Refinancing behavior is known to be very volatile and difficult to parameterize in terms of observables (DeFusco and Mondragon, 2020), so it is critical to have a counterfactual for the refinancing behavior of treated borrowers. If demand for refinancing follows parallel trends above and below the conforming loan limits, then borrowers below the conforming limits will provide a valid counterfactual for refinancing behavior of borrowers above the limits. Consistent with this assumption, refinancing rates for borrowers above and below the conforming limits were essentially identical and moved in lockstep until March 2020. After this both sets of borrowers begin refinancing at much higher rates, but borrowers with loans above the limit and so more dependent on the jumbo market are much less likely to refinance than borrowers with loans below the limit. Even after the emergence of this gap, refinancing for the two sets of borrowers still largely move together, consistent with the demand for refinancing in both groups of borrowers moving in parallel. Controlling for a rich host of observable differences across borrowers including credit scores, leverage, and location, I again find that there is essentially no difference in refinancing rates leading up to the pandemic, but then jumbo borrower refinancing falls sharply relative to the counterfactual. The magnitude of these effects is large: from April 2020 to May 2021 the monthly jumbo borrower refinancing rate is about 1 to 1.5 percentage points lower than the counterfactual, a decline of about 25 to 50 percent relative to the average.

One concern is that the differences in refinancing I estimate reflect some latent difference in demand that is correlated with loan size. However, in the data I find that refinancing rates are essentially identical above and below the conforming limits before the pandemic, with no apparent correlation between distance to the conforming limits and the probability

[5] Whether or not a loan is eligible for sale to a GSE also requires that it is underwritten in accordance with GSE standards, for example that it was approved by a GSE automated underwriting system such as Desktop Underwriter.

of refinancing. After mortgage rates fall, refinancing increases for all borrowers, but borrowers with loans directly above the conforming loan limit are now significantly less likely to refinance relative to borrowers directly below the limit, consistent with reduced credit supply above the limit. While the probability of refinancing is uncorrelated with loan size below the conforming limit, after credit conditions tighten borrowers with loans above the limit become are less likely to refinance the further their loan is from the limit. This suggests that as credit supply tightened, some jumbo borrowers would refinance into the conforming market by paying down their balance, but this becomes more difficult as the amount that the borrower must pay down increases. All of these results are robust to controlling for an exhaustive set of controls and point to their being no significant differences in the demand for refinancing above and below the limit.

I next examine how tight credit supply affected the intensive margin, or the change in how much the borrower was borrowing conditional on refinancing. Using consumer credit bureau records merged to loans, I track the change in a borrower's total mortgage debt as well as the change in interest rates on the loans. Thus, I can estimate the effect of tight credit supply on the amount that refinancing borrowers actually take out and what they paid. The identification assumption here is identical to that before: I assume that the demand for debt follows parallel trends for borrowers above and below the conforming limit. This assumption implies that any differences in borrowing, even conditional on refinancing, will be attributed to differences in supply. Consistent with this assumption, I find that borrowers refinancing jumbo loans made similar borrowing decisions to borrowers refinancing conforming loans leading up to the supply disruptions. But from March 2020 to late 2021 jumbo borrowers that refinanced reduced their borrowing by four to six percent relative to conforming borrowers that refinanced. This relative fall in borrowing is effectively constant and economically large. So in addition to reducing access to lower interest rates for jumbo borrowers, tight credit supply reduced the actual quantity of debt taken on by refinancing borrowers.

One possibility is that this reduction in borrowing was caused by an increase in the rate that jumbo borrowers faced. I provide two estimates of the effect of tight credit supply on interest rates paid by jumbo refinancers. First, I look at all newly originated refinance loans and estimate that jumbo refinancers faced a maximum premium of about 20 basis points in mid-2020, controlling for a full set of pricing characteristics. This is smaller than the premium estimated in Fuster et al. (2021) using posted offer sheets and also has very different dynamics, which could reflect borrower search across lenders and differences in composition of lenders. I also use the sample of borrowers matched across loans where I can observe the rates on their old and new loans and estimate slightly lower rate premia. Overall, borrowers who did refinance jumbo loans paid about 14-16 basis points more than borrowers refinancing conforming loans.

One way to think about the magnitude of these interest rate premia is to combine them with the changes in borrowing and estimate the semi-elasticity of mortgage debt to interest rates. Specifically, I regress the change in borrowing on the change in interest rates, where I instrument for the change in with the interaction of indicators for being above the limit and after March 2020. To interpret this estimate as the semi-elasticity of demand requires the additional exclusion restriction that there are no simultaneous non-price changes in credit supply that would affect the borrowing decision. Under this assumption, I get estimates ranging from -0.29 to -0.37, or that a 100 basis point increase in rates reduces mortgage borrowing by 29 to 37 percent. This estimate is much larger, implausibly so, than related estimates in the literature such as DeFusco and Paciorek (2017); Best, Cloyne, Ilzetzki and Kleven (2020). For example, if we take the preferred estimate of -0.02 from DeFusco and Paciorek (2017), the observed effect on borrowing would imply an increase in interest rates of 250 basis points, over ten times larger than what I actually estimate. While the type of variation I use is distinct from the approach in these bunching/notch studies, the likely reason the estimates are so different is that changes in non-price mechanisms did affect how much borrowers borrowed.

I identify one specific non-price mechanism, a large reduction in the supply of cash-out refinances. Because cash-out loans involve large increases in leverage they are often priced differently and subject to different underwriting requirements including credit score thresholds, loan-to-value thresholds, income ratios, and income documentation. Because they are treated as a distinct product lenders have the ability to change criteria just on these loans or even to stop offering them at all. I find that, conditional on refinancing, the probability a jumbo refinancer received a cash-out refinance fell by 13 to 19 percentage points relative to conforming borrowers. This is a large decline, equivalent to about 50 to 70 percent relative to pre-pandemic rates.

To quantify the importance of this mechanism, I derive a simple linear decomposition of the decline in borrowing into price and non-price shifts in credit supply. Specifically, I decompose the total intensive-margin effect on jumbo borrowing into the price effect on borrowing in rate refinances, the price effect on borrowing in cash-out refinances, and the non-price shift from cash-out to rate refinances. Together the price effects explain about 25 percent of the total decline in leverage. The decline in cash-out refinancing caused borrowing to fall by at least 50 percent of the total decline. Overall, I find that the non-price mechanism was two to three times as important as the price effect in explaining the decline in borrowing. Intuitively, this is because cash-out loans typically increase a borrower's debt by about 19 percent, significantly more than the one percent increase in debt taken for rate refinances. Thus, any shift of refinancing from cash-out to rate refinances will have a significant effect on overall changes in borrowing. Combining the price and non-price effects at the same time explains about 80 percent of the total decline, suggesting that the simple linear decomposition captures most of the relevant mechanisms. However, this decomposition likely understates the true scope for non-price mechanisms as it assumes that within cash-out and rate refinances there were not additional shifts in non-price aspects of the loan that reduced how much refinancers could borrow.

In the next section I describe the institutional background and data. Then I present the emprical results and decomposition. Finally, I conclude.

2 Institutional Background and Data

In this section I describe the important features of the institutional background that are central to the identifying variation in credit supply and then the data I use for the analysis.

2.A Institutional Background

The U.S. mortgage market is composed of several important segments primarily defined by who ends up holding the credit or default risk of the borrower. The conforming mortgage market, defined as loans eligible for purchase by the government-sponsored enterprises (GSEs) Fannie Mae or Freddie Mac, is typically the largest segment. These loans are originated and priced by lenders but underwritten according to the criteria set out by the GSEs and typically by GSE software directly. So long as these loans satisfy the underwriting criteria, they may be sold to a GSE (Stanton, Walden and Wallace, 2014). This means the GSE has largely assumed the credit risk of the loan.[6] The loans purchased by the GSEs are typically packaged into so-called agency mortgage-backed securities (MBS) with the credit risk retained by the GSE, so that investors in agency MBS will not lose any principal from defaults. As a result, agency MBS are widely held and traded, providing significant liquidity in the conforming mortgage market.

If a loan is not eligible for sale to a GSE or for insurance through a government program like FHA, then the loan is private and the credit risk will reside with some combination of the loan originator and any investor that may purchase the loan. The size of this market and the types of loans originated have varied substantially over the years. At the mid-2000s peak, the non-GSE, non-government share of the market was well over half of the total loan market, much of it passing into the private-label MBS market.[7] Following the financial crisis,

[6] This assumption of credit risk is not absolute since the originator is still responsible for representations and warranties for the loan's quality. So the GSE can force the seller to repurchase ("putback") the loan. Similarly, the company responsible for servicing the loan can be exposed to some liquidity risk in the event of default as they resolve the loan's foreclosure or become responsible for forwarding payments until the resolution of the default (Fuster, Goodman, Lucca, Madar, Molloy and Willen, 2013).

