How do Capital Requirements Affect Loan Rates? Evidence from High Volatility Commercial Real Estate*

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Abstract

We study how bank loan rates responded to a 50% increase in capital requirements for a subcategory of construction lending, High Volatility Commercial Real Estate (HVCRE). To identify this effect, we exploit variation in the terms determining whether a loan is classified as HVCRE and the time that a treated loan would be subject to the increased capital requirements. We estimate that the HVCRE rule increases loan rates by 34 basis points for HVCRE loans, indicating that a one percentage point increase in required capital raises loan rates by 8.5 basis points.

Keywords: Capital requirements, Basel III, Commercial Real Estate
JEL Classification: G21, G28, G38

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1 Introduction

How do capital requirements affect the cost of borrowing from a bank? Requiring banks to further fund themselves with equity, as opposed to other potentially cheaper sources of funding, can result in increased funding costs for banks and higher loan rates for their borrowers.[1] As higher loan rates have been shown to influence firm investment and consumer spending, such a change can have adverse effects on the welfare of bank borrowers and economic activity in general.[2] However, empirically determining the sensitivity of loan rates to capital requirements is difficult, as changes to capital requirements are infrequent, fairly uniform across loans, and often correspond with periods of stress.

This paper uses loan-level data from bank stress tests to investigate how loan rates responded to a new rule that increased capital requirements on high leverage construction loans. This is a particularly useful setting for studying the question at hand for two reasons. First, the rule created variation in capital requirements across loan terms, allowing for within-bank estimation of the effect of changes in capital requirements. Second, the rule went into effect well into the recovery after the financial crisis, making the findings likely more reflective of conditions in normal times. This is important as most of the other literature exploiting within-bank variation in capital requirements study policies implemented during the global financial crisis.

On June 7, 2012, U.S. bank regulators proposed a new set of rules for banks' risk-weighted capital requirements. Motivated by significant losses on construction loans during the crisis, part of the proposal sought to increase capital requirements for particularly risky acquisition, development, and construction (ADC) loans. Non-1-4 family ADC loans without sufficient borrower contributed capital were deemed "High Volatility Commercial Real Estate" (HVCRE) and the risk weight on these loans increased from 100% to 150%. As banks face an 8 percent regulatory minimum ratio of total capital to risk weighted assets,

[1] Were Modigliani and Miller (1958) to hold, funding costs would be invariant to capital structure, as the cost to switching to a more expensive funding source is offset by changes in the costs of debt and equity as leverage changes.

[2] See Gertler and Gilchrist (1994) and Ippolito et al. (2018) for a discussion of how changes in rates affect businesses and Di Maggio et al. (2017) and Wong (2018) for analysis of loan rates for households.

this rule meant that banks would need to fund 12 percent of an HVCRE loan with equity once the rule went into effect in 2015, compared to 8 percent before 2015. The capital requirement for 1-4 family ADC loans, or other ADC loans with a sufficient down payment, stayed at 8 percent. Thus, if a greater portion of the life of a loan occurs after 2015, then banks will have a greater average capital requirement should the loan fall into the HVCRE category.

The design of the HVCRE rule facilitates a difference-in-differences strategy to identifying the effects of capital requirements on loan rates. Our treatment variables are an indicator for whether the loan-to-value ratio (LTV) exceeds the threshold for the loan to be subject to higher capital requirements, and the exposure of the loan to the post-implementation period (the percent of the loan-life occurring after 2015). If capital is costly and banks anticipate the future increases in capital requirements, banks should require higher interest rates for high LTV loans if they will be subject to the higher capital requirements longer.[3] We employ our regulatory loan-level data on banks' CRE portfolios to study the effect of the rule. Our data covers the CRE loan portfolios of about 30 of the largest banks in the United States, and has a host of information on the loans, such as the interest rate, LTV, dates of origination and maturity, borrower risk rating, as well as other loan and property characteristics. This allows us to test for the effect of the HVCRE rule, while controlling for other key loan terms and risk characteristics that could influence loan pricing.

We find that the increase in capital requirements caused banks to raise interest rates on HVCRE loans by 34 basis points, with the effect being predominantly driven by banks closer to a risk-based capital constraint. Given that the rule increased required capital for an HVCRE loan by 4 percentage points (from 8 percent to 12 percent), our estimate implies an 8.5 basis points increase in loan rates per percentage point increase in capital.

How does our baseline estimate compare to others in the literature? Our estimated effect on loan rates is on the lower end of the broad range of estimates of coming from calibrated models (the range is 2-20 basis points for each 1 percentage point increase in

[3]Figure 1 shows how capital requirements vary by HVCRE status and time for four hypothetical loans, thus demonstrating the source of variation used in this study.

required capital; see (Dagher et al., 2016)).[4] Benetton et al. (2017) also exploits within-bank variation in loan risk weights to study how capital requirements affect interest rates on bank loan originations, and finds larger effects.[5] We attribute the difference in estimates to Benetton et al. (2017) studying a policy that was implemented in 2008, when bank funding costs had spiked, while our paper studies a rule that was implemented later in the recovery, when bank funding costs had normalized.[6] Altogether, we see our paper as delivering a useful estimate of the effect of capital requirements on loan rates in "normal times" (Carlson et al., 2013).

Our findings are robust to several alternative specifications and falsification tests. First, we exploit the fact that not all CRE loan categories were subject to the rule, which enables us to use these other loan categories as additional controls groups in a triple difference exercise. We show that the increase in interest rates for high LTV loans which are exposed to the post-implementation period only occurs for non-1-4 family ADC loans. No such effects were found for 1-4 family residential construction loans or for non-ADC CRE loans, both of which continued to have a 100% risk weight following the implementation of the rule, regardless of LTV. This indicates that the effect we find is due to the HVCRE rule instead of reflecting a general pricing relationship for long-maturity, high LTV CRE loans.

Second, we run a placebo test to demonstrate that the pricing of construction loans only interacts with maturity and LTV to the extent that it influences risk weights under the HVCRE rule. Specifically, we repeat our baseline diff-in-diff analysis for a sequence of placebo HVCRE announcement and implementation dates. The estimated effect is maximized around when the placebo dates correspond with the real announcement and

[4]Calibrated bank funding cost models need to make an assumption about the degree of Modigliani-Miller effects to form an estimate of how capital requirements affect funding costs. Papers estimating small effects on loan rates like Kashyap et al. (2010) generally assume bank deleveraging significantly reduces the required return on equity, while estimates at the higher end of the range, such as Slovik and Cournède (2011), tend to assume that costs of debt and equity are fixed, and thus increasing equity substantially raises costs. Kisin and Manela (2016) also estimate the cost of capital requirements from a calibrated model, however they take the unique approach of studying the cost that banks paid to utilize a pre-crisis loophole which effectively reduced the risk-weight on their assets. They found the cost of capital requirements to be minimal.

[5]Fraisse et al. (2015) and Behn et al. (2016) similarly exploit within-bank variation in risk weights, however they focus on volumes rather than pricing.

[6]In a contemporaneous working paper, Plosser and Santos (2018) study how changes in fees are affected by capital requirements. Consistent with our result regarding the effect being modest in "normal times," the authors also find modest effects of changes in fees on undrawn commitments following the increase in risk weights on longer-term unused commitments around the Basel I implementation in the early 1990's.

implementation dates. Additionally, the estimated effect falls to around zero when the placebo dates are far enough before or after the real dates that the placebo exposure to the post-implementation period is orthogonal to the actual exposure. That the effects are timed precisely with the rule indicates that our estimate doesn't reflect a general pricing relationship for long-maturity, high LTV, non-1-4 family ADC loans.

Third, we exploit across-bank variation in proximity to capital requirements to test whether our effects are driven by banks for which a risk-based capital requirement is likely to be binding. If risk-based capital constraints are slack, a bank should be less affected a the change in risk weights (see Greenwood et al. (2017)). Instead, it should be the banks closer to a risk-based constraint that would need additional equity in order to fund an HVCRE loan as a result of the rule. Indeed, we find that the increase in interest rates in response to the HVCRE rule is driven almost entirely by banks that are closer to their Tier 1 risk-based capital constraint. This indicates that our results are driven by a supply-side response to the HVCRE rule, instead of something like an increase in the demand for long maturity, high LTV loans timed with the announcement of the rule.

While this array of tests consistently indicates the the HVCRE rule affected loan pricing, we find little evidence of an effect on quantities. The share of loans with high LTVs did not notably change after the rule was announced, even for more capital constrained banks.[7] That the HVCRE rule seems to have predominantly affected the pricing of high LTV loans, instead of volumes, may be a consequence of us studying a market with little non-bank competition or securitization.[8] The lack of alternative financing options means that developers are more likely to pay higher rates when bank funding costs rise, instead of turning to non-banks as borrowers might in other markets.

Our paper is related to the large literature on how capital requirements affect lending

[7]The natural variation the rule creates is admittedly better suited for studying pricing than quantities. We have less statistical power when studying quantities in that we can only exploit time series variation in when the rule was announced. Furthermore, not all post-announcement loan would be affected by the HVCRE rule as they could mature before 2015.

[8]According to an industry report by RCA, Banks originated about 75% of all construction loans, with no loans reported as being securitized into CMBS. See: `https://www.rcanalytics.com/usct-preview-lenders`. To our knowledge, the other papers using loan-level data study either residential mortgages or commercial and industrial loans, where non-bank lenders are more prevalent and securitization is more common.

policies. This literature has generally focused on quantities more than pricing, showing that better capitalized banks have modestly faster loan growth (Bernanke et al., 1991; Berrospide and Edge, 2010; Carlson et al., 2013) and that tighter capital constraints reduce banks loan volumes (Peek and Rosengren, 1997; Gambacorta and Mistrulli, 2004; Aiyar et al., 2014). More recent papers have used across-bank variation in capital requirements or capitalization and demonstrated that tighter capital requirements induce a migration of lending to either less constrained banks (Basten and Koch, 2015; Gropp et al., 2018; Jiménez et al., 2017) or to non-banks (Irani et al., 2018).[9]

Our paper is also complementary to work assessing the optimal level of capital requirements. Miles et al. (2013), Firestone et al. (2017) and Barth and Miller (2018) estimate the net benefits of higher capital requirements by comparing the costs in terms of higher loan rates and the benefits in terms of less frequent crises. To estimate the costs of capital requirements, the authors rely on calibrated models of banks funding costs to determine how changes in capitalization would affect loan rates. By producing a credible empirical estimate of this effect during normal times, we create an alternative to relying on calibrations which are sensitive to assumptions about Modigliani and Miller (1958) effects and the applicability of the CAPM (Baker and Wurgler, 2015).

The rest of the paper proceeds as follows. Section 2 describes our data, provides further background on the HVCRE rule, and discusses our methodologies for our empirical exercises. Section 3 discusses the results. Section 4 concludes. In the Online Appendix, we present results from some additional robustness exercises.

2 Data and Empirical Strategy

This section reviews the data used in the paper. It then provides further details on the HVCRE regulation and how we construct the treatment and exposure variables. Finally, we review the empirical strategies used to test for the effect of the HVCRE rule on bank lending policies.

[9] Additionally, Auer and Ongena (2019) study how capital requirements in one loan category can affect lending in another loan category and Wallen (2017) studies the relationship between bank capitalization and interest rates on U.S. syndicated loans.

2.1 Data

The primary data used in this paper comes from Schedule H.2 of the FR Y-14Q, which contains loan-level data on the commercial real estate (CRE) portfolios of large banks. This data is collected by the Federal Reserve in order to project stressed losses as part of the Comprehensive Capital Analysis and Review (CCAR) for banks with at least $50 billion in total consolidated assets.[10] Banks report this microdata for all loans with a committed exposure above $1 million.

The data includes key loan characteristics such as interest rate, size, purpose (e.g., land acquisition/development, construction, or renovation), whether the rate is fixed or floating, the dates of origination and maturity, as well as the borrower risk rating. Data on the property securing the loan includes the property's zipcode, structure type (e.g, 1-4 family, multifamily, office, retail, or other), appraised value and the basis for the appraised value (e.g, "as is" vs. "as stabilized"). Details on data cleaning and variable construction are in the Appendix.

2.2 Identifying HVCRE Loans

The initial proposed HVCRE rule was released in June 2012, to go into effect starting on January 1, 2015. The final rule, which was released in July 2013, mostly followed the initial proposal, although it allowed for additional exemptions for agricultural loans and community development loans.[11] Critical for our empirical strategy, there was no grandfathering in of earlier originated loans. Namely, any ADC loan which failed to meet the conditions to be exempt from the HVCRE designation would be subject to a 50% increase in the amount of capital required to fund the loan starting on January 1, 2015. Thus loans originated after June 2012 and maturing after January 2015 would be priced by banks with the understanding that having an LTV exceeding supervisory limits would result in greater capital requirements in the future.[12]

[10]Bank assets are measured by the average over the previous four quarters of FR Y-9C filings.

[11]Community development loans include investments "designed primarily to promote the public welfare" (12 USC §338a), "qualified investments" under the community reinvestment act (12 CFR §345) and activities that promote development by funding businesses meeting SBA standards (12 CFR §25.12(g)(3)).

[12]Although we do not focus on this in our paper, the U.S. Congress amended the HVCRE rule as part of the Economic Growth, Regulatory Relief, and Consumer Protection Act, which was passed on May 24, 2018.