[7] See origination volume and composition at https://www.urban.org/sites/default/files/publication/

the private origination and secondary markets have been much smaller.

While there are numerous characteristics that can make a loan ineligible for the GSE market, one central requirement is based on the size of the loan. The Federal Housing Finance Agency (FHFA) specifies the conforming loan limits (CLLs) each year, which determine for each county the largest loan size that is still eligible for sale to a GSE.[8] Loans that are above these limits are called "jumbo" and the credit risk will be held by either the originator or investor. These limits are set nationally as a function of house price appreciation with county-level exceptions for counties where median home values exceed the limit by 115 percent.[9] Since the financial crisis, these loans have typically made up 4 to 5 percent of all purchase and refinance first-lien loans, but 10 to 17 percent of total loan dollars due to the larger size of each loan.[10] Jumbo loans have sometimes been subject to a price premium reflecting the higher risk and lower liquidity in the market (DeFusco and Paciorek, 2017), but often there is an apparent discount in the cost of a jumbo loan, even adjusting for borrower quality.

From the perspective of the lender, the difference between a loan above or below the limit, even to the same borrower, is significant. A jumbo loan will need to be held on the balance sheet or sold to another balance-sheet investor (such as a very large bank), as opposed to conventional loans, which are typically quickly sold off to a GSE. So jumbo loans can be more expensive to originate, especially when balance sheet space is costly. Similarly, changes in the risk environment will matter much more for a jumbo loan, where all of the costs of default are borne by the lender/investor. While conforming loans in default may still be costly to resolve, lenders necessarily bear less cost from default itself. It is this strict division in the risk and liquidity of lending across these two markets that I will exploit to identify relative shifts in credit supply.

103746/housing-finance-at-a-glance-a-monthly-chartbook-february-2021_0.pdf

[8] This limit is a necessary, but not sufficient condition as the loan must still be underwritten to conform with GSE standards in order to be eligible for purchase.

[9] https://www.fhfa.gov/DataTools/Downloads/Documents/Conforming-Loan-Limits/FHFACLL-FAQs.pdf

[10] https://files.consumerfinance.gov/f/documents/cfpb_2019-mortgage-market-activity-trends_report.pdf

2.B Data Sources

I rely on the Equifax Credit Risks Insight Servicing McDash and Black Knight McDash Data for the analysis. These data are constructed from a merge of mortgage performance and origination data to credit bureau data. Merged loans will have a broad set of credit burea data for each month the loan data are collected as well as six months before the loan appears and six month after the loan is terminated. While the loan performance data record standard repayment information, including whether or not a loan is paid off or if it has entered into foreclosure, they do not distinguish between payoffs from sales or from refinances. To address this issue I rely on the credit bureau data. These data allow me to observe the total mortgage balances carried by a borrower as well as information on whether or not the borrower has moved. These allow me to determine if a borrower that has paid off their loan did so through a sale, a refinance, or otherwise.[11]

I also use a subsample of borrowers that have paid off their loans who are then matched into a new loan in the same data.[12] When this is the case I can observe all of the origination features of both the old and new loan, as well as any other junior lien mortgage debt the borrower may be carrying on their credit records. Critically, I can calculate the change in the rate the borrower is paying on the old and new loans, which I use to estimate the semi-elasticity of mortgage debt.

2.C Sample Selection and Description

To construct the analysis sample I select all the loans that had a balance within $250,000 of the relevant CLL at any point between December 2018 and December 2019, although for much of the analysis I restrict the window to loans within $150,000 of the CLL. I then pull all origination, performance, and credit bureau data for the loans and borrowers associated

[11] Specifically, I define a payoff event as a refinance if the credit report shows a mortgage balance three months after the loan has closed and if there is no change in address reported on the borrower's credit file.

[12] These matches happen when both the old and the new loan happen to be serviced by the same set of servicers that provide these data.

with these loans from December 2019 to December 2022 unless they are paid off sooner. By focusing the analysis on this cohort of loans constructed from pre-pandemic criteria, I avoid any concerns about selection into or out of the jumbo market by new loans after the onset of the crisis. I further restrict the analysis to first-lien, fixed-rate, single-family, owner-occupied mortgages with non-missing measures of current risk score and estimates of current loan-to-value. I drop borrowers linked to multiple mortgages at the same time unless one loan is being paid off and I randomly select a borrower for a loan if multiple borrowers are matched to that loan. I define a refinance as when a loan is paid off, the borrower does not change address in the credit bureau data for six months before or after the payoff date, and the borrower's credit records show valid mortgage balances six months after the payoff date.[13]

The final analysis contains approximately 65 million loan-month observations generated from over 2.1 million unique loans in the initial cohort. I present summary statistics on these loans in Table I. The vast majority of these loans are below the conforming loan limit and only 90,000 are jumbo. Of loans that refinance, I identify about 133,000 of the new refinanced loans, roughly 5,000 of which are jumbos. The sample is heavily skewed to loans below the conforming limit, consistent with the much smaller size of the jumbo market overall.

Among differences in origination characteristics, jumbo loans are much larger, tend to have higher credit scores, lower LTVs, and lower debt-to-income ratios. All consistent with lenders setting tighter underwriting standards for jumbo borrowers. Origination rates on jumbo loans also tend to be somewhat lower, although these interest rates are not conditioned on differences in borrower characteristics.

The unconditional rates on the new loans into which borrowers refinance are broadly similar, with the average borrower reducing their rate by a little more than one percentage point. On average borrowers increase their debt by five percent and about 20 percent of all refinances are cash-out refinances, defined as loans where the change in debt was more than

[13] The long window for the mortgage balance is needed to allow time for the mortgage that is paid off to roll off of the credit records.

five percent (Bhutta and Keys, 2016). On average, cash-out refinances increase mortgage debt by about 19 percent, while rate refinances increase debt by about one percent. Interestingly, the average jumbo rate refinance actually reduces debt, consistent with some jumbo refinancers deleveraging to access the conforming market.

Finally, the average borrower-loan has a relatively low current LTV at 61 percent, consistent with the rapid growth in house prices. Jumbo loans tend to be slightly younger, possibly reflecting the typically higher refinancing rate of jumbo borrowers. However, over this sample period jumbo loans have a lower likelihood of refinancing each month, consistent with tighter credit supply conditions in the jumbo market.

3 Empirical Results

In this section, I document that credit supply in the jumbo market tightened up in March 2020, estimate how it affected access to refinancing, the cost of refinancing, and borrowing. I begin with the probability of refinancing in part because this is useful for establishing that there was a relative tightening in credit supply. I then move to the cost of borrowing and the intensive margin of how much to borrow in order to quantify the relative importance of price and non-price mechanisms.

To estimate a valid counterfactual for jumbo refinancing rates, I adopt a difference-in-differences strategy leveraging the fact that credit supply conditions varied discretely with whether or not a borrower had a loan above or below the CLL. If borrowers with loans above the CLL have similar demand for refinancing to borrowers below the CLL, then the refinancing behavior of borrowers below the limit will provide a plausible counterfactual of refinancing with more relaxed credit supply. I provide evidence supporting this assumption below.

The treatment in this context is whether or not the borrower's loan is above or below the limit, so that treatment occurs simultaneously for all treated borrowers. This helps to avoid complications with interpreting the treatment effect in the context of dynamic different-in-differences (Goodman-Bacon, 2018). However, there is another nuance in this environment in that borrowers both above and below the limit are affected by differences in credit supply across the limit. For example, a borrower with a conforming loan may want to do a cash-out refinance, in which the equity they extract could push them above the CLL. Therefore, changes in jumbo credit supply may also have an effect on conforming borrowers. Similarly, borrowers with loans right above the limit are potentially much less affected by credit conditions for loans above the limit since a small reduction in their balance would let them access the conforming market. Together these effects would lead me to underestimate effects of tight credit supply. I address this concern by dropping loans within a narrow range of the CLLs to run a "donut" analysis. This will avoid using jumbo borrowers for whom the CLL is least binding (for example, a borrower with a loan one dollar above the limit) and conforming borrowers that are most affected by the CLL.

3.A Results

Graphical Evidence

As motivation for the empirical strategy, I begin by presenting simple graphical evidence indicating that the refinancing trends across the conforming and jumbo loan markets move in parallel until a sharp change at the onset of the pandemic. In Figure I Panel A, I plot monthly refinancing probabilities for borrowers above and below the CLL. Refinancing rates were essentially identical with only slight deviations in the levels up until March 2020. Then both sets of borrowers see substantial increases in refinancing as rates fall, but borrowers with loans below the CLL are about one percentage point more likely to refinance than borrowers below the limit. After this spread in refinancing rates opens up, the monthly variation in refinancing is actually very strongly correlated across both sets of borrowers with nearly identical peaks and troughs. That these two fairly volatile series are so strongly correlated suggests that the underlying factors driving refinancing demand, such as interest rate savings and sufficient levels of equity, are moving in parallel across both markets. The gap in refinancing rates starts to narrow around May and April 2021 and disappears completely by October 2021.