The rule defines an HVCRE loan as a credit facility to finance the acquisition, development or construction of property unless the facility either financed the construction of a 1-4 family residential property, or if the project met certain requirements pertaining to the LTV ratio and borrower contributor capital. Specifically, a non-1-4 family ADC loan is *not* considered to be HVCRE if the following conditions hold: (i) the LTV ratio does not exceed supervisory limits, (ii) the borrower contributed capital in the form of cash, marketable assets or out of pocket development expenses is at least 15% of the property's appraised "as completed" value, and (iii) the contributed capital is contractually required to remain in the project until the facility is sold, paid off or converted to permanent financing.[13] Meanwhile, the risk weight for other CRE loans, namely non-ADC CRE loans and ADC loans exempt from the HVCRE rule, remained at 100%.[14]

We take the following steps to identify HVCRE loans in our sample. First, the loan must finance the acquisition, development or construction of a non-1-4 family property. To identify whether a loan falls in to a category impacted by the HVCRE rule, we construct a dummy variable, Non-1-4 family $\text{ADC}_{i,b,t}$, which takes a value of 1 for loans whose "Loan Purpose" is "Construction Build to Suit/Credit Tenant Lease", "Land Acquisition & Development", or "Construction Other" and which is not reported as being a 1-4 family residential construction loan in the Y-9C.

Second, the loan must have either an LTV exceeding supervisory guidelines, or borrower contributed capital that is less than 15% of the value of the project. As data on borrower contributed capital is unavailable, we focus on the LTV requirement. We create a dummy variable, High $\text{LTV}_{i,b,t}$, which indicates whether the LTV exceeds supervisory limits. Loans for the purpose of "land acquisition and development" are defined as having a high LTV if the LTV ratio exceeds the supervisory limit for land development of 0.75. Loans for raw land have a lower limit of 0.65 but cannot be separately identified by the categories in the

[13] The supervisory LTV limits are 65% for loans backed by raw land, 75% for land development, 80% for non-residential construction, and 85% for construction for property improvement, as is laid out in the Code of Federal Regulations.

[14] The word-for-word text of the rule can be found on page 62165 on the Federal Register Vol. 78 No. 198 released on October 11, 2013, which can be found at the following url: `https://www.gpo.gov/fdsys/pkg/FR-2013-10-11/pdf/2013-21653.pdf`.

Y-14Q data.[15] Construction loans are considered to have a high LTV if the LTV is above 0.80 unless the loan purpose is "Construction Other" and the property has non-zero and non-missing net operating income (NOI), in which case we assume the loan's purpose is to improve an existing property and use 0.85 as the threshold. The lack of data on borrower contributed capital and inability to distinguish loans backed by raw land from loans for land development means that some loans that are classified as non-HVCRE loans will potentially actually be HVCRE loans. In this case, our estimated effect of capital requirements on loan rates will be downward biased. In Section 3, we perform tests to estimate the size of this bias and find it to be small.

Finally, non-1-4 family ADC loans with a high LTV are only subject to higher capital requirements after January 1, 2015. If banks price loans based on the average cost of capital over the life of the loan, the surcharge on HVCRE loans will be proportional to the percentage of the loan life occurring after the implementation date, which we define as Pct. $\text{HVCRE}_{i,b,t}$. This variable will be equal to 0 for loans maturing before 2015, while for loans maturing after January 1, 2015 it will equal the number of days between the maturity date and January 1, 2015 divided by the number of days between the maturity date and the origination date.

2.3 Empirical Strategy

The basic empirical strategy is to study how the interest rate markup on high LTV construction loans vary by how long the loan is subject to the increased capital requirement from the HVCRE rule. Loans with a high LTV will not qualify for the exemption from the HVCRE designation and thus will have a higher cost of funding for the bank if the life of the loan significantly covers the post January 1, 2015 period where HVCRE loans have the 150% risk weight.

More concretely, suppose banks fund loans with capital and deposits subject to a minimum ratio of total capital to risk weighted assets of 8%. For simplicity, assume that

[15] Since most ADC loans are below supervisory limits, there is a greater bias from mistakenly classifying a loan as exceeding the limit than mistakenly classifying a loan as not exceeding the limit. Hence we take the higher supervisory limit when we cannot distinguish.

deposits are available at a zero interest rate, while banks have a required return on equity of r^e. This means that HVCRE loans after the implementation date have a cost of capital of $0.08 \times 1.5 \times r^e$ while non-HVCRE construction loans or HVCRE construction loans before the implementation date have a 100% risk weight and a cost of capital of $0.08 \times r^e$. Thus a loan i from bank b originated at time t with a maturity M_i will have an average cost of capital:

$$
\begin{aligned}
\text{Funding Cost}_{i,b,t} &= \frac{1}{M_i}\sum_{\tau=t+1}^{t+M_i} 0.08r_b^e + 0.04r_b^e \mathbb{1}_{\text{Post HVCRE}_\tau}\mathbb{1}_{\text{HVCRE loan}_i} \\
&= 0.08r_b^e + 0.04r_b^e \mathbb{1}_{\text{HVCRE loan}_i}\Big(\frac{1}{M_i}\sum_{\tau=t+1}^{t+M_i} \mathbb{1}_{\text{Post HVCRE}_\tau}\Big).
\end{aligned}
$$

That is, the impact of the HVCRE rule will depend on the percentage of the life of the loan occurring after the implementation date ($\frac{1}{M_i}\sum_{\tau=t+1}^{t+M_i} \mathbb{1}_{\text{Post HVCRE}_\tau}$) and whether or not the construction loan meets the conditions to be classified as an HVCRE loan ($\mathbb{1}_{\text{HVCRE loan}_i}$).

2.3.1 Baseline Diff-in-Diff

The rule thus facilitates a diff-in-diff approach to estimating the effect of the HVCRE rule on the pricing of ADC loans. Our treatment variable is an indicator for whether the LTV is high enough to classify the loan as HVCRE. Then, instead of the normal "Post" variable indicating dates after a policy goes into effect, we have a continuous variable representing the percentage of the loan's life that occurs after the implementation date. Intuitively, a loan originated after the announcement of the HVCRE rule that matures only shortly after the implementation date should be minimally affected, as the risk weight would be 100% for most of the life of the loan. However, longer-lived loans or loans originated closer to the implementation date would be more affected by the rule.

The baseline specification is:

$$
r_{i,b,t} = \beta(\text{High LTV}_{i,b,t} \times \text{Pct. HVCRE}_{i,b,t}) + \gamma X_{i,b,t} + \tau_{b,t} + \varepsilon_{i,b,t}, \tag{1}
$$

where $r_{i,b,t}$ is the interest rate on loan i originated at time t by bank b. The variable

High $\text{LTV}_{i,b,t}$ is an indicator taking the value of one if the loan to value ratio on the loan is above the limit for the HVCRE rule, and Pct. $\text{HVCRE}_{i,b,t}$ is the percentage of the life of the loan occurring after the implementation date. We include loan-level controls ($X_{i,b,t}$) and bank-quarter fixed effects ($\tau_{b,t}$). The loan level controls include the non-interacted treatment variables High $\text{LTV}_{i,b,t}$ and Pct. $\text{HVCRE}_{i,b,t}$, as well as controls for the following loan characteristics: the annual volatility of zip code level house prices, dummies for the risk rating of the loan, the logarithm of the committed exposure, property types dummies (Multifamily, Office, Retail or Other), loan purpose dummies (Land Acquisition/Development, Construction, or Renovation), dummies for the type of appraised value ("as is", "as completed" or "as stabilized"), as well as an indicator variable specifying whether the loan rate is fixed or floating.[16] In our more parsimonious specifications, we include these controls linearly. In our preferred fully-interacted specifications, $X_{i,b,t}$ also includes the interactions of High $\text{LTV}_{i,b,t}$ and Pct. $\text{HVCRE}_{i,b,t}$ with the other controls. In robustness tests, we also include core-based statistical area (CBSA)-quarter fixed effects. Standard errors are clustered at the bank-quarter level. In extensions, we also replace $r_{i,b,t}$ with various other characteristics or non-price loan terms, such as the risk rating of the loan or the house price volatility in the zip code.

We run this analysis for the sample of ADC loans which were originated between the announcement of the rule in June 2012 and the implementation of the rule in January 2015. We exclude loans for the construction of 1-4 family properties, as these loans do not qualify for the increased capital requirements.

An estimate of $\beta > 0$ would indicate that high LTV construction loans (i.e. loans missing the exemption for the HVCRE designation) require higher interest rates for loans more exposed to the period with higher capital requirements, consistent with the HVCRE rule increasing the cost of construction loans.

2.3.2 Triple Difference Methodology

A second complementary approach exploits another source of variation: that non-1-4 family ADC loans were subject to the HVCRE rule, while 1-4 family ADC loans and other

[16] See the Appendix for details on data construction. The risk rating varies from (1)-(10), where (10="AAA",9="AA",8="A",7="BBB",6="BB",5="B",4="CCC",3="CC",2="C",1="D").

types of CRE loans were not. This allows us to estimate the effect of the HVCRE rule using the following triple difference specification:

$$\begin{aligned} r_{i,b,t} &= \beta(\text{High LTV}_{i,b,t} \times \text{Pct. HVCRE}_{i,b,t} \times \text{Non-1-4 family ADC}_{i,b,t}) \\ &\quad + \gamma \text{X}_{i,b,t} + \tau_{b,t} + \varepsilon_{i,b,t}. \end{aligned} \tag{2}$$

In this specification, the variables are the same as in (1) except there is an additional interaction with an indicator for whether the loan is a non-1-4 family ADC loan and $\text{X}_{i,b,t}$ is expanded to include all lower level interactions of the three treatment variables and the interaction of the loan controls with the non-1-4 family ADC loan indicator.

We run this analysis for two samples of CRE loans. First, we run this for all ADC loans originated between the announcement and the implementation of the rule. Here, β reflects the increase in interest rates for high LTV loans exposed to the post-implementation period for non-1-4 family ADC loans relative to the increase for 1-4 family construction loans. 1-4 family ADC loans have the most similar characteristics to non-1-4 family ADC loans of any loan category, but the specification adds fewer than 2,000 loans to our analysis, so our estimates will be more imprecise. In turn, we also run the triple difference regressions on the sample of all CRE loans. The larger sample allows for more precision in our estimates, however this comes at the cost of the control group being mostly constituted of non-ADC loans, which typically have different terms and pricing formulas.

This triple difference methodology tests whether banks just charge higher interest rates on longer-maturity, high-LTV loans in general. Were this the case, high-LTV loans maturing further after 2015 would have higher interest rates for 1-4 family construction loans and non-construction CRE loans along with the non-1-4 family ADC loans which actually were affected by the HVCRE rule. This effect would show up in the interaction of High $\text{LTV}_{i,b,t}$ and Pct. $\text{HVCRE}_{i,b,t}$ instead of the triple interaction. The triple-interaction term differences out the effect of these variables on untreated loan categories and thus may remove a potential bias.

2.3.3 Placebo Tests

Even if our baseline tests show a positive effect of the rule, there could be a concern that our estimates reflect a pricing relationship for non-1-4 family ADC loans that is independent of the rule. We test for this with a placebo test, shifting the announcement to implementation window away from the actual one. For each placebo announcement date t', we construct a variable Placebo Pct. $\text{HVCRE}_{i,b,t,t'}$ equaling the percentage of the life of the loan occurring after the placebo HVCRE implementation date $t' + k$, where k is the time between the real announcement and implementation dates of the HVCRE rule (938 days). We then estimate our diff-in-diff specification as before, but instead using a sample of loans originated between t' and $t' + k$ and using Placebo Pct. $\text{HVCRE}_{i,b,t,t'}$ to measure the exposure of the loan to the post-implementation period instead of the actual exposure to the post-implementation period.

If our findings reflect the general pricing of longer-maturity, high-LTV loans, the estimate should be flat as we change the Placebo announcement date from the actual announcement date. However, what would be expected to happen if our results were entirely due to the HVCRE rule? Note that based on the estimated HVCRE effect of $\hat{\beta}$ in our diff-in-diff specification, we would expect interest rates to be:

$$r_{i,b,t} = \hat{\beta} \times (\text{High LTV}_{i,b,t} \times \text{Pct. HVCRE}_{i,b,t} \times \mathbb{1}_{t \text{ after HVCRE announcement}}) + \hat{\gamma} X_{i,b,t}, \tag{3}$$

where $\mathbb{1}_{t \text{ after HVCRE announcement}}$ is an indicator for whether the loan was originated after the announcement of the HVCRE rule. The indicator variable accounts for the fact that, if a loan was originated before the rule was announced, banks would be unaware that high LTV loans would carry a higher risk weight after January 1, 2015, and thus the effect should not be priced in. If Placebo Pct. $\text{HVCRE}_{i,b,t,t'}$ only relates to interest rates to the extent that it correlates with Pct. $\text{HVCRE}_{i,b,t} \times \mathbb{1}_{t \text{ after HVCRE announcement}}$ then the coefficient on the interaction term in the placebo test should be:

$$\left.\frac{\partial r_{i,b,t}}{\partial \text{Placebo Pct. HVCRE}_{i,b,t,t'}}\right|_{\text{High LTV}=1} = \hat{\beta} \times \frac{\partial \text{Pct. HVCRE}_{i,b,t} \times \mathbb{1}_{t \text{ after HVCRE announcement}}}{\partial \text{Placebo Pct. HVCRE}_{i,b,t,t'}}.$$

2.3.4 Exploiting Heterogeneity in Banks' Capital Constraints

If our baseline estimate is greater than zero due to a supply response to a change in risk weights, the effect should be stronger for banks closer to a risk-based capital constraint. To understand why banks would differ in their sensitivity to risk weights, consider the variety of capital constraints to which banks are subject. In addition to other capital ratios, banks need to maintain regulatory minimums for both the ratio of Tier 1 capital to average total assets (leverage ratio) and the ratio of Tier 1 capital to risk-weighted assets (Tier 1 risk-based ratio). As the numerators of these constraints are the same, the degree to which each constraint is binding will depend on the composition of the assets of the lenders. Banks with more U.S. Treasuries or other low risk-weighted assets may be closer to their leverage ratio. Since this ratio is determined by assets instead of risk-weighted assets, the higher risk weight under the HVCRE rule would not impact required capital. In contrast, banks for which the Tier 1 risk-based ratio is binding will be sensitive to changes in the risk weights. As the risk-based constraint is not slack, an increase in the risk weight on a loan will increase the bank's minimum Tier 1 capital. It is thus these banks that are closer to the risk-based capital ratio who should respond to the HVCRE rule.

To test for this heterogeneous effect, we follow Greenwood et al. (2017) and construct a measure of how close banks are to their capital constraints. Our measure of distance to a risk weighted capital constraint for bank b at time t is $\frac{\text{Tier 1 Capital}}{\text{Risk Weighted Assets}}_{b,t} - 0.06 - \text{Surcharge}_b$, where Surcharge_b is the bank-specific surcharge over regulatory minimum capital requirements.[17] Using this distance variable, we construct a dummy variable, $\text{Capital Constrained}_{b,t}$, which takes a value of one if the bank originating the loan has a distance to the constraint that is less than the median for the quarter. We then repeat our primary analysis, additionally including interactions with the indicator for whether the bank is close to its Tier 1 risk-based capital constraint.

[17] This includes the capital conservation buffer and the surcharge for global systemically important banks. Since these were phased in between 2015 and 2019, and the average maturity of a non-1-4 family ADC loan is about five years, we take the surcharge to be half of the fully phased in amount, which would reflect the surcharge for 2017. The bank specific G-SIB surcharges are listed here: `http://www.fsb.org/wp-content/uploads/2016-list-of-global-systemically-important-banks-G-SIBs.pdf`

3 Empirical Analysis

In this section, we discuss properties of our data and present results from the tests discussed in Section 2.3.

3.1 Sample Properties

We present summary statistics for our variables of interest and controls in Table 1, which includes data on loans from 31 bank holding companies. The top panel shows the summary statistics for our baseline sample of non-1-4 family ADC loans which were originated between the June 2012 announcement of the HVCRE rule and the January 2015 implementation. The middle panel shows summary statistics for loans identified as HVCRE in this sample, while the bottom panel shows summary statistics for all other loans.

We can see that most ADC loans have LTVs under the supervisory threshold, with only about 14 perceent of loans having an LTV qualifying the loan for the HVCRE category. These high LTV loans on average have interest rates that are about 50bp higher than other loans and are also rated as being slightly riskier than other loans.

Two additional variables also stand out as differing across the samples. First, HVCRE loans are more exposed to the post-implementation period, with 62 percent of the life of the average loan occuring after January 1, 2015, compared to 55 percent for low LTV loans. This difference is largley attirbutatble to longer terms at the upper end of the maturity distribtuion. Second, HVCRE loans are almost 20 percentage points more likely to have fixed interest rates. All these variables and their interactions with our treament and exposure variable will be used as controls in our regressions.

3.2 Evidence on Quantities

We begin our analysis by examining the evidence on quantities, as this allows us to further explore some of the trends in our data. Were the rule to have an effect on quantities, the natural place for this to show up would be in the propensity to originate high LTV, non-1-4 family loans, since these are the loans which would be classified as HVCRE and obtain a higher risk weight. Figure 2 demonstrates that there is little trend in the propensity to originate high-LTV, non-1-4 family ADC loans. Since 2011, high LTV originations constitute between 10 and 20 percent of non-1-4 family ADC originations just about every quarter, with no visible change around the rule announcement. As we near the implementation date, meaning that newly originated loans would be more exposed to the rule, the high LTV share actually rises.

In Figure 3, we plot the average loan size and property valuation for originations of non-1-4 family ADC loans over time to better understand the trends in the numerator and denominator of the LTV ratio. Each series shows a steady upward trend, but again there is little apparent change around the time of announcement. The decline in the share of loans with a high LTV before the rule was announced seems to be attributable to low valuations for properties securing loans in the early aftermath of the financial crisis.

Moreover, we see no evidence that more capital constrained banks reduced high LTV lending around the announcement of the HVCRE rule. Given that banks closer to their minimum Tier 1 ratio are found to raise interest rates the most in response to the rule, it would be these constrained banks that would be expected to originate fewer high LTV loans. Instead, Figure 4 shows that constrained banks generally are more prone to originate high LTV loans, and this doesn't change in the quarters following the announcement of the rule.

3.3 Main Results for Loan Rates

Table 2 present findings from the diff-in-diff specification exploiting variation in loan-to-value ratios and the extent to which a loan is exposed to the period after the implementation of the HVCRE rule. The key variable of interest is the interaction between whether the loan LTV exceeds the limit for being exempted from the HVCRE rule (High LTV) and the percentage of the loan extending past the implementation date (Pct. HVCRE). In the most parsimonious specification with just the treatment variables, loan controls, and quarter fixed effects, we get a coefficient of 0.57 on the interaction term. This means that a high LTV loan is expected to carry an interest rate which is 57 basis points (bp) higher as a result of the HVCRE rule.

The estimated effect however drops when we account for interactions between the controls and the treatment variables. The specification in column 2 adds in interactions of the fixed rate dummy with Pct. HVCRE and High LTV and the estimated effect of the HVCRE rule declines to 32bp. This decline is because high LTV loans disproportionately have fixed interest rates, thus the effect in column 1 likely reflects both the elevated interest rate risk from lending at a fixed rate for a longer duration, and the higher capital requirements from making an HVCRE loan exposed to the post-implementation period.

Once the interaction with the fixed rate indicator is accounted for, the estimated effect of the HVCRE rule is not sensitive to the inclusion of other controls. The specification in the third column additionally includes interactions of the rest of the control variables with the treatment variables without meaningfully changing the results. The specification in the fourth column includes these interactions along with bank-quarter fixed effects and the estimate is little changed at 34 basis points. This 34 basis point effect found in the fully-interacted specification with bank-time fixed effects is our preferred estimate of the effect of the HVCRE rule.[18]

For the sake of comparing this effect to those found in the rest of the literature, it is useful to translate this estimate into an elasticity between loan rates and capital requirements instead of risk weights. Focusing on the 8% minimum required ratio of total capital to risk weighted assets, the HVCRE rule increased the capital needed to fund an HVCRE loan from 8% to 12% of the loan, or four percentage points. This means that a 1 percentage point increase in capital requirements raises loan rates by about 8.5 basis points.[19] In their survey of the literature, Dagher et al. (2016) notes that other estimates of this elasticity generally range between 2bp and 20bp, placing us on the lower end of the range of prior estimates.

Table 3 shows results from our baseline difference-in-difference estimation strategy when we additionally include CBSA-quarter fixed effects. The results are generally in line

[18]Estimates are similar if we use a regression discontinuity design. When we repeat this analysis for the set of loans within 0.05 of the LTV limit, we estimate the effect to be 37 basis points in our preferred specification. The estimate is insignificant however, as the sample size drops to fewer than 1,100 loans.

[19]Banks face multiple and heterogeneous capital constraints, thus the proper denominator in this exercise varies by the type of constraint and bank. For example, a 50% increase in the 4.5% common equity tier 1 constraint means a 2.25 percentage points increase in required common equity. Meanwhile, a bank facing the maximum G-SIB surcharge and a fully phased in capital conservation buffer would need a total capital ratio of 13%, making a 50% increase in risk weights increase total required capital by 6.5 percentage points.

with those from Table 2, with the estimated effects modestly smaller and standard errors modestly higher. Nonetheless, the coefficient on the interaction term is still significant at at least the 5% level in every specification. We are hesitant to treat this as our baseline specification, as there are over 2,000 unique CBSA-quarter observations and our sample size is less than 10,000 loans. This results in us dropping over 10 percent of the sample due to there being only a single loan in the market that quarter.

3.4 Triple Difference Results for Loan Rates

While our results are robust to a battery of controls and seem reasonable given the rest of the literature, the sensitivity of our estimates to the selection of controls highlights a weakness in the identification: our treatment is not randomly assigned. The LTV of a loan may interact with other characteristics in ways that influence loan pricing independent of risk-weighted capital requirements.[20]

Our triple difference approach is one way to address the concern that our results are driven by pricing considerations separate from the HVCRE rule. We study how the increase in interest rates for high LTV loans that are exposed to the HVCRE period differs between non-1-4 family ADC loans, which were subject to the rule, and other CRE loans, which were not. If the estimates in the diff-in-diff specification reflect a general pricing rule for all CRE loans, the triple difference would remove this effect.

Table 4 presents the triple difference results, using 1-4 family ADC loans (columns (1)-(4)) or non-ADC CRE loans (columns (5)-(8)) as controls for how the interaction of High LTV$_{i,b,t}$ and Pct. HVCRE$_{i,b,t}$ influence the pricing of CRE loans independent of the regulation.[21] Our estimated effect of the rule on interest rates is the coefficient on High LTV$_{i,b,t}$ $\times$ Pct. HVCRE$_{i,b,t}$ $\times$ Non-1-4 family ADC$_{i,b,t}$.

We find that the increase in interest rates documented in the diff-in-diff specification only occurs for non-1-4 family ADC loans. Columns (1)-(4) run the triple difference specification

[20] For example, longer maturity loans allow for more variation in property values over the life of the loan. This volatility in property values may be especially problematic for high LTV loans, as borrowers would be more likely to end up underwater and default on their loan, justifying a higher interest rate.

[21] In Online Appendix Table 1, we present summary statistics showing how the baseline sample of non-1-4 family ADC loans compares with the sample of 1-4 family ADC loans.

for the sample of ADC loans originated between the announcement and implementation of the HVCRE rule. The columns follow the format of those in the baseline diff-in-diff in terms of the layering on of controls and fixed effects. The coefficient on the interaction between the high LTV indicator and the percentage of the loan extending past the implementation, reflecting the effect of these variables on the pricing of 1-4 family construction loans, is consistently negative, and is insignificant in specifications with fully interacted controls. Consequently, the estimated effect of the HVCRE rule is consistently higher in the triple difference specification than in the corresponding diff-in-diff specification. For the baseline specification with fully interacted controls and bank-quarter fixed effects, the estimated effect is 50 basis points, up from 34 basis points in the baseline diff-in-diff specification. The increase in estimates is larger in the other specifications.

One limitation of using 1-4 family construction loans as a control group is the limited sample size.[22] The data include fewer than 2000 1-4 family construction loans, and only about a tenth of them have an LTV above 0.8. This results in imprecise estimates, with standard errors about doubling relative to in the diff-in-diff specifications.

Columns (5)-(8) run the triple differences specification for the full sample of CRE loans, and thus uses non-ADC loans as a control category instead of only focusing on construction loans. For these non-ADC loans, we also find a negative interaction between LTV and exposure to the HVCRE period. The estimate in the specification with interacted controls and bank quarter fixed effects is 51 basis points, similar to when 1-4 family construction loans were used as the control group. This effect is more precisely estimated due the much larger sample size, however the control category is also much more dissimilar to the treatment category than before, thus we would be hesitant to take this finding as a strong indication of a downward bias in the earlier estimates.

[22]The $1 million reporting threshold is more problematic for 1-4 family construction loans than loans for larger commercial or multifamily construction projects. Additionally, large home builders usually have lines of credit with banks instead of loans secured by particular properties, resulting in those loans for the purpose of home building to appear as a commercial and industrial loans instead of commercial real estate loans.

3.5 Placebo Test for Loan Rates

Thus far we have shown that banks increase interest rates on high LTV, non-1-4 family ADC loans that are more exposed to the period in which these loans would carry higher capital requirements. The fact that this increase in pricing is found solely in the category of CRE loans which are subject to HVCRE rule, and not in other construction loans or other CRE loans, indicates that this increase in pricing is the result of the rule itself, instead of some other characteristic impacting the pricing of CRE loans. One might be concerned however that there is something specific to non-1-4 family ADC loans (besides the HVCRE rule) which causes the higher interest rate on long-maturity, high-LTV loans and is thus not addressed in the triple difference approach. We address this concern with a placebo test repeating the primary methodology for a sequence of placebo HVCRE announcement and implementation dates, as is discussed in Section 2.3.

Figure 5 shows that the coefficient in the placebo regression for different placebo announcement dates follows pretty closely what would be expected if the results were entirely due to the HVCRE rule. The x-axis indexes the placebo announcement date (t'), and the solid line shows the coefficient on Placebo Pct. $\text{HVCRE}_{i,b,t,t'} \times \text{High LTV}_{i,b}$ for the corresponding regression. We also plot 0.34 times the coefficient from regressing Pct. $\text{HVCRE}_{i,b,t} \times \mathbb{1}_{t \text{ after HVCRE announcement}}$ on Placebo Pct. $\text{HVCRE}_{i,b,t,t'}$ (the dotted line), which represents the expected coefficient from the placebo regression under the assumption that the results are driven by the HVCRE rule, and the rule announcement was a surprise. The coefficient from the placebo regression is maximized around when the placebo announcement date corresponds with the real announcement date and thus the specification is the same as in the baseline diff-in-diff approach. The estimated coefficient then declines as the placebo announcement dates gets further from the real dates.