In the second panel of Figure I, I sort loan-month observations into 40 bins according to the difference between the loan balance and the CLL and then plot average refinancing rates for different periods.[14] First, refinancing rates for borrowers above and below the conforming loan limit were essentially identical before the pandemic with no clear correlation between distance to the limit and refinancing probability. From March 2020 to April 2021, refinancing rates increased across the board, but a stark difference emerges between borrowers above and below the CLL. Borrowers immediately above the CLL refinanced at lower rates than borrowers just below the CLL, and refinancing rates continued to decline as distance to the CLL increased. The fact that jumbo refinancing seems to decline with distance to the CLL is consistent with jumbo credit supply being constrained, but these constraints become less binding as borrowers are closer to the CLL and it becomes less costly to refinance with a conforming loan. From May 2021 to December 2021 the gap between conforming and jumbo refinancing rates closes, although this is accomplished primarily by a decline in conforming refinancing rates.

These results are all suggestive that refinancing demand moved in parallel for jumbo and conforming borrowers and that supply-side constraints may have reduced refinancing among jumbo borrowers. As further evidence, Figure II plots how the rate gap or difference between the borrower's rate and the average rate on new originations varies with distance to the CLL. The rate gap is a simple but empirically useful measure of refinancing demand (Berger, Milbradt, Tourre and Vavra, 2018). The figure shows that rate gaps were more or less identical on either side of the CLL before March 2020 and throughout the refinancing boom, suggesting that different gains from refinancing are unlikely to explain the differences in refinancing rates. However, after the boom has concluded rate gaps are significantly higher

[14] I drop loans that are within $1,000 to focus on the differences for loans clearly above or below the limit, but in the analysis below I include these loans.

for borrowers above the CLL, reflecting the fact that they were less likely to refinance while rates were very low.

Figure II Panel B plots the number of mortgage inquiries recorded by the credit bureau as a function of distance to the CLL. Mortgage inquiries are not a perfect measure of refinance demand as a borrower that is likely to be ineligible for a loan may be dissuaded from submitting an application that would initiate an inquiry, but they should still be informative about refinancing activity in general. The figure shows that mortgage inquiries are completely uncorrelated with distance from the CLL in the pre-pandemic period, consistent with borrowers above and below the limits sharing similar demand and supply conditions. As refinancing goes up inquiries are systematically lower for borrowers above the limits, again consistent with these borrowers being unable to find credit. After May 2021 the inquiry levels are broadly similar again, although borrowers above the limits seem to have relatively higher inquiry rates, potentially suggesting some pent up demand (although this is not evident in actual refinancing rates).

Together, with the tight relationship between refinancing rates across time, these results suggest that demand for refinancing is uncorrelated with being above or below the conforming limit or with distance from the limit.

Probability of Refinancing

I first estimate a model that allows the effect of being above the CLL to vary with each month:

$$Refinance_{it} = \alpha + \delta_t + X'_{it}\gamma + \sum_t \beta_{1t} \cdot AboveLimit_{it} + \epsilon_{it}, \tag{1}$$

The coefficients of interest are the β_{1t}'s, which give the differential refinancing behavior of jumbo borrowers. This specification serves as an additional check on pre-trends and allows me to trace out the dynamics of tight credit supply across time. The control vector X_{it} includes the interaction of bins of contemporaneous credit score and LTV, deciles of the rate gap or difference between the borrower's current rate and the average newly originated rate (Berger et al., 2018), deciles of the remaining maturity of the loan, and fixed effects for whether the original loan was a purchase or refinance. All of these are then interacted with a "Post" fixed effect to allow their effects to vary after the onset of the pandemic. I also include zip-level fixed effects.

The estimated β_{1t}'s are plotted in Figure III Panel A along with 95% confidence intervals from standard errors double-clustered on bins of distance from the CLL and month. The estimates show that differences in refinancing between conforming and jumbo borrowers were effectively non-existent or small in the months leading up to the pandemic. But beginning in March 2020, borrowers with jumbo loans become significantly less likely to refinance their loan. A 50 basis point relative decline in March grows to over 100 basis points by April 2020. This wedge between jumbo and conforming refinancing rates then shrinks quickly in April 2021, at which point it gradually declines until there is again zero difference between jumbo and conforming refinancing rates by October 2021.

There are several interesting features to these dynamics. First, the decline is almost immediate and then is relatively constant for almost a year. This is despite large changes in refinancing volume, house prices, and employment dynamics over this period. Second, the gap in refinancing does not begin to decline until aggregate refinancing volume declines (see Figure I), suggesting it may have evolved from a way to manage credit risk to a way of managing capacity constraints.

This specification recovers the average effect of being above the CLL relative to the average borrower below the CLL. However, it may be the case that I am inadvertently picking up some latent difference in refinancing demand that is correlated with the size of the loan. To check for this I allow the relationship between the limit difference and refinancing to vary non-parametrically and interacting a "Post" indicator with a full set of indicators for the difference between the loan size and the conforming loan limit

$$Refinance_{it} = \alpha + X_{it}'\gamma + \sum_j (\beta_{1j} 1_j (L_{it} - \bar{L}_{it})) + \sum_j (\beta_{2j} 1_j (L_{it} - \bar{L}_{it}) \cdot Post_{it}) + \epsilon_{it}, \quad (2)$$

where $1_j(L_{it} - \bar{L}_{it})$ is an indicator for whether or not the difference between the loan and the conforming loan limit falls in the interval j and with the full set of controls.

Figure III plots these estimates with 95% confidence intervals. I restrict the post coefficients to cover the period from March 2020 to April 2021, before the effect on refinancing begins to decline. The bin covering the limit is held out as the reference category, so all estimates are relative to being at the conforming loan limit. The first conclusion from this figure is that both before and after the onset of the pandemic, refinancing rates to the left of the conforming loan limit are essentially identical to the rates at the limit itself. This shows that there is unlikely to be any correlation between the demand for refinancing and distance from the limit. Second, the estimates for bins above the CLL before the pandemic are essentially identical to those below the limit. This is again consistent with there being no important latent factor correlated with the relative loan size. Finally, after the onset of the pandemic, relative refinancing rates begin to decline sharply once the loan size passes the conforming loan limit. For borrowers in the bin closest to the CLL the decline is only about 50 basis points, but as borrowers move further from the CLL the decline becomes larger, eventually peaking at lower refinancing rates of 150 basis points. The shape of this effect is consistent with the change in refinancing being caused by a relative contraction in credit supply of jumbo loans, which meant borrowers very near to the limit are less constrained than borrowers further above the limit who must pay down a much larger amount on their loan to qualify for a conforming refinance.

Debt

The results above show that tight credit supply in the jumbo market had an economically significant effect on the likelihood a jumbo borrower could refinance. In addition to this extensive margin, tight credit supply can also affect the intensive margin, or the actual change in amount borrowed for refinancing borrowers. When refinancing a borrower may decide to keep their leverage unchanged and only change the rate, or they may change the rate and borrow more or less. I now turn to quantifying the effect of tight credit supply in the jumbo market on the borrowing decision of borrowers that actually refinanced.[15]

For this analysis I use the subsection of borrowers for whom I can observe the new loan after the refinancing event. This is a much smaller sample since not all refinancers will have their new loan end up at a servicer in the pool of servicers that supply data. However, this sample has the significant advantage of allowing me to combine the change in leverage with the rate actually paid on the new debt.

I estimate a similar model to the time-varying model, equation (3), except now the outcome is the change in debt among borrowers refinancing loans.[16] Specifically, I compare the change in debt across loans for borrowers refinancing jumbo loans to borrowers refinancing conforming loans:

$$\%\Delta D_{it} = \alpha + \delta_t + X_{it}'\gamma + \sum_t \beta_{1t} \cdot AboveLimit_{it} + \epsilon_{it}. \tag{3}$$

The identification assumption here is essentially identical to those in the models of the probability of refinancing. Here I must assume that the demand for debt *conditional on successfully refinancing* follows parallel trends for jumbo and conforming borrowers. This assumption would be violated if, conditional on refinancing, jumbo borrowers happened to

[15]Borrowers unable to refinance may also be change how much they borrow by paying more or less each month, but this appears to be unimportant in practice.

[16]The change in mortgage debt is calculated using the sum of first and junior lien mortgage debts before and after the refinancing event.

have different demand for debt than borrowers in the conforming market. Importantly, it is not a violation of the identification assumption if tight credit supply results in potential refinancers that would have taken out more debt being denied loans. Instead, this would be evidence of differential supply conditions selecting out specific kinds of borrowers the exact mechanism of interest.