The coefficients are also close to zero for the dates when Placebo Pct. $\text{HVCRE}_{i,b,t,t'}$ no longer correlates with the expected time that a high LTV loan would be subject to higher capital requirements. When the placebo announcement date is about 10 quarters before the real announcement date, there should be no relationship between interest rates and the interaction between maturity and LTV because the sample for that regression covers loans originated before banks were aware of the HVCRE rule. We can see that the coefficient is indeed near 0 for placebo announcement dates in the beginning of 2010. We also should not see any effects for placebo dates after 2015, as high LTV loans would be subject to the HVCRE rule for their entire duration, making the interaction with maturity irrelevant. We can see that the placebo coefficient achieves a minimum around January 1, 2015 and is negative for dates after that.

Table 4 provides more detail for the pre-announcement placebo findings. Each specification mirrors those from Table 2, except for a sample of loans originated between January 1, 2010 and the HVCRE announcement date, and using the real announcement date as the placebo implementation date.[23] Again, as the rule was not known when these loans were originated, we should find no effects. The coefficients on the primary interaction terms are much smaller than in the main results and are statistically insignificant in every specification. In the most conservative diff-in-diff specification in column (4), which produced a coefficient of 0.34 in the baseline results, we recover a coefficient of 0.04 in the placebo sample. In Online Appendix Table 2, we show the results from the triple difference specification for the placebo sample. The coefficient on the triple interaction term is either negative or negligible, and is generally insignificant.

3.6 Heterogeneous Effects for Loan Rates

While the placebo test shows that the increase in interest rates we find is specific to the period leading up to the implementation of the HVCRE rule, there may be a concern that some other development in the market for non-1-4 family ADC loans occurred at a similar time, such as in increase in demand for high LTV, longer maturity loans.[24] We address this concern by exploiting across-bank variation in proximity to risk based capital constraints. If

[23]In Online Appendix Table 1, we present summary statistics showing how the baseline sample of non-1-4 family ADC loans compares with the placebo sample.

[24]Papers using loan level data frequently use borrower-time fixed effects to control for demand (Khwaja and Mian, 2008). Unfortunately, while we have the borrower name, the 8,823 observations in the baseline sample includes 7,441 unique names, with many of the repeated names being "Individual" or "Confidential" . Thus we lack the statistical power to use within-borrower variation. Table 3 shows that our results are robust to incorporating CBSA-quarter fixed effects, so do control for geography specific changes in demand.

interest rates rose due to elevated demand, this effect would likely be similar across banks. However, if the increase in interest rates reflects higher risk weights on treated loans, this would matter most to banks with a binding risk based capital constraint. Banks with a larger buffer, perhaps due to more binding non-risk based constraints, wouldn't need to increase capital on the margin to fund an HVCRE loan.

Table 6 present the results from interacting the variables in our diff-in-diff specification with the capital constrained dummy. We can see that the estimated effect of the HVCRE rule is almost entirely driven by the banks which are closer to their Tier 1 capital constraint. Looking at the coefficient on the interaction of High $\text{LTV}_{i,b,t}$ and Pct. $\text{HVCRE}_{i,b,t}$, we see that unconstrained banks react little to the HVCRE rules. These banks are estimated as changing interest rates by between -6 and 13 basis points depending on the specification, with an estimated effect of 7 basis points in the preferred specification with fully interacted controls and bank-quarter fixed effects. In contrast, constrained banks are estimated as increasing interest rates by between 50 and 65 basis points, with the difference from non-capital constrained banks being significant in each specification.

3.7 Effect on Loan Composition

While the evidence points towards the HVCRE rule causing an increase in interest rates, there may still be a question as to whether this entirely reflects the pass-through of changes in bank funding costs to loan rates. If the composition of borrowers endogenously changes in response to the rule, the effect we identify may partially reflect changes in funding costs, but also partially reflect changes in the risk characteristics of borrowers.

The direction of such a selection bias is ambiguous. On the one hand, better quality borrowers may be more able to raise equity and fund projects with an LTV low enough to avoid the HVCRE designation and the higher rates that go with it. This would mean that borrowers who take out loans that are more treated by the HVCRE rule would be riskier than other borrowers. On the other hand, if funding costs go up, banks could respond by raising interest rates for strong borrowers, who are expected to be able to make the higher interest payments, while rationing weaker borrowers, for whom debt service may become problematic at higher rates. This would cause a negative bias in our estimated effect of the HVCRE rule.

Either way, such a change in composition would result in fewer high LTV loans. Recall from Figure 2 that there wasn't a noticeable change in the total share of non-1-4 family ADC loans that had a high LTV following the announcement of the rule. There may have been some changes on the margin however. Figure 6 plots the distribution of LTVs relative to regulatory limits for both the sample of pre-announcement non-1-4 family ADC loans and the baseline post-announcement sample. There is clearly bunching below the regulatory limit in the post-announcement sample, with the density falling by over half for the bin just above the limit. However, much of this bunching may not be a result of the HVCRE rule as density also fell by over a third in the sample of loans originated before the rule was announced.[25] Taken together, these figures suggest that the HVCRE rule may have induced some borderline loans to reduce LTVs to just under the threshold, but this effect was too small to notably affect high LTV in aggregate. Consequently, the rule is unlikely to notably affect the composition of high LTV borrowers.

We also directly test whether loans more affected by the HVCRE rule differ in risk characteristics. Table 7 repeats the baseline diff-in-diff analysis, but uses loan risk measures as the dependent variable. In the first four columns, the dependent variable is the risk rating of the loan, which varies from (1)-(10), where (10) is the equivalent of a "AAA" rated bond and (1) a "D" rated bond. The coefficient on the interaction term is statistically and economically insignificant in every specification. Columns (5)-(8) present results using zip code house price volatility as the dependent variable. The loans more affected by the HVCRE rule are originated in zip codes with more volatile house prices, but the effect is insignificant in all but the most parsimonious specification.[26]

Overall, there is little to indicate that the increase in interest rates found in our diff-in-

[25]There is also a clear shift in the distribution to lower LTVs after the announcement of the rule. However, Figure 2 shows that most of this decline in LTVs happened before the rule was announced, and is thus likely not due to the rule itself.

[26]Another geographic risk measure that is more CRE specific is the vacancy rate in the market. We run a similar test using the vacancy rate for a given MSA-property type using data from CBRE and find no evidence that loans more affected by the HVCRE rule occur in properties with different vacancy rates. We don't include this as a control as we lose about 3,000 loans from markets where this data is unavailable.

diff results reflect a change in the composition of loans. The share of loans with a high LTV didn't change after the rule was announced, and risk characteristics on treated loans generally didn't differ from those for control loans. It seems that the primary effect of the rule was to change pricing instead of quantities.

3.8 Evaluating Potential Bias From Misclassification

One final concern is that some of the loans we identify as having a low LTV are actually HVCRE loans, attenuating our estimate of the effect of the rule. There are two primary reasons such a misclassification could occur. First, HVCRE status depends on borrower contributed capital and LTV, but we only observe LTV. Some low LTV loans may thus be HVCRE due to lacking sufficient borrower contributed capital. Second, the loan categories reported in the Y-14 don't line-up perfectly with the categories in the rule. Most notably, we can't distinguish loans for raw land (which have a regulatory minimum LTV of 0.65) from loans for land development (with a minimum LTV of 0.75). This means some raw land loans with an LTV exceeding 0.65 may be misclassified as having a low LTV.

Table 8 reports findings from our diff-in-diff specification dropping loans that are at a greater risk of being misclassified. Columns (1)-(4) of Table 8 present results excluding loans with an LTV between 0.50 and the supervisory limit. Since LTV and borrower contributed capital are inversely related, loans with LTVs under 0.5 are unlikely fail to meet the borrower contributed capital requirement.[27] Despite the sample size being reduced by over half, the coefficient estimates are similar to the main results in Table 2, generally rising a few basis points in specifications without bank-quarter fixed effects and falling a few basis points in the specification with them.

Columns (5)-(8) restrict the sample to just construction loans for properties with no reported operating income. Unlike for land acquisition and development loans, where the

[27]Recall that a loan is exempt from the rule if it has (1) an LTV not exceeding supervisory limits and (2) borrower contributed capital that is at least 15% of the completed value of the project. A loan may meet the first criteria but fail the second if the borrower makes a low investment but gets a favorable appraisal on the completed property. For example, if a construction project costs $9 million and produces a $10 million property, an LTV of 0.8 would correspond with a borrower contributed capital of 10%, making the loan fail the borrower contributed capital criteria. At an LTV of 0.5 however, the borrower would be contributing 40% of the competed value, and would thus comfortably avoid being HVCRE.

appropriate supervisory limit is somewhat uncertain, we can be reasonably sure that these loans have a supervisory limit of 0.8. The sample size falls by a bit over a third relative to the main table, but again the point estimates change little. The estimated effect of the HVCRE rule rises to 38 basis points in our preferred specification, compared to 34 basis points for the full sample. While this is consistent with a downward bias due to misclassification, it indicates that the bias is small.

There is also some evidence form our triple difference specification that the bias from misclassification is minor. If a significant portion of loans with a low LTV were actually HVCRE loans, and priced as such, then non-1-4 family ADC loans with greater exposure to the post-implementation period should have carried higher interest rates than comparable 1-4 family ADC loans. However, in the triple difference specification in Table 4, the coefficient on Non-1-4 family $\text{ADC}_{i,b,t} \times$ Pct. $\text{HVCRE}_{i,b,t}$ is small and insignificant. In other words, differences in the pricing of exposure to the post-implementation period only occurs for high LTV loans, indicating that the high LTV indicator effectively measures HVCRE status.

4 Conclusion

Our paper studies the effect of a 50% increase in the amount of capital required to fund High Volatility Commercial Real Estate loans. Exploiting variation in whether loan terms qualify a loan to be categorized as HVCRE and the portion of the life of a loan covering the period in which the HVCRE rule is in effect, we estimate that the rule increased the interest rate on treated loans by about 34 basis points. We rule out alternative explanations for this finding by demonstrating that the effect is only found for non-1-4 family ADC loans, only found for the period following the announcement of the rule, and only found for banks close to a risk-based capital constraint.

How well is this elasticity of loan rates with respect to capital requirements likely to generalize to other markets? As was discussed in the introduction, the market for construction loans is unique in the extent to which lending is dominated by banks. This means that results in other markets are likely to differ. Given the assortment of non-bank lenders providing financing to business and the prevalence of securitization for mortgages, an increase in capital requirements is more likely to cause a migration of these loans outside the banking sector. This availability of non-bank financing may hinder banks' abilities to fully pass through a change in funding costs to borrowers. Consequently, other markets are likely observe larger effects on bank loan volumes and smaller effects on loan rates.

However, even though the findings likely don't translate directly to other markets, they are still useful for understanding these markets. The fundamental cost of higher capital requirements is an increase in bank funding costs, resulting in a downward shift in supply. In a market with inelastic demand, the magnitude of a supply shift will be captured by the change in pricing, and not be partially offset by movement along the supply curve. Since we study a market with relatively inelastic demand, the 34 basis point change in loan rates likely reflects the change in funding costs as a result of higher capital requirements. This reflects the magnitude the supply shift which would hold across markets. How this would translate to prices and quantities would then depend on the specific competitive environment in a given market.

What do our estimates imply regarding the desireability of higher capital requirements? Evaluating proper capital requirements entails identifying the costs of more stringent requirements, which come in the form of a higher cost of borrowing for bank customers, and weighing these costs against the benefits in the form of greater financial stability. This paper contributes to the first part of this calculation by demonstrating that the effects of increased capital requirements are modest, but not negligible. If there are substantial benefits to increased capitalization of the banking system, as is estimated by Miles et al. (2013) and Firestone et al. (2017), our findings would generally be supportive of recent regulatory efforts to increase capital requirements. Furthermore, the increase in interest rates we identify may reflect the attenuation of distortions from government guarantees or the tax advantage of debt, in which case the costs of greater capital requirements would be private instead of social (Admati and Hellwig, 2014).

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Data Appendix

The data from the Y-14Q Schedule H.2 was downloaded on April 26, 2019 from the Wholesale Data Mart, which is maintained by staff at the Federal Reserve Bank of Chicago.[28]

[28]The instruction and reporting forms for the Y-14Q Schedule H.2 can be found here: `https://www.federalreserve.gov/apps/reportforms/reporthistory.aspx?sOoYJ+5BzDZGWnsSjRJKDwRxOb5Kb1hL`.

We clean the raw Y-14Q download by dropping observations that have missing values for any variables we require for our analysis, this includes "loan purpose" (MDRM G073), the line reported on the FR Y-9C (MDRM K449), interest rate (MDRM 7889), committed exposure (MDRM G074), interest rate variability category (MDRM K461), maturity date (MDRM 9914), origination date (MDRM 9912), 5-digit zip code of the property (MDRM K453), the type of appraised value (MDRM K456), and loans with zipcodes that don't match to the house price data. We also drop extreme observations: interest rates below zero or above 25 percent, times to maturity below 0 or above 30 years, and negative committed exposures. We also drop missing or negative observations for the risk rating of the loan, which is a standardized version of the internal rating of the loan (MDRM G080) constructed by bank supervisors. The ratings are reviewed by multiple supervisors and, at times, there are two ratings reported for the loan. In these cases, we grab the minimum risk rating. Further, we drop observations not relevant to our analysis, such as observations with originations prior to 2010.

Our loan to value ratio measure is constructed by taking the ratio of the loan's committed exposure to its value at origination (MDRM K449). In cases where the value at origination is missing, we divide by the "current value" (MDRM M209) at the earliest appearance in the data. We drop observations missing or negative LTVs. Loan interest rates and loan to value ratios are winsorized at the 1% level.

The data is reported quarterly. However, since we are interested in the loan characteristics as of origination, we only keep a loan as of the first time it appears in the panel. In the raw data, for loans which are fully undrawn, interest rates are coded as zero and data on whether rates are fixed or floating are not available until the loan is drawn. For these loans, we take the interest rate and interest rate variability category as of the first time that data is available (that is, at the time of the first draw).

Loans are identified by their "loan number" (MDRM G063). We drop observations where a new "loan number" appears but differs from the "original loan number" (MDRM G064), as these are unlikely to truly be new loans. We also drop observations where the origination date differs from the earliest origination date, as it is unclear the extent to which the terms on modified loans may reflect conditions at the stated date of origination or the earlier date of origination.

To compute the house price volatility in the zipcode, we take the standard deviation of annual house price changes. This variables uses data from the Federal Housing Finance Agency zipcode level House Price Index.[29] We compute the standard deviation of the given year-over-year change in house prices between 1990 and 2011 and merge this by zip code with our loan-level dataset. For the broader geographic controls, a CBSA in our data is either the official core-based statistical area (CBSA), or the county for counties not in a CBSA.

We also merge in bank-holding company level data by quarter from the FR Y-9C. In the few cases in which the loan origination occurs (in the Y-14Q data) in quarters where subsidiaries of the bank holding company did not file a Y-9C form, we drop these observations from our heterogeneous effects analysis, but not from our baseline or placebo analysis. Our results are basically unchanged if we drop these observations from our baseline and placebo analyses as well. In calculating the bank-level measure of the distance from the tier 1 capital constraint, we assume the G-SIB surcharge (as of January 2017) and Capital Conservation buffers are half-way phased in.[30] That is, the constraint is 6% plus half of the phase in of the 2.5% capital conservation buffer (so 7.25% total) for most banks in our sample, with an extra half of 2.5% (due to the G-SIB surcharge) for JP Morgan Chase & Co. (RSSDID 1039502) and Citigroup Inc. (RSSD ID 1951350), 2% for Bank of America Corporation (RSSD ID 1073757), DB USA Corporation (RSSD ID 2816906), and HSBC North America Holdings Inc. (RSSD ID 3232316), 1.5% for Wells Fargo & Company (RSSD ID 1120754) and The Goldman Sachs Group, Inc. (RSSD ID 2384403), and 1% for Morgan Stanley (RSSD ID 2162966), State Street Corporation (RSSD ID 1111435), Bank of New York Mellon Corporation (RSSD ID 3587146), Santander Holdings USA, Inc. USA (RSSD ID 3981856). We compute the distance from the constraint as Tier 1 capital (BHCK

[29]The dataset is downloaded from here `https://www.fhfa.gov/DataTools/Downloads/pages/house-price-index-datasets.aspx`.

[30]The capital conservation buffer does not vary by bank, so assumptions about the phase-in have no bearing on the relative proximity to capital constraints.

8274) relative to the bank's total risk-weighted assets (BHCK A223) less the bank-specific capital constraint.

Tables and Figures

Table 1
Summary Statistics for Loan Variables in the Baseline Sample of non-1-4 family ADC loans

	All Loans							
	Mean	Std	p1	p25	p50	p75	p99	N
Interest rate (percentage points)	3.24	0.99	1.55	2.50	3.00	3.75	6.00	8823
Percent maturing after January 1, 2015	0.56	0.34	0.00	0.26	0.64	0.87	1.00	8823
High LTV (1 if LTV exceeds supervisory max)	0.14	0.34	0.00	0.00	0.00	0.00	1.00	8823
Risk rating (1-10)	6.11	0.76	4.00	6.00	6.00	6.00	8.00	8823
Committed exposure at origination ($ millions)	11.63	13.81	0.28	2.10	5.92	16.00	68.00	8823
$\sigma(\Delta$ ln(House Prices))	6.76	3.33	1.91	3.92	6.34	9.12	14.92	8823
Time to maturity at origination (yrs.)	4.57	5.19	0.44	2.00	3.00	5.00	25.50	8823
Floating rate (0) or fixed (1)	0.13	0.34	0.00	0.00	0.00	0.00	1.00	8823
Loan to Value ratio	0.67	0.59	0.03	0.48	0.62	0.75	4.87	8823
	Loans above LTV Limits (High LTV)							
	Mean	Std	p1	p25	p50	p75	p99	N
Interest rate (percentage points)	3.66	1.25	1.55	2.65	3.44	4.75	6.00	1214
Percent maturing after January 1, 2015	0.62	0.36	0.00	0.31	0.78	0.94	1.00	1214
High LTV (1 if LTV exceeds supervisory max)	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1214
Risk rating (1-10)	6.05	0.80	2.00	6.00	6.00	6.00	7.00	1214
Committed exposure at origination ($ millions)	8.44	11.92	1.01	1.58	3.25	10.10	65.39	1214
$\sigma(\Delta$ ln(House Prices))	6.69	3.47	1.93	3.75	5.98	9.22	16.05	1214
Time to maturity at origination (yrs.)	8.25	8.90	0.47	2.00	3.07	11.00	26.00	1214
Floating rate (0) or fixed (1)	0.30	0.46	0.00	0.00	0.00	1.00	1.00	1214
Loan to Value ratio	1.51	1.21	0.76	0.85	0.95	1.41	4.87	1214
	Loans below LTV Limits (Low LTV)							
	Mean	Std	p1	p25	p50	p75	p99	N
Interest rate (percentage points)	3.18	0.93	1.55	2.50	2.94	3.70	5.90	7609
Percent maturing after January 1, 2015	0.55	0.34	0.00	0.25	0.62	0.86	1.00	7609
High LTV (1 if LTV exceeds supervisory max)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7609
Risk rating (1-10)	6.12	0.75	4.00	6.00	6.00	6.00	8.00	7609
Committed exposure at origination ($ millions)	12.13	14.02	0.28	2.28	6.40	17.00	68.00	7609
$\sigma(\Delta$ ln(House Prices))	6.77	3.31	1.91	3.95	6.41	9.09	14.87	7609
Time to maturity at origination (yrs.)	3.98	4.02	0.44	2.00	3.00	4.38	23.65	7609
Floating rate (0) or fixed (1)	0.11	0.31	0.00	0.00	0.00	0.00	1.00	7609
Loan to Value ratio	0.54	0.20	0.03	0.44	0.59	0.69	0.80	7609

This table reports the distribution of the loan level variables used in our baseline sample of non-1-4 family ADC loans. We show information on the full sample (top panel), the sample of loans we identify as HVCRE loans (middle panel), and the sample of loans we identify as non-HVCRE loans (bottom panel). N is the number of nonmissing observations for a given variable. The variable $\sigma(\Delta\ln$(House Prices)) is the standard deviation of the annual change in house prices of the zip code of loan. The risk rating varies from (1)-(10), where (10="AAA",9="AA",8="A",7="BBB",6="BB",5="B",4="CCC",3="CC",2="C",1="D"). Further information on variable construction can be found in the Appendix.

Table 2
Effect of HVCRE Rule on Loan Rates: Baseline Diff-in-Diff

	Effect on Interest Rates			
	(1)	(2)	(3)	(4)
High LTV x Pct. HVCRE	0.57**	0.32**	0.32**	0.34**
	(0.12)	(0.11)	(0.11)	(0.10)
Pct. HVCRE	-0.15**	-0.33**	-1.10	-1.11
	(0.05)	(0.06)	(0.86)	(0.85)
High LTV	-0.18*	-0.15*	1.92**	1.76**
	(0.08)	(0.07)	(0.66)	(0.66)
Loan controls	X	X	X	X
Qtr FE	X	X	X	
$\mathbb{1}_{\text{Fixed Rate}} \times$ {Pct. HVCRE; High LTV}		X		
Controls $\times$ {Pct. HVCRE; High LTV}			X	X
Bank-Qtr FE				X
R^2_a	0.352	0.372	0.379	0.457
No. banks	31	31	31	31
No. loans	8823	8823	8823	8823

This table reports coefficients from the following regression:

$$r_{i,b,t} = \beta(\text{High LTV}_{i,b,t} \times \text{Pct. HVCRE}_{i,b,t}) + \gamma X_{i,b,t} + \tau_{b,t} + \varepsilon_{i,b,t},$$

where $r_{i,b,t}$ is the interest rate on loan i from bank b at time t. The variable High LTV$_{i,b,t}$ is an indicator function taking the value of one if the loan to value ratio on the construction loan is above the HVCRE limit, and the variable Pct. HVCRE$_{i,b,t}$ is the percentage of the life of the loan occurring after the implementation date. $X_{i,b,t}$ includes the following loan level controls: the annual volatility of zip code level house prices, the logarithm of the committed exposure, property types dummies (Multi-family, Office, Retail or Other), risk rating dummies, loan purpose dummies (Land Acquisition/Development, Construction, or Renovation), appraised type dummies ("as is", "as completed" or "as stabilized"), as well as an indicator variable specifying whether the loan rate is fixed or floating. $X_{i,b,t}$ also includes the treatment variables and in some specifications the interaction of these variables with the loan controls. $\tau_{b,t}$ is a bank-quarter fixed effect. Each column presents coefficients from the difference-in-difference specification for the sample of non-1-4 family ADC loans originated between the announcement and implementation of the HVCRE rule. Column (1) includes the set of controls and quarter fixed effects, column (2) adds an interaction of the fixed rate dummy with High LTV$_{i,b,t}$ and Pct. HVCRE$_{i,b,t}$, column (3) additionally includes interactions of the rest of the controls with the treatment variables, and column (4) additionally includes bank-quarter fixed effects. Standard errors, in parentheses, are clustered at the bank-quarter level. +,*,** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 3
Baseline Diff-in-Diff with CBSA-quarter Fixed Effects

	Effect on Interest Rates			
	(1)	(2)	(3)	(4)
High LTV x Pct. HVCRE	0.47**	0.27*	0.27*	0.30**
	(0.12)	(0.12)	(0.11)	(0.11)
Pct. HVCRE	-0.05	-0.25**	-0.17	-0.22
	(0.06)	(0.06)	(0.93)	(0.92)
High LTV	-0.11	-0.09	2.08**	1.88**
	(0.08)	(0.08)	(0.72)	(0.71)
Loan controls	X	X	X	X
Qtr FE	X	X	X	
$\mathbb{1}_{\text{Fixed Rate}} \times$ {Pct. HVCRE; High LTV}		X		
Controls $\times$ {Pct. HVCRE; High LTV}			X	X
Bank-Qtr FE				X
CBSA-Qtr FE	X	X	X	X
R_a^2	0.414	0.430	0.439	0.497
No. banks	31	31	31	29
No. loans	7853	7853	7853	7829

This table presents the same information as in Table 2, except the regression specifications all include CBSA-quarter fixed effects. Specifically, it reports coefficients from the following regression:

$$r_{i,b,t} = \beta(\text{High LTV}_{i,b,t} \times \text{Pct. HVCRE}_{i,b,t}) + \gamma X_{i,b,t} + \tau_{b,t} + \varepsilon_{i,b,t},$$

where $r_{i,b,t}$ is the interest rate on loan i from bank b at time t. The variable High $\text{LTV}_{i,b,t}$ is an indicator function taking the value of one if the loan to value ratio on the construction loan is above the HVCRE limit, and the variable Pct. $\text{HVCRE}_{i,b,t}$ is the percentage of the life of the loan occurring after the implementation date. $X_{i,b,t}$ is a vector of the loan level controls, the two treatment variables, and in some specifications the interaction of these variables with the loan controls (controls are listed in Table 2 and Section 2.3). $\tau_{b,t}$ is a bank-quarter fixed effect. All specifications also include CBSA-quarter fixed effects. Each column presents coefficients from the difference-in-difference specification for the sample of non-1-4 family ADC loans originated between the announcement and implementation of the HVCRE rule. Column (1) includes the set of controls and quarter fixed effects, column (2) adds an interaction of the fixed rate dummy with High $\text{LTV}_{i,b,t}$ and Pct. $\text{HVCRE}_{i,b,t}$, column (3) additionally includes interactions of the rest of the controls with the treatment variables, and column (4) additionally includes bank-quarter fixed effects. Standard errors, in parentheses, are clustered at the bank-quarter level. +,*,** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 4
Triple Difference Estimates