The fact that monthly movements in refinancing rates are so similar for both jumbo and conforming borrowers (Figure I) is evidence that jumbo refinancing is being driven by demand shocks that parallel those in the conforming market. Since jumbo refinancing rates behave so much like conforming market rates, it is reasonable to assume that actual demand for debt conditional on refinancing is also moving similarly (conditional on differences in interest rates faced by borrowers, which is a supply-shift I address later). To further guard against this concern, I include a full set of controls for the characteristics of the new loan and borrower: interactions of fixed effects for the risk score and LTV on the new loan also interacted with a jumbo indicator, and the interaction of the distance from the CLL interacted with whether or not the borrower's original loan was above the CLL. This last control is meant to capture any differential demand for leverage correlated with distance to the conforming loan limit, such as jumbo borrowers close to the limit being more likely to pay down their loan in order to qualify for a conforming loan. Finally, I include monthly and county fixed effects, dropping zipcode fixed effects due to the significantly smaller sample size.

Figure IV Panel A plots the estimated effects along with 95% confidence intervals from standard errors clustered by bins of distance to the CLL. Leading up to the pandemic, changes in debt for conforming and jumbo borrowers are statistically indistinguishable with point estimates mostly clustered around zero. Almost immediately in February 2020, jumbo borrowers that refinance borrow significantly less than conforming borrowers that refinance. From February 2020 to July 2021 jumbo refinancers take out five to six percent less debt when they refinance, an economically significant decline considering that the average change in debt in a refinance is about five percent.[17] This decline is also essentially constant through the sample window, in contrast to the extensive margin effect which both changed more and disappeared by late 2021. These estimates show that tight credit supply not only reduced total refinancing by jumbo borrowers, but that it also significantly reduced borrowing by jumbo borrowers who did successfully refinance.

Rate Premium

One potential explanation for why jumbo borrower refinancing and borrowing might have declined so significantly is because the increased risk to lenders and reduced capacity resulted in jumbo loans being priced at very high rates. In this section I provide estimates of the interest rate premium faced by jumbo borrowers due to tighter supply constraints. Fuster et al. (2021) use offer rates by lenders to estimate a peak jumbo premium of about 50 basis points, which would be about half of the average change in rates for borrowers that did refinance (see Table I). One concern about this estimate is that these posted rates do not necessarily need to translate into originated loan rates if there is sufficient dispersion and borrowers search or negotiate for cheaper rates (Bhutta, Fuster and Hizmo, 2020). Moreover, their estimated premium had largely disappeared by January 2021, so it cannot explain the tightness in the market observed beyond that point.

A simple way to estimate the jumbo premium paid by borrowers is simply to compare rates on newly originated jumbo loans to rates on newly originated conforming loans, holding constant important dimensions that are priced such as risk score and LTV. To implement this I pull all of the refinance loans originated within $150,000 of the CLL and estimate a simple difference-in-differences model for the time-varying premium of refinancing in the jumbo market:

$$r_{it} = \alpha + \delta_t + X_{it}'\gamma + \sum_t \beta_{0t} \cdot AboveLimit_{it} + \sum_t \beta_{1t} \cdot AboveLimit_{it} + \epsilon_{it}. \tag{4}$$

[17] The shorter window of observation for this subsample is due to the rolling nature of the merging process and the unavailability of enough loans merged to the more recent months.

In addition to the full set of interactions between risk score and LTV, I also interact a jumbo indicator and an indicator if a loan is a cash-out refinance and jumbo interacted with property-type fixed effects, in addition to county-level fixed effects.

These estimates are plotted as the red line, along with 95% confidence intervals, in Figure IV Panel B. Consistent with Fuster et al. (2021), there was a slight discount on jumbo loans in some of the months leading up to the pandemic, although this was generally zero in the months immediately preceding the pandemic. After the onset of the pandemic, jumbo borrowers started to pay a modest premium, initially just about 10 basis points. This climbed to 20 basis points by late 2020 but then declined again to about 10 basis points in mid- to late- 2021. These estimates are smaller and have different dynamics than those in Fuster et al. (2021), which spike immediately and then gradually decay. This might be due to differences in the sample of lenders as well as borrower search leading to lower contracted rates than the posted rates.

This premium may overstate the actual premium paid by borrowers refinancing jumbo loans because a significant fraction of jumbo borrowers will refinance into conforming loan to avoid any jumbo market premium. Therefore, I use the sample of borrowers that have been matched across loans after refinancing to estimate the actual premium they faced on their new loan. This also allows me to match the premium borrowers paid to their change in debt, which I exploit later to directly estimate the semi-elasticity of debt.

I estimate the same model (4), with identical controls to maintain comparability. The estimates are reported in the blue line of the second panel of Figure IV. The smaller sample size leads to much wider confidence intervals, but the overall trend is quite similar to the origination sample. The point estimates suggest the actual rates paid by borrowers refinancing jumbo loans tend to be lower than the rates on jumbo loans themselves, consistent with some fraction of jumbo borrowers refinancing into the conforming market. The premium faced by these borrowers ranges from zero in the early part of the pandemic, suggesting borrowers simply did not refinance much or searched effectively at the moments when the posted premia found by Fuster et al. (2021) were at their peak, to about 20 basis points in mid-2020. The premium again effectively disappears by mid-2021.

These results suggest that tight credit supply did result in a higher cost of borrowing for jumbo borrowers, but this cost was ultimately quite modest. This small price effect likely reflects some selection: the borrowers facing the highest cost of borrowing may have elected to not refinance at all given the upfront costs and time required. In order to properly quantify the size of this price effect and the impact it had on quantities it is necessary to combine the prices paid with the actual changes in leverage.

Semi-elasticity of Debt

In this section I take advantage of observing both prices and quantities of debt in the sample of refinancers that are matched across loans to directly estimate the semi-elasticity of mortgage debt to interest rates. I estimate an instrumental variable system of equations of the effect of interest rates on the change in debt, where I instrument for the new interest rate with exposure to the jumbo market after the onset of the pandemic. Specifically, the model is:

$$\text{First Stage:} \quad r_{it} = \kappa + \theta_t + X_{it}'\rho + \sigma_0 \cdot AboveLimit_i + \sigma_1 \cdot AboveLimit_i \times Post_t + \zeta_{it} \tag{5}$$

$$\text{Second Stage:} \quad \%\Delta D_{it} = \alpha + \delta_t + X_{it}'\gamma + \beta_0 \cdot AboveLimit_i + \beta_1 \cdot \widehat{r}_{it} + \epsilon_{it} \tag{6}$$

In addition to the relevance assumption, which has already been satisfied given the observed effects on interest rates, the same identification assumptions apply to this model as applied to the difference-in-differences models above. However, there is an additional exclusion restriction needed in order for the estimate of β_1 to recover the interest rate semi-elasticity of debt: there cannot be any non-price changes in jumbo credit supply that also affect changes in debt. For example, if lenders applied more stringent underwriting standards to jumbo borrowers, then β_1 will be over-estimated. If lenders do not adjust non-price mechanisms and only rely on prices, then this restriction will hold. I discuss this further below.

Columns (1)-(3) of Table II report the first stage, reduced form, and IV estimates of model (6). I include the same host of controls as in the price regressions above and cluster the standard errors similarly. Column (1) estimates the first stage and shows that, on average, borrowers refinancing jumbo loans paid a premium of 14 basis points. Column (2) estimates the reduced form and shows that jumbo refinancers borrowed 4 percent less than those refinancing conforming loans after the onset of the pandemic. Column (3) estimates the IV model and recovers a semi-elasticity of -0.29, or for every 100 basis point increase in the interest rate borrowers will reduce their debt by 29 percent. The most closely related estimates of the semi-elasticity are from DeFusco and Paciorek (2017) who also use the difference between the jumbo and conforming markets. They estimate a range from -0.015 to -0.05, with preferred estimates ranging from -0.02 to -0.03. Therefore, the estimate of -0.29 is an order of magnitude larger than prior estimates.

The most likely reason for this implausibly large estimate is a violation of the exclusion restriction that there are no other non-price changes in the supply of jumbo credit that also affect leverage. Lenders may have changed underwriting standards, documentation requirements, and even the product space itself for jumbo borrowers at the same time that they charged jumbo borrowers an interest rate premium. These kinds of changes would bias the estimate of the semi-elasticity upwards.

In fact, column (4) gives clear evidence of a non-price shift in credit supply that could directly affect how much refinancers could borrow. In column (4) I estimate the same difference-in-differences model as in columns (1) and (2), but now the outcome is an indicator for whether or not a borrower took out a cash-out refinance when they refinanced. I estimate that jumbo refinancers saw a relative decline of almost 13 percentage points in the probability of taking out a cash-out loan. This is economically very large considering it is almost 50 percent of pre-pandemic levels.