	Effect on Interest Rates (percentage points)							
	Sample of ADC Loans				Sample of CRE Loans			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
High LTV x Pct. HVCRE x Non-1-4 family ADC	0.99**	0.65**	0.63**	0.50*	0.85**	0.58**	0.49**	0.51**
	(0.21)	(0.21)	(0.21)	(0.21)	(0.15)	(0.14)	(0.13)	(0.12)
High LTV x Pct. HVCRE	-0.42*	-0.31+	-0.28	-0.16	-0.27**	-0.20*	-0.10	-0.07
	(0.17)	(0.17)	(0.17)	(0.17)	(0.10)	(0.10)	(0.09)	(0.09)
Pct. HVCRE	-0.13	-0.36**	-0.52	-1.06	-0.23**	-0.51**	-0.78	-1.07*
	(0.12)	(0.13)	(0.75)	(0.78)	(0.06)	(0.06)	(0.55)	(0.52)
High LTV	0.24*	0.18+	2.02**	1.89**	0.27**	0.22**	0.62+	0.60+
	(0.09)	(0.10)	(0.55)	(0.56)	(0.06)	(0.07)	(0.35)	(0.33)
Non-1-4 family ADC x Pct. HVCRE	-0.05	0.00	-0.08	-0.04	0.04	0.16*	0.04	0.07
	(0.11)	(0.12)	(0.13)	(0.12)	(0.07)	(0.07)	(0.08)	(0.07)
High LTV x Non-1-4 family ADC	-0.42**	-0.34**	-0.22+	-0.19	-0.46**	-0.36**	-0.28**	-0.23**
	(0.12)	(0.12)	(0.13)	(0.12)	(0.09)	(0.09)	(0.09)	(0.08)
Non-1-4 family ADC	0.07	0.07	0.08	-0.70	0.32	0.05	0.10	-0.17
	(0.48)	(0.48)	(0.48)	(0.50)	(0.37)	(0.38)	(0.38)	(0.36)
Loan controls	X	X	X	X	X	X	X	X
Qtr FE	X	X	X		X	X	X	
Controls×{Non-1-4 Fam ADC}	X	X	X	X	X	X	X	X
$\mathbb{1}_{\text{Fixed Rate}}$×{Pct. HVCRE; High LTV}		X				X		
Controls×{Pct. HVCRE; High LTV}			X	X			X	X
Bank-Qtr FE				X				X
R^2_a	0.390	0.406	0.412	0.487	0.389	0.410	0.414	0.471
No. banks	31	31	31	31	36	36	36	36
No. loans	10860	10860	10860	10860	32280	32280	32280	32280

This table reports coefficients from the following regression:

$$r_{i,b,t} = \beta(\text{High LTV}_{i,b,t} \times \text{Pct. HVCRE}_{i,b,t} \times \text{Non-1-4 family ADC}_{i,b,t}) + \gamma X_{i,b,t} + \tau_{b,t} + \varepsilon_{i,b,t},$$

where $r_{i,b,t}$ is the interest rate on loan i from bank b at time t. The variable High LTV$_{i,b,t}$ is an indicator function taking the value of one if the loan to value ratio on the construction loan is above the HVCRE limit, the variable Pct. HVCRE$_{i,b,t}$ is the percentage of the life of the loan occurring after the implementation date, and the variable Non-1-4 family ADC$_{i,b,t}$ is an indicator for whether the loan is an ADC loan for a non-1-4 family property. $X_{i,b,t}$ is a vector of the loanlevel controls, the lower order interactions of the treatment variables and in some specifications the interaction of these treatment variables with the loan controls (controls are listed in Table 2 and Section 2.3). $\tau_{b,t}$ is a bank-quarter fixed effect. Columns (1)-(4) present the triple difference results for the sample of ADC loans, while columns (5)-(8) present the findings for the full sample of CRE loans. Columns (1) and (5) includes the set of controls and quarter fixed effects, columns (2) and (6) adds an interaction of the fixed rate dummy with High LTV$_{i,b,t}$ and Pct. HVCRE$_{i,b,t}$, columns (3) and (7) additionally includes interactions of the rest of the controls with the treatment variables, and columns (4) and (8) additionally includes bank-quarter fixed effects. Standard errors, in parentheses, are clustered at the bank-quarter level. +,*,** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 5
Baseline Diff-in-Diff: Placebo Sample

	Effect on Interest Rates			
	(1)	(2)	(3)	(4)
High LTV x Pct. HVCRE	0.20^{+}	0.14	0.11	0.04
	(0.11)	(0.10)	(0.12)	(0.11)
Pct. HVCRE	-0.40**	-0.45**	0.51	0.15
	(0.08)	(0.09)	(0.77)	(0.77)
High LTV	-0.08	-0.09	-0.11	0.07
	(0.05)	(0.05)	(0.62)	(0.63)
Loan controls	X	X	X	X
Qtr FE	X	X	X	
$\mathbb{1}_{\text{Fixed Rate}}\times$\{Pct. HVCRE; High LTV\}		X		
Controls$\times$\{Pct. HVCRE; High LTV\}			X	X
Bank-Qtr FE				X
R_a^2	0.251	0.253	0.260	0.329
No. banks	29	29	29	29
No. loans	6712	6712	6712	6712

This table reports coefficients from the following regression:

$$r_{i,b,t} = \beta(\text{High LTV}_{i,b,t} \times \text{Pct. HVCRE}_{i,b,t}) + \gamma X_{i,b,t} + \tau_{b,t} + \varepsilon_{i,b,t},$$

for the sample of loans originated between January 1, 2010 and the announcement of the HVCRE rule. All other variables are as in Table 2. The variable $r_{i,b,t}$ is the interest rate on loan i from bank b at time t. The variable High LTV$_{i,b,t}$ is an indicator function taking the value of one if the loan to value ratio on the construction loan is above the HVCRE limit, and the variable Pct. HVCRE$_{i,b,t}$ is the percentage of the life of the loan occurring after the announcement date. $X_{i,b,t}$ is a vector of the loan level controls, the two treatment variables, and in some specifications the interaction of these variables with the loan controls (controls are listed in Table 2 and Section 2.3). $\tau_{b,t}$ is a bank-quarter fixed effect. Each column presents coefficients from the difference-in-difference specification for the sample of non-1-4 family ADC loans originated between the announcement and implementation of the HVCRE rule. Column (1) includes the set of controls and quarter fixed effects, column (2) adds an interaction of the fixed rate dummy with High LTV$_{i,b,t}$ and Pct. HVCRE$_{i,b,t}$, column (3) additionally includes interactions of the rest of the controls with the treatment variables, and column (4) additionally includes bank-quarter fixed effects. Standard errors, in parentheses, are clustered at the bank-quarter level. +,*,** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 6
Heterogeneous Effects By Distance to Capital Constraints

	Effect on Interest Rates			
	(1)	(2)	(3)	(4)
Capital Constrained				
x High LTV x Pct. HVCRE	0.52^{+}	0.60*	0.51*	0.43*
	(0.31)	(0.25)	(0.22)	(0.20)
x Pct. HVCRE	-0.04	-0.04	-0.05	-0.01
	(0.11)	(0.11)	(0.11)	(0.11)
x High LTV	-0.29^{+}	-0.31*	-0.23^{+}	-0.24^{+}
	(0.16)	(0.15)	(0.14)	(0.13)
High LTV x Pct. HVCRE	0.13	-0.06	0.01	0.07
	(0.21)	(0.18)	(0.16)	(0.15)
Pct. HVCRE	-0.14^{+}	-0.30**	-1.64^{+}	-1.68^{+}
	(0.08)	(0.08)	(0.90)	(0.89)
High LTV	0.04	0.05	2.19**	2.05**
	(0.12)	(0.11)	(0.72)	(0.72)
Loan controls	X	X	X	X
Qtr FE	X	X	X	
Bank-Time FE				X
All Controls×{Pct. HVCRE; High LTV; Capital Constrained}			X	X
R^2_a	0.301	0.318	0.330	0.415
No. banks	30	30	30	30
No. loans	7628	7628	7628	7628

This table reports coefficients from the following regression:

$$r_{i,b,t} = \beta(\text{High LTV}_{i,b,t} \times \text{HVCRE}_{i,b,t} \times \text{Capital Constrained}_{i,b,t}) + \gamma X_{i,b,t} + \tau_{b,t} + \varepsilon_{i,b,t},$$

where Capital Constrained$_{i,b,t}$ is an indicator for whether bank b is closer than the median to a regulatory minimum risk weighted capital ratio in quarter t. The variable $r_{i,b,t}$ is the interest rate on loan i from bank b at time t. The variable High LTV$_{i,b,t}$ is an indicator function taking the value of one if the loan to value ratio on the construction loan is above the HVCRE limit, and the variable Pct. HVCRE$_{i,b,t}$ is the percentage of the life of the loan occurring after the implementation date. $X_{i,b,t}$ is a vector of the loan level controls, the three treatment variables, and in some specifications the interaction of these variables with the loan controls (controls are listed in Table 2 and Section 2.3). $\tau_{b,t}$ is a bank-quarter fixed effect. Each column presents coefficients from the difference-in-difference specification for the sample of non-1-4 family ADC loans originated between the announcement and implementation of the HVCRE rule. Column (1) includes the set of controls and quarter fixed effects, column (2) adds an interaction of the fixed rate dummy with High LTV$_{i,b,t}$ and Pct. HVCRE$_{i,b,t}$, column (3) additionally includes interactions of the rest of the controls with the treatment variables, and column (4) additionally includes bank-quarter fixed effects. Standard errors, in parentheses, are clustered at the bank-quarter level. +,*,** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 7
Estimated Effect on Risk Characteristics

	Effect on Risk Ratings				Effect on Volatility of House Prices			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
High LTV x Pct. HVCRE	0.13	0.18	0.15	0.14	0.72*	0.45	0.28	0.23
	(0.10)	(0.11)	(0.10)	(0.10)	(0.36)	(0.36)	(0.34)	(0.34)
Pct. HVCRE	0.01	0.04	1.09*	0.37	-0.80**	-1.10**	5.91**	4.41*
	(0.06)	(0.06)	(0.42)	(0.40)	(0.21)	(0.21)	(1.77)	(1.78)
High LTV	-0.13	-0.13	0.00	0.20	-0.28	-0.22	0.57	1.55
	(0.08)	(0.08)	(0.46)	(0.45)	(0.27)	(0.27)	(1.73)	(1.78)
Loan controls	X	X	X	X	X	X	X	X
Qtr FE	X	X	X		X	X	X	
$\mathbb{1}_{\text{Fixed Rate}} \times$ {Pct. HVCRE; High LTV}		X				X		
Controls $\times$ {Pct. HVCRE; High LTV}			X	X			X	X
Bank-Qtr FE				X				X
R^2_a	0.018	0.019	0.027	0.210	0.024	0.028	0.033	0.116
No. banks	31	31	31	31	31	31	31	31
No. loans	8823	8823	8823	8823	8823	8823	8823	8823

This table reports coefficients from the following regression:

$$\text{Risk measure}_{i,b,t} = \beta(\text{High LTV}_{i,b,t} \times \text{Pct. HVCRE}_{i,b,t}) + \gamma X_{i,b,t} + \tau_{b,t} + \varepsilon_{i,b,t},$$

where $\text{Risk measure}_{i,b,t}$ is the risk measure on loan i from bank b at time t. The variable $\text{High LTV}_{i,b,t}$ is an indicator function taking the value of one if the loan to value ratio on the construction loan is above the HVCRE limit, and the variable $\text{Pct. HVCRE}_{i,b,t}$ is the percentage of the life of the loan occurring after the implementation date. $X_{i,b,t}$ is a vector of the loan level controls, the two treatment variables, and in some specifications the interaction of these variables with the loan controls (controls are those listed in Table 2 excluding the two risk measures used as dependent variables here). $\tau_{b,t}$ is a bank-quarter fixed effect. Each column presents coefficients from the difference-in-difference specification for the sample of non-1-4 family ADC loans originated between the announcement and implementation of the HVCRE rule. In columns (1)-(4), the risk measure is the risk rating on the loan, while in columns (5)-(8), the risk measure is the volatility of house prices in the zip code of the property. The risk rating varies from (1)-(10), where (10="AAA",9="AA",8="A",7="BBB",6="BB",5="B",4="CCC",3="CC",2="C",1="D"). Columns (1) and (5) includes the set of controls and quarter fixed effects, columns (2) and (6) adds an interaction of the fixed rate dummy with $\text{High LTV}_{i,b,t}$ and $\text{Pct. HVCRE}_{i,b,t}$, columns (3) and (7) additionally includes interactions of the rest of the controls with the treatment variables, and columns (4) and (8) additionally includes bank-quarter fixed effects. Standard errors, in parentheses, are clustered at the bank-quarter level. +,*,** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 8
Tests for Bias from Potential Misclassification of Treatment

	Effect on Interest Rates (percentage points)							
	Excluding loans with Marginal LTV				Sample Limited to only Construction Loans			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
High LTV x Pct. HVCRE	0.57**	0.35**	0.37**	0.29*	0.62**	0.34*	0.37**	0.38**
	(0.14)	(0.12)	(0.12)	(0.11)	(0.14)	(0.13)	(0.12)	(0.11)
Pct. HVCRE	-0.22*	-0.47**	-0.13	-0.23	-0.10	-0.31**	-3.21**	-2.89*
	(0.09)	(0.09)	(1.08)	(1.08)	(0.07)	(0.07)	(1.18)	(1.19)
High LTV	-0.20*	-0.18*	3.68**	3.47**	-0.16+	-0.14	2.81**	2.48**
	(0.08)	(0.08)	(0.69)	(0.69)	(0.09)	(0.09)	(0.70)	(0.79)
Loan controls	X	X	X	X	X	X	X	X
Qtr FE	X	X	X		X	X	X	
$\mathbb{1}_{\text{Fixed Rate}} \times$ {Pct. HVCRE; High LTV}		X				X		
Controls $\times$ {Pct. HVCRE; High LTV}			X	X			X	X
Bank-Qtr FE				X				X
R^2_a	0.360	0.390	0.406	0.495	0.389	0.410	0.418	0.505
No. banks	31	31	31	31	31	31	31	31
No. loans	3710	3710	3710	3710	5744	5744	5744	5744

This table reports coefficients from the following regression:

$$r_{i,b,t} = \beta(\text{High LTV}_{i,b,t} \times \text{Pct. HVCRE}_{i,b,t}) + \gamma X_{i,b,t} + \tau_{b,t} + \varepsilon_{i,b,t},$$

where $r_{i,b,t}$ is the interest rate on loan i from bank b at time t. The variable High $\text{LTV}_{i,b,t}$ is an indicator function taking the value of one if the loan to value ratio on the construction loan is above the HVCRE limit, and the variable Pct. $\text{HVCRE}_{i,b,t}$ is the percentage of the life of the loan occurring after the implementation date. $X_{i,b,t}$ is a vector of the loan level controls, the two treatment variables, and in some specifications the interaction of these variables with the loan controls (controls are listed in Table 2 and Section 2.3). $\tau_{b,t}$ is a bank-quarter fixed effect. Each column presents coefficients from the difference-in-difference specification for the sample of non-1-4 family ADC loans originated between the announcement and implementation of the HVCRE rule. Columns (1)-(4) present coefficients from the difference-in-difference specification excluding loans with an LTV between 0.50 and the supervisory maximum. Columns (5)-(8) restrict the sample to construction loans with no reported net operating income. Columns (1) and (5) includes the set of controls and quarter fixed effects, columns (2) and (6) adds an interaction of the fixed rate dummy with High $\text{LTV}_{i,b,t}$ and Pct. $\text{HVCRE}_{i,b,t}$, columns (3) and (7) additionally includes interactions of the rest of the controls with the treatment variables, and columns (4) and (8) additionally includes bank-quarter fixed effects. Standard errors, in parentheses, are clustered at the bank-quarter level. +,*,** indicate significance at the 10%, 5%, and 1% levels, respectively.

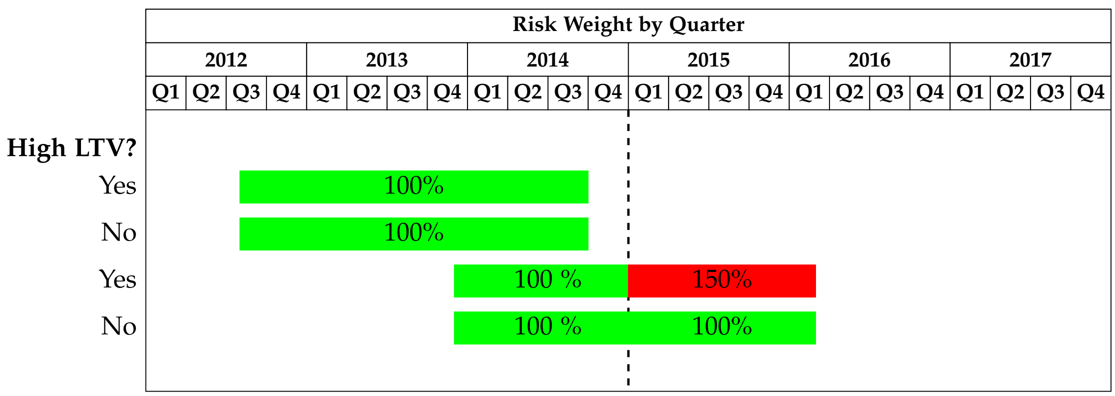


Figure 1: Sources of Variation

This figure shows four loans that are originated after the announcement of the HVCRE rule in June 2012. Two of the loans mature before the HVCRE implementation date in January 2015 (the dotted line), and two of the loans mature after implementation. Two of the loans are classified as HVCRE as they are high LTV, and two are classified as non-HVCRE as they are not. Non-HVCRE loans always carry a 100% risk weight. Before implementation, HVCRE loans carry a 100% risk weight. In the post-implementation period, HVCRE loans carry a 150% risk weight. The average risk weight over the life of the loan will depend on the LTV and exposure to the post-implementation period.

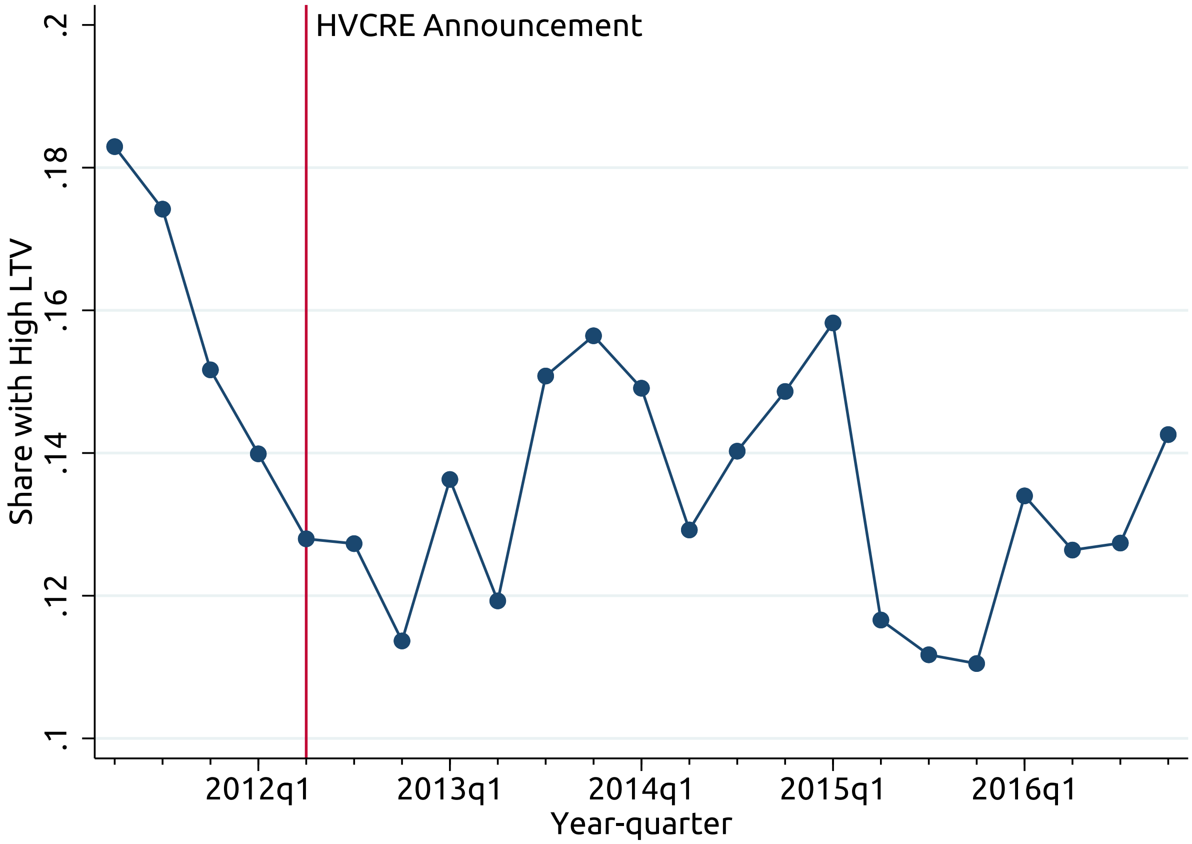
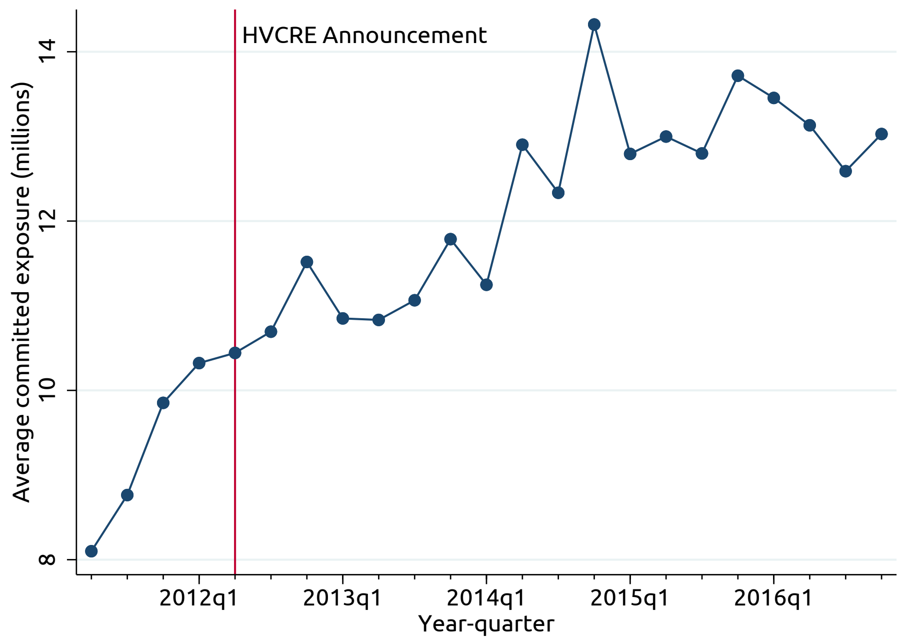
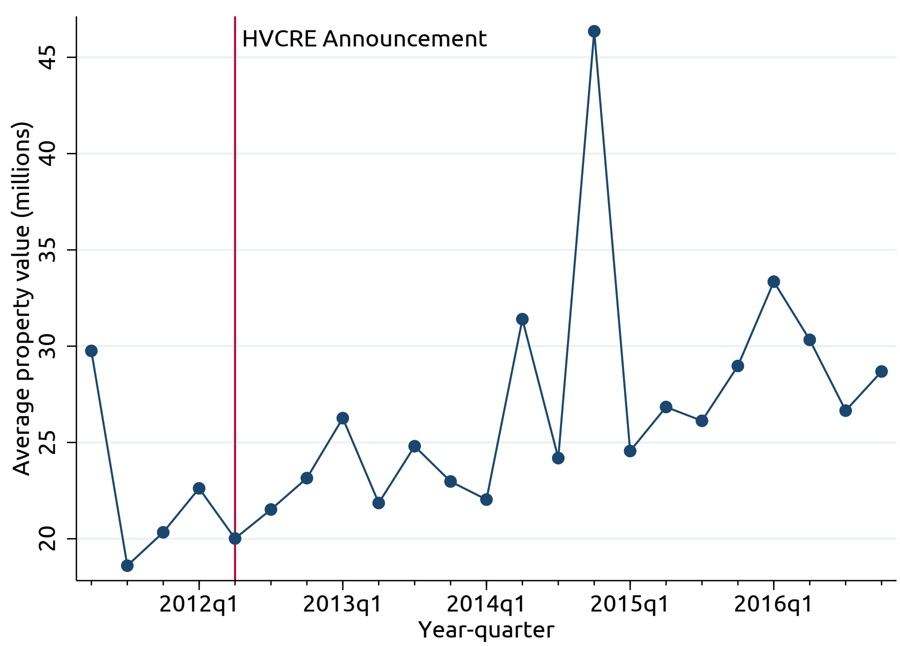


Figure 2: Percent of Newly Originated Non-1-4 Family ADC Loans with a High LTV

This figure displays the quarterly share of newly originated non-1-4 family ADC loans with high LTVs from 2011:Q2 through 2016:Q4.



(a) Average Loan Size



(b) Average Property Value

Figure 3: Average Loan Size and Property Value by Quarter of Origination

The first subfigure shows the average committed exposure (millions) by quarter from 2011:Q2 through 2016:Q4. The second subfigure shows the average property value (millions) by quarter. Valuations and committed exposures are winsorized at the 1% level for this figure.

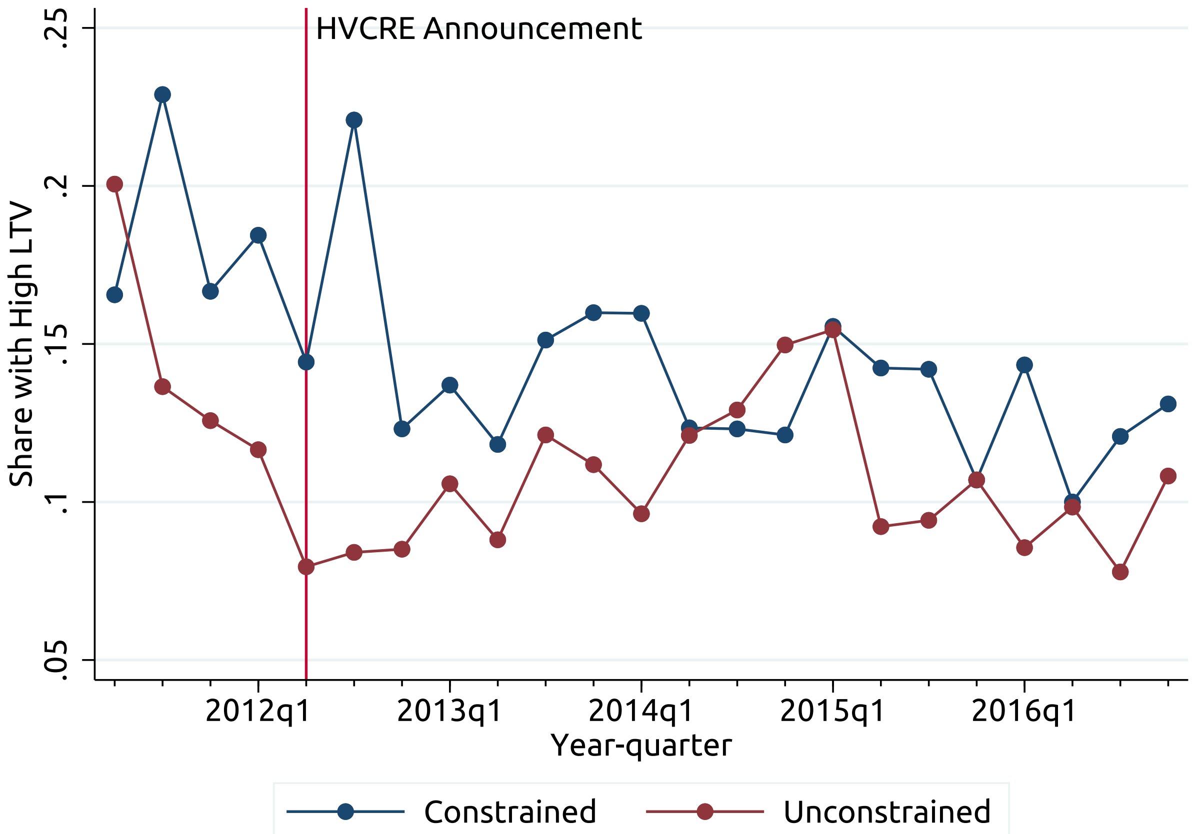


Figure 4: Percent of Newly Originated Non-1-4 Family ADC Loans with a High LTV, by Proximity to Minimal Capital Ratios

This figure displays the quarterly share of newly originated non-1-4 family ADC loans with high LTVs by whether or not the lending bank is classified as capital constrained. Banks are considered constrained if they are closer than the median to its minimum Tier 1 ratio in 2012:Q2 (see the Appendix for details).