Given this large shift in the probability of extracting equity, it may make sense to re-estimate the semi-elasticity holding fixed this margin of adjustment. Specifically, I re-estimate these same IV regressions separately within the sets of borrowers taking out rate refinances and cash-out refinances. In this way, I hold the reduction in access to cash-out refinances fixed. The resulting estimate may still overestimate the effect of prices if other non-price mechanisms are adjusting within the space of rate or cash-out refinances, but it will at least shut down the shift out of cash-out refinances.

Columns (5)-(7) of Table II report these estimates for rate refinances and columns (8)-(10) report the estimates for cash-out refinances. The premium for rate refinances is still modest, about 12 basis points, but now the decline in debt has fallen considerably to minus one percent. The new estimate of the semi-elasticity is much lower at about -0.07, well within the range of plausible estimates. Similarly, cash-out refinances faced a higher premium of about 24 basis points and saw a larger decline in leverage of about 1.4 percent, although not statistically distinguishable from zero. Together, these give a semi-elasticity estimate of -0.068, not precisely estimated but well within the range of plausible estimates.

An important robustness concern is that both borrowers above and below the CLL will have their leverage decisions affected by tightness in the jumbo market. For example, conforming refinancers will be less willing to take out a cash-out refinance if it means entering the jumbo market and paying a higher premium. This kind of mechanism would likely lead me to understate the true effects since the control group is also being treated, albeit to a lesser extent. To address this concern I run a "donut" specification where I drop all borrowers who refinanced loans within $50,000 of the CLL on either side. While this still may allow some pollution of the control group, it should reduce its importance.

Table III reports these estimates and does show that some contamination of the control group may have been attenuating my estimates. While the estimated semi-elasticities within the refinance categories are broadly similar, the effect on access to cash-out refinances in column (4) is much larger, now giving an effect of about 19 percentage points.

Together these estimates show that, holding fixed one potentially major shift in non-price features of the jumbo credit market, I recover independent estimates of the interest rate semi-elasticity of debt that are similar to those in the literature. This is despite the very substantial differences in identification, estimators, and sources of variation. However, these results also show that there was a large move in a non-price mechanism, the supply of cash-out refinances and that this may have had important effects on leverage. A central question, then, is how much of the decline in leverage can be attributed to the price effect and the subsequent decline in demand for debt relative to the dramtic decline in cash-out refinances.

Decomposition of the Quantity Effect

In this section I provide a linear decomposition of the decline in borrowing caused by tight credit supply in the jumbo market. This simple framework allows me to quantify the relative contribution of the price and non-price effects on the decline in borrowing by jumbo borrowers using simple moments from the data and the causal estimates provided above.

Let the average percentage change in borrowing by refinancers in the jumbo market in period 0 (the pre-period) be given by the following decomposition, where a tilde indicates a percentage change:

$$\tilde{d}_{0J} = \tilde{d}^{rate}(r_{0J}^{rate}, \epsilon_0^{rate}) \cdot \pi^{rate}(\Psi_{0J}, \epsilon_0^{\pi}) + \tilde{d}^{cash}(r_{0J}^{cash}, \epsilon_0^{cash}) \cdot (1 - \pi^{rate}(\Psi_{0J}, \epsilon_0^{\pi})). \tag{7}$$

The change in debt depends on rates at which new debt is issued (r) and on any demand shifters ϵ with rate refinances and cash-out refinances eaching being priced separately and having specific demand shifters. Similarly, π^{rate} is the fraction of borrowers taking out rate refinances and depends on non-price supply-side factors Ψ_{0J} and any demand shifts across products. This specification does impose several important constraints, which I discuss further below after deriving the approximation.

I then take a linear approximation of the change in average jumbo borrowing between period 0 and period 1 where Δ indicates the difference between periods 0 and 1:

$$\begin{aligned}\tilde{d}_{1J} \approx \tilde{d}_{0J} &+ \frac{\partial \tilde{d}_{0J}}{\partial r_J^{rate}} \Delta r_J^{rate} + \frac{\partial \tilde{d}_{0J}}{\partial r_J^{cash}} \Delta r_J^{cash} + \frac{\partial \tilde{d}_{0J}}{\partial \Psi_J} \Delta \Psi_J \\ &+ \frac{\partial \tilde{d}_{0J}}{\partial \epsilon^{rate}} \Delta \epsilon^{rate} + \frac{\partial \tilde{d}_{0J}}{\partial \epsilon^{cash}} \Delta \epsilon^{cash} + \frac{\partial \tilde{d}_{0J}}{\partial \epsilon^{\pi}} \Delta \epsilon^{\pi}\end{aligned}$$

This expression can be simplified by noting that the derivative of the percentage change in debt is just the derivative of the demand for new debt, which is expressed in logs as d_{0J}^*. This is because the old loan is fixed and so does not vary with the new rate:[18]

$$\begin{aligned}\frac{\partial \tilde{d}_{0J}}{\partial r_J^{rate}} &\approx \frac{\partial (d_{0J}^{rate*} - d_{0J})}{\partial r_J^{rate}} \pi_J^{rate} \\ &\approx \frac{\partial d_{0J}^{rate*}}{\partial r_J^{rate}} \pi_J^{rate}.\end{aligned}$$

Accordingly, the decomposition simplifies to the following after plugging in the definition of the average change

$$\begin{aligned}\tilde{d}_{1J} - \tilde{d}_{0J} \approx &\frac{\partial d_{0J}^{rate*}}{\partial r_J^{rate}} \pi_J^{rate} \Delta r_J^{rate} + \frac{\partial d_{0J}^{cash*}}{\partial r_J^{cash}} * (1 - \pi_J^{rate}) \Delta r_J^{cash} + \frac{\partial \pi_{0J}}{\partial \Psi_{0J}} (\tilde{d}_J^{rate} - \tilde{d}_J^{cash}) \Delta \Psi_J + \\ &\frac{\partial \tilde{d}_{0J}}{\partial \epsilon^{rate}} \Delta \epsilon^{rate} + \frac{\partial \tilde{d}_{0J}}{\partial \epsilon^{cash}} \Delta \epsilon^{cash} + \frac{\partial \tilde{d}_{0J}}{\partial \epsilon^{\pi}} \Delta \epsilon^{\pi}.\end{aligned}$$

This expression gives the change in jumbo refinancer borrowing between the periods as a linear function of supply-side shifts in price and non-price mechanisms in the first line plus a host of demand-side shifters in the second line. An analogous expression can be derived for conforming borrowers, which allows me to give an expression for the difference-in-differences estimator. For simplicity of exposition, I normalize supply-side shifts in the conforming market to be zero. This is innocuous since in practice I estimate the relative

[18] The approximation here is due to the differences between the log difference and the percentage change. I use the log differences here for simplicity of exposition.

shift. The identification assumption of the DiD estimator is that demand shifters will cancel out between the jumbo and conforming markets, so we are left with the following:

$$
\begin{aligned}
DiD \equiv \tilde{d}_{1J} - \tilde{d}_{0J} - (\tilde{d}_{1C} - \tilde{d}_{0C}) \approx & \frac{\partial d_{0J}^{rate*}}{\partial r_J^{rate}} \pi_J^{rate} \Delta r_J^{rate} + \frac{\partial d_{0J}^{cash*}}{\partial r_J^{cash}} (1 - \pi_J^{rate}) \Delta r_J^{cash} + \\
& \frac{\partial \pi_{0J}}{\partial \Psi_{0J}} (\tilde{d}_J^{rate} - \tilde{d}_J^{cash}) \Delta \Psi_J + \\
& \frac{\partial \tilde{d}_{0J}}{\partial \epsilon^{rate}} \Delta \epsilon^{rate} + \frac{\partial \tilde{d}_{0J}}{\partial \epsilon^{cash}} \Delta \epsilon^{cash} + \frac{\partial \tilde{d}_{0J}}{\partial \epsilon^{\pi}} \Delta \epsilon^{\pi} - \\
& (\frac{\partial \tilde{d}_{0C}}{\partial \epsilon^{rate}} \Delta \epsilon^{rate} + \frac{\partial \tilde{d}_{0C}}{\partial \epsilon^{cash}} \Delta \epsilon^{cash} + \frac{\partial \tilde{d}_{0C}}{\partial \epsilon^{\pi}} \Delta \epsilon^{\pi}) \\
& \Rightarrow \\
\tilde{d}_{1J} - \tilde{d}_{0J} - (\tilde{d}_{1C} - \tilde{d}_{0C}) \approx & \frac{\partial d_{0J}^{rate*}}{\partial r_J^{rate}} \pi_J^{rate} \Delta r_J^{rate} + \frac{\partial d_{0J}^{cash*}}{\partial r_J^{cash}} (1 - \pi_J^{rate}) \Delta r_J^{cash} + \\
& (\tilde{d}_J^{rate} - \tilde{d}_J^{cash}) \frac{\partial \pi_{0J}}{\partial \Psi_{0J}} \Delta \Psi_J. \\
= & \frac{\partial d_{0J}^{rate*}}{\partial r_J^{rate}} \pi_J^{rate} \Delta r_J^{rate} + \frac{\partial d_{0J}^{cash*}}{\partial r_J^{cash}} (1 - \pi_J^{rate}) \Delta r_J^{cash} + \\
& (\tilde{d}_J^{rate} - \tilde{d}_J^{cash}) \Delta \pi_J^{rate}.
\end{aligned}
$$

The second to last line substitutes $\Delta \pi_J^{rate} = \frac{\partial \pi_{0J}}{\partial \Psi_{0J}} \Delta \Psi_J$ since the underlying shift in non-price mechanisms is only observable through (and equivalent to) the change in probabilities.

This last line allows me to decompose the recovered difference-in-differences estimate into the price and non-price effects using the estimated semi-elasticities, estimated price premia, and shift in cash out probabilities from Table II or Table III. I also need the average pre-pandemic changes in debt for jumbo rate and cash-out refinances and the fraction of rate refinances pre-pandemic.

This framework has several important assumptions embedded in it. First, I assume prices have no effect on the likelihood of taking out a cash-out loan relative to a rate refinance. In principle, there could be some elasticity of demand that would generate this kind of switching. This effect would end up in the residual of my decomposition, so the fraction of the effect not explained by my characterization of the price and non-price effects will be informative about the potential size of this channel. Second, I assume that there is no role for non-price mechanisms within the debt demand for each type of refinance. This is almost certainly not true in reality, but making this assumption biases the share of the decline that can be explained by the price effect up so long as the unobserved non-price mechanisms affect debt in the same way that the observed price mechanisms affect debt.

Table IV reports two decompositions, each using a set of estimates from Table II and Table III. The donut specification is my preferred specification as it reduces the bias from conforming borrowers that are also constrained by jumbo market credit supply. The first panel gives the parameters used to calculate the decomposition and the second panel gives the results, with the bottom two rows being the most important. In both columns the non-price effect is at least twice as large as the price effect, with both channels explaining about 80 percent of the total effect. In other words, these results show that the non-price mechanism was the primary way that the shift in credit supply affected jumbo borrowers leverage decision.

4 Conclusion

Higher interest rates caused by tight credit supply played a relatively small role in driving the large decline in borrowing by jumbo refinancers. Instead, it was a shift in access to cash-out refinancing that drove the majority of the decline in borrowing. The shift was sharp, likely reflecting initial worries about credit risk, and persistent, potentially the result of lenders managing capacity constraints in the mortgage market. Together, these results suggest non-price mechanisms are a central way that lenders respond to shocks in credit market environments. If, as earlier work thought, the use of non-price mechanisms is a broader feature of credit markets in general, it has important implications for how to accurately characterize credit markets. Additionally, it suggests the important question of why lenders do not rely more on price mechanisms. While there are well-known theoretical explanations like adverse selection, there is no empirical evidence that these frictions explain the results documented here. It may even be the case that the explanation for the results here is closely related to explanations for non-financial price-stickiness such as implicit contracts or uncertainty (Blinder, Canetti, Lebow and Rudd, 1998; Weitzman, 1974).

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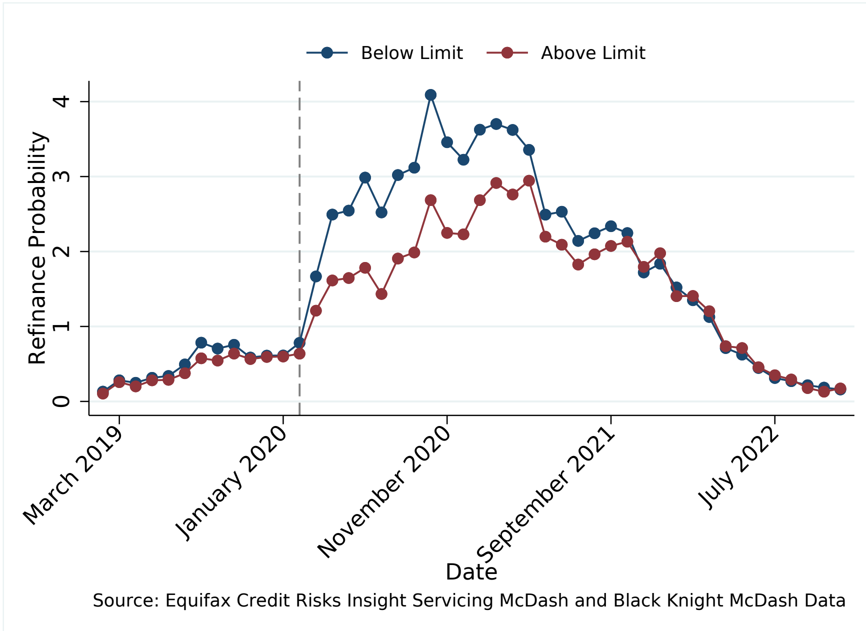
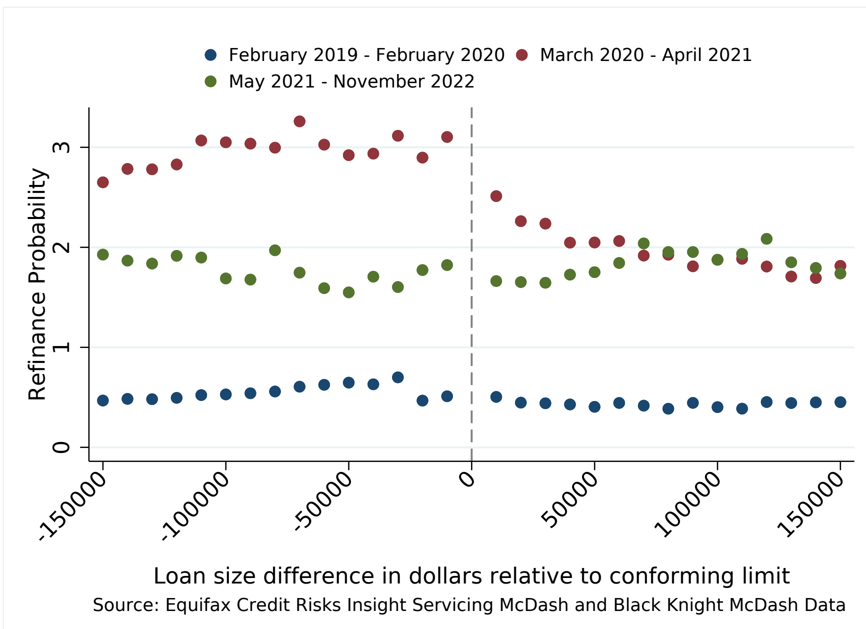
5 Figures



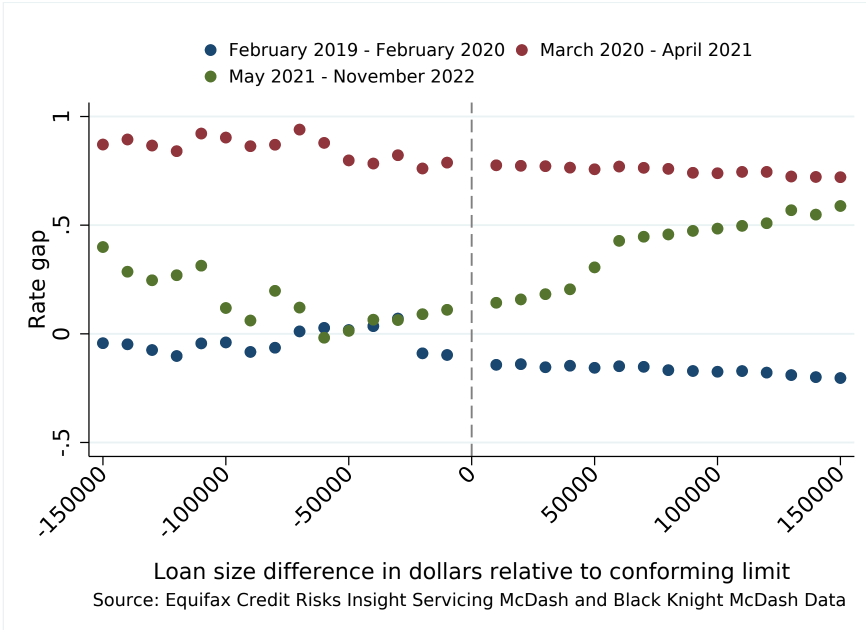
A. Monthly Effects



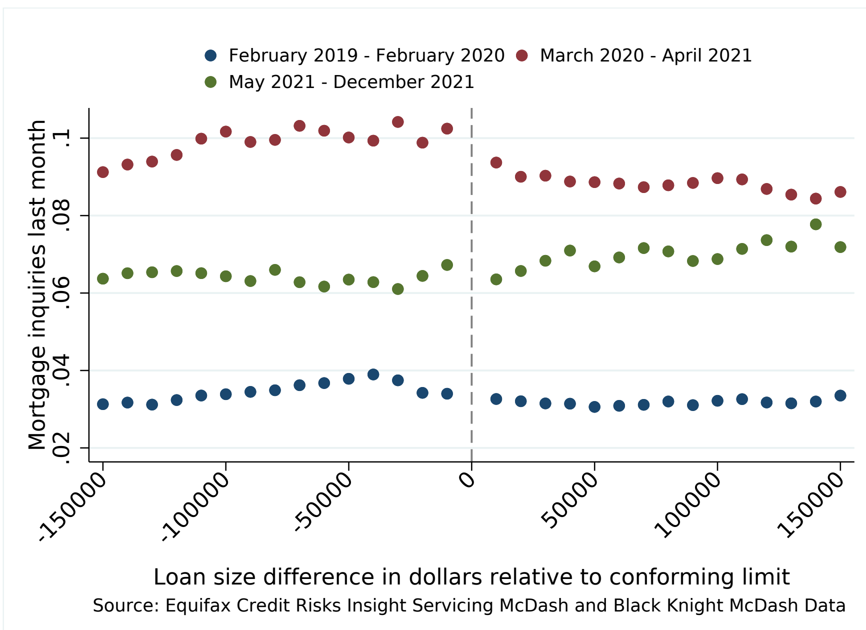
B. Non-Parametric Effects

FIGURE I
Non-parametric and Monthly Averages of the Effect of the Conforming Loan Limit

Note.—The top figure plots the average refinancing rates by month for loans above and below the conforming loan limits. The bottom figure plots the average refinancing rate within bins of the difference between loan size and the conforming loan limit for various periods. Loans within $1,000 of the CLL are dropped.



A. Rate Gaps

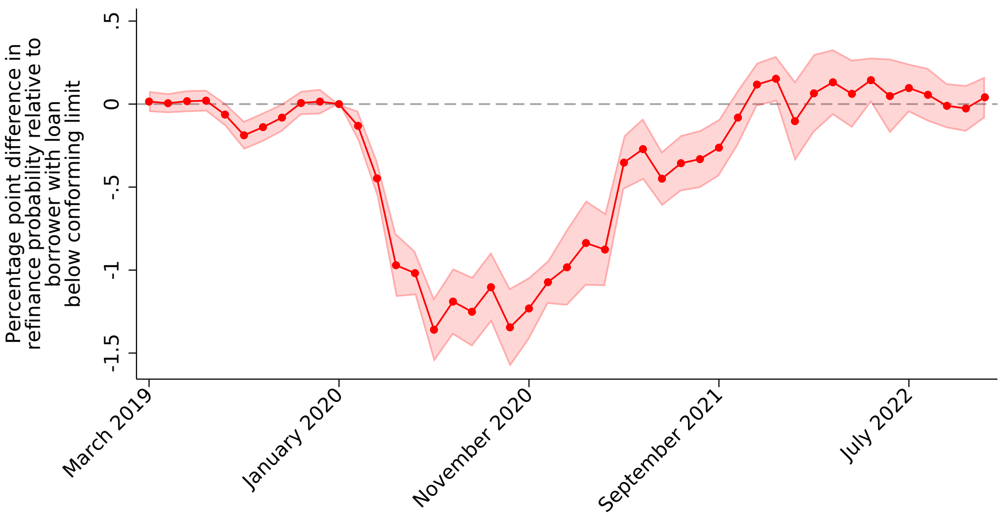


B. Mortgage Inquiries

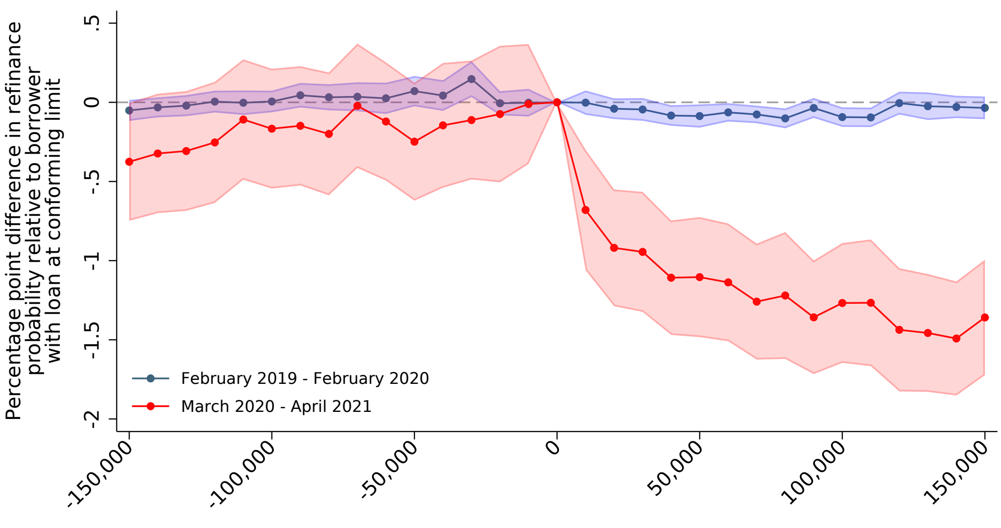
FIGURE II

Non-parametric Averages of the Effect of the Conforming Loan Limit on Refinancing Demand

NOTE.—The top figure plots the average rate gap, defined as the difference between the borrower's current rate and the average rate on new 30-year fixed rate loans, within bins of the difference between loan size and the conforming loan limit for various periods. The bottom figure plots the number of mortgage inquiries within bins of the difference between loan size and the conforming loan limit for various periods. Loans within $1,000 of the CLL are dropped.



A. Monthly Effects

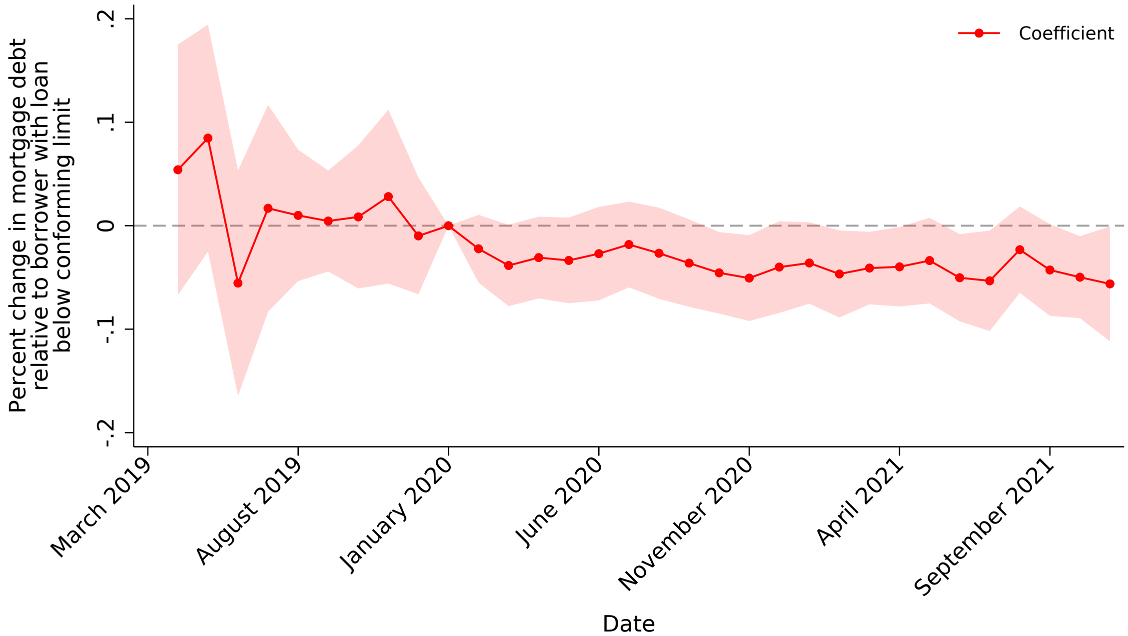


B. Non-Parametric Effects

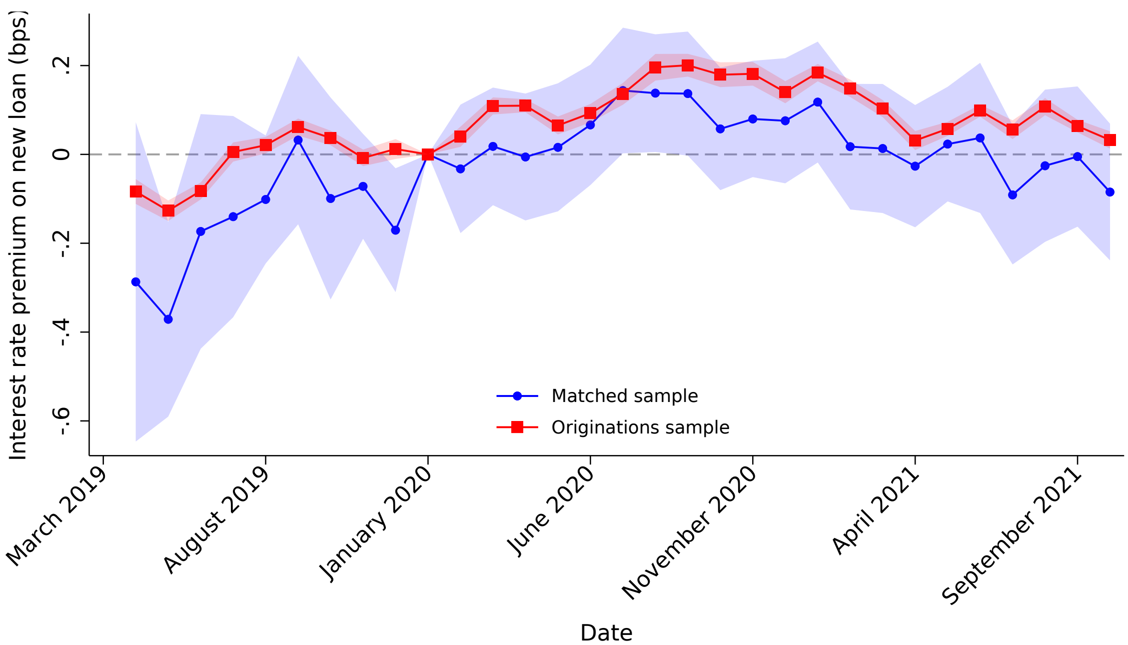
FIGURE III

Monthly and Non-parametric Estimates of the Effect of the Conforming Loan Limit

NOTE.—This figure plots the estimates from two models of the effects of the conforming loan limit on borrower refinancing probabilities.



A. Leverage effects



B. Rate effects

FIGURE IV
Leverage and rate effects

NOTE.—This figure plots the estimates from two models of the effects of the conforming loan limit on borrower refinancing probabilities.

6 Tables

TABLE I
Descriptive Statistics

	All Loans	Conforming	Jumbo
Panel A. Loan-level Characteristics at Origination			
Loan Amount ($1000's)	393.50	374.25	750.76
	(170.88)	(143.80)	(229.99)
FICO Score	738.59	737.23	763.83
	(63.76)	(64.51)	(40.10)
Loan-to-Value	82.31	82.71	74.95
	(30.16)	(28.17)	(54.87)
Back-End Debt-to-Income	34.41	34.58	32.09
	(10.42)	(10.49)	(9.19)
Interest Rate	4.06	4.06	3.92
	(0.61)	(0.61)	(0.56)
Panel B. New Loan Characteristics			
Interest Rate	2.93	2.92	3.03
	(0.46)	(0.46)	(0.45)
Change in Interest Rate	−1.16	−1.17	−0.93
	(0.55)	(0.55)	(0.48)
Change in debt (%)	4.94	5.04	2.57
	(9.00)	(8.98)	(9.25)
Percent Cash Out	0.19	0.19	0.13
	—	—	—
Change in debt: Cash Out (%)	18.26	18.21	20.22
	(13.25)	(13.24)	(13.32)
Change in debt: Rate (%)	1.77	1.86	−0.10
	(2.52)	(2.38)	(4.15)
Panel C. Loan-month Characteristics			
Current Balance ($1000's)	342.84	324.92	673.79
	(146.61)	(122.03)	(167.38)
Current Loan-to-Value	61.40	61.55	58.75
	(31.40)	(30.88)	(39.60)
Loan Age (Years)	4.13	4.16	3.61
	(3.02)	(3.04)	(2.63)
Distance to CLL	−210.98	−227.74	93.41
	(122.43)	(100.75)	(71.54)
Probability Refinanced	0.70	0.71	0.60
	—	—	—
Number of Loans	2,194,758	2,104,446	90,312
Number of New Loans	133,992	128,657	5,350
Number of Loan-months	65,962,706	63,115,637	2,847,069

Note.—This table reports summary statistics for the base cohort of loans at origination, for the set of newly originated loans that are matched to refinancing loans, and for all loan-month observations. Source: Equifax Credit Risks Insight Servicing McDash and Black Knight McDash Data and author's calculations.

TABLE II
Rate and Debt Effects

	All				Rate Refinances			Cash Out Refinances		
	(1) New Rate	(2) %Δ Debt	(3) Semi-elasticity	(4) Probability(Cash Out)	(5) New Rate	(6) %Δ Debt	(7) Semi-elasticity	(8) New Rate	(9) %Δ Debt	(10) Semi-elasticity
New Rate			−0.295***				−0.074***			−0.068
			(0.071)				(0.028)			(0.055)
Above Limit × Post Feb 2020	0.144***	−0.042***		−0.130***	0.122***	−0.009***		0.241***	−0.017	
	(0.021)	(0.008)		(0.032)	(0.028)	(0.002)		(0.039)	(0.014)	
Above Limit	−0.155***	−0.018*		0.030	−0.124***	−0.023***		−0.276***	−0.019	
	(0.024)	(0.009)		(0.029)	(0.032)	(0.005)		(0.042)	(0.023)	
FICO x LTV x Jumbo FEs	X	X	X	X	X	X	X	X	X	X
County FEs	X	X	X	X	X	X	X	X	X	X
Month FEs	X	X	X	X	X	X	X	X	X	X
Clusters	40	40	40	40	40	40	40	40	40	40
KP F-stat			45.0				19.4			38.7
Number of Observations	48,307	48,307	48,307	48,307	41,564	41,564	41,564	6,553	6,553	6,553

Note.—This table reports estimates of the effect of the conforming loan limit on prices, Debt, and cash out refinance probabilities. Source: Equifax Credit Risks Insight Servicing McDash and Black Knight McDash Data and author's calculations.

TABLE III
Rate and Debt Effects: Donut Specification

	All				Rate Refinances			Cash Out Refinances		
	(1) New Rate	(2) %Δ Debt	(3) Semi-elasticity	(4) Probability(Cash Out)	(5) New Rate	(6) %Δ Debt	(7) Semi-elasticity	(8) New Rate	(9) %Δ Debt	(10) Semi-elasticity
New Rate			−0.372***				−0.073**			−0.123**
			(0.078)				(0.033)			(0.055)
Above Limit × Post Feb 2020	0.161***	−0.060***		−0.191***	0.134***	−0.010***		0.279***	−0.034**	
	(0.027)	(0.007)		(0.035)	(0.038)	(0.002)		(0.042)	(0.015)	
Above Limit	−0.210***	−0.034***		0.020	−0.178***	−0.041***		−0.340***	0.043	
	(0.036)	(0.010)		(0.039)	(0.043)	(0.010)		(0.064)	(0.034)	
FICO x LTV x Jumbo FEs	X	X	X	X	X	X	X	X	X	X
County FEs	X	X	X	X	X	X	X	X	X	X
Month FEs	X	X	X	X	X	X	X	X	X	X
Clusters	30	30	30	30	30	30	30	30	30	30
KP F-stat			35.1				12.2			43.8
Number of Observations	42,398	42,398	42,398	42,398	36,158	36,158	36,158	6,048	6,048	6,048

Note.—This table reports estimates of the effect of the conforming loan limit on prices, debt, and cash out refinance probabilities. Source: Equifax Credit Risks Insight Servicing McDash and Black Knight McDash Data and author's calculations.

TABLE IV
Decomposition Table

	All Loans	Donut Sample
Panel A. Parameters for Calculation		
$\frac{\partial d^{rate}}{\partial r}$	−0.074	−0.073
Δr^{rate}	0.122	0.134
π^{rate}	0.762	0.757
$\frac{\partial d^{cash}}{\partial r}$	−0.068	−0.123
Δr^{cash}	0.241	0.279
$\tilde{d}^{rate}$	0.016	0.017
$\tilde{d}^{cash}$	0.189	0.189
$\Delta \pi^{rate}$	0.13	0.191
Panel B. Estimated Effects		
Total Effect	−0.042	−0.06
Price Effect: Rate Refis	−0.007	−0.007
Price Effect: Cash Outs	−0.004	−0.008
Total Price Effect	−0.011	−0.016
Non-price Effect	−0.022	−0.033

Note.—This table reports the parameters and calculated effects from the decomposition of the quantity effect described in Section 3. Source: Equifax Credit Risks Insight Servicing McDash and Black Knight McDash Data and author's calculations.