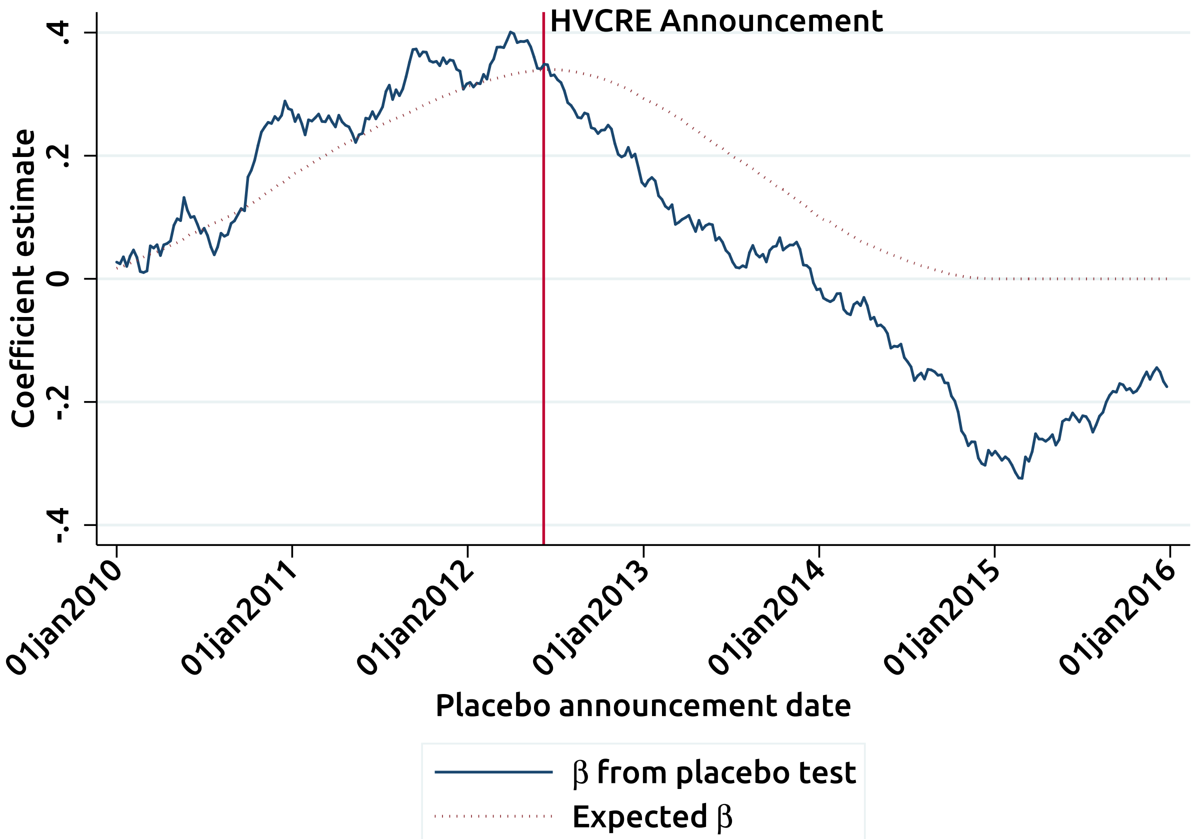


Figure 5: Regression Coefficients By Placebo Announcement Date

This figure plots regression coefficients from placebo tests varying the announcement and implementation dates of the HVCRE rule. The solid line plots the estimated effect of the HVCRE rule for a given placebo announcement date, and the dotted line plots the estimate we would expect assuming pricing was determined by the true announcement/implementation dates.

Specifically, for each week from January 1, 2010 to December 23, 2016, we plot the coefficient from the regression $r_{i,b,t} = \beta(\text{High LTV}_{i,b,t} \times \text{Placebo Pct. HVCRE}_{i,b,t,t'}) + \gamma X_{i,b,t} + \tau_{b,t} + \varepsilon_{i,b,t}$, where Placebo Pct. $\text{HVCRE}_{i,b,t,t'}$ is constructed as if that week (t') were the HVCRE announcement date, holding fixed the time between the placebo announcement and implementation date at the real length (938 days). Besides changing the sample of loans to being those originated between the placebo announcement and implementation date, and changing Placebo Pct. HVCRE to measuring the exposure of a loan to the period after a placebo implementation date, the rest of the variables are as in our baseline specification. That is, $r_{i,b,t,}$ is the interest rate on loan i from bank b at time t. The variable High $\text{LTV}_{i,b,t}$ is an indicator function taking the value of one if the loan to value ratio on the construction loan is above the HVCRE limit, $X_{i,b,t}$ is a vector of the loan level controls (listed in the text) interacted with the two treatment variables, and $\tau_{b,t}$ is a bank-quarter fixed effect.

The dotted line ("Expected β") plots 0.34 times the coefficient from regressing Pct. $\text{HVCRE}_{i,b,t} \times \mathbb{1}_{t \text{ after HVCRE announcement}}$ on Placebo Pct. $\text{HVCRE}_{i,b,t,t'}$, and thus represents the expected coefficient on the placebo regression under the assumption that the results are driven by the HVCRE rule. This reflects how well the placebo HVCRE exposure variable measures the actual exposure to the post-implementation period, adjusting for the fact that the effects of the HVCRE rule should not be priced in before the rule was announced.

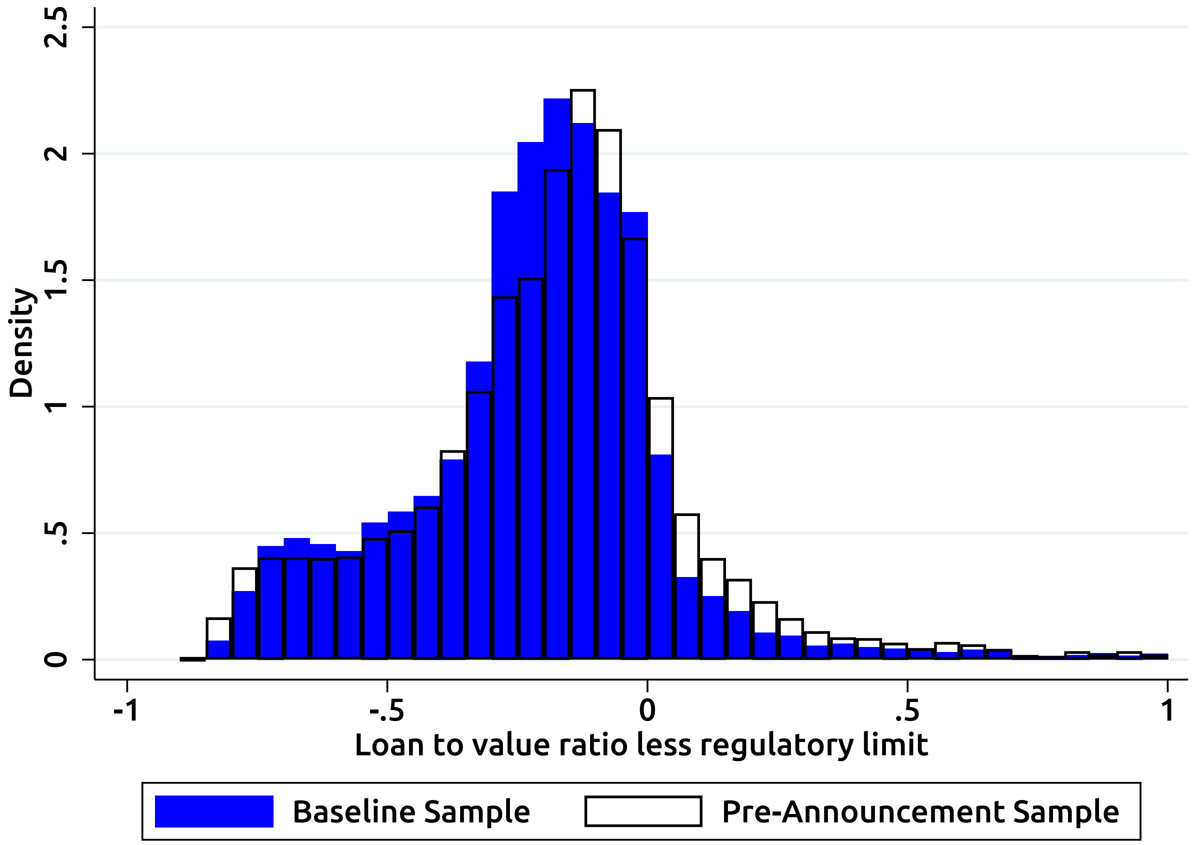


Figure 6: Density of Loan to Value Ratios Relative to Regulatory Limit

This figure displays the distribution of the difference between the loan to value ratio of a non-1-4 family ADC loan, and the supervisory LTV limit for that type of loan. The histogram for post-announcement loans is in blue, and pre-announcement loans is in white. Values above 1 are suppressed due to a long right tail in the LTV distribution.

A Online Appendix

In this online appendix, we present additional summary statistics and results.

Online Appendix Table 1
Summary Statistics for Loan Variables in the Different Samples

	Baseline sample of non-1-4 family ADC loans							
	Mean	Std	p1	p25	p50	p75	p99	N
Interest rate (percentage points)	3.24	0.99	1.55	2.50	3.00	3.75	6.00	8823
Percent maturing after January 1, 2015	0.56	0.34	0.00	0.26	0.64	0.87	1.00	8823
High LTV (1 if LTV exceeds supervisory max)	0.14	0.34	0.00	0.00	0.00	0.00	1.00	8823
Risk rating (1-10)	6.11	0.76	4.00	6.00	6.00	6.00	8.00	8823
Committed exposure at origination ($ millions)	11.63	13.81	0.28	2.10	5.92	16.00	68.00	8823
σ(Δ ln(House Prices))	6.76	3.33	1.91	3.92	6.34	9.12	14.92	8823
Time to maturity at origination (yrs.)	4.57	5.19	0.44	2.00	3.00	5.00	25.50	8823
Floating rate (0) or fixed (1)	0.13	0.34	0.00	0.00	0.00	0.00	1.00	8823
Loan to Value ratio	0.67	0.59	0.03	0.48	0.62	0.75	4.87	8823
	Sample of 1-4 family construction loans							
	Mean	Std	p1	p25	p50	p75	p99	N
Interest rate (percentage points)	4.02	0.89	2.25	3.25	4.00	4.75	6.00	2037
Percent maturing after January 1, 2015	0.40	0.35	0.00	0.00	0.37	0.72	0.99	2037
High LTV (1 if LTV exceeds supervisory max)	0.11	0.32	0.00	0.00	0.00	0.00	1.00	2037
Risk rating (1-10)	5.95	0.89	2.00	6.00	6.00	6.00	7.00	2037
Committed exposure at origination ($ millions)	4.70	7.05	0.08	1.20	2.00	5.00	45.00	2037
σ(Δ ln(House Prices))	7.13	3.23	2.05	4.33	7.03	9.75	14.17	2037
Time to maturity at origination (yrs.)	2.01	2.62	0.34	1.00	1.49	2.00	16.98	2037
Floating rate (0) or fixed (1)	0.16	0.36	0.00	0.00	0.00	0.00	1.00	2037
Loan to Value ratio	0.71	0.71	0.00	0.44	0.67	0.75	5.26	2037
	Sample of loans originated before announcement							
	Mean	Std	p1	p25	p50	p75	p99	N
Interest rate (percentage points)	3.97	1.19	1.56	3.01	4.00	4.80	7.25	6712
Percent maturing after June 7, 2012	0.45	0.37	0.00	0.00	0.49	0.81	0.99	6712
High LTV (1 if LTV exceeds supervisory max)	0.19	0.39	0.00	0.00	0.00	0.00	1.00	6712
Risk rating (1-10)	5.41	1.49	1.00	5.00	6.00	6.00	8.00	6712
Committed exposure at origination ($ millions)	8.08	9.86	0.36	1.83	4.09	10.00	50.75	6712
σ(Δ ln(House Prices))	6.63	3.32	1.93	3.71	6.16	8.85	15.24	6712
Time to maturity at origination (yrs.)	3.48	4.34	0.11	1.11	2.01	3.49	25.00	6712
Floating rate (0) or fixed (1)	0.12	0.33	0.00	0.00	0.00	0.00	1.00	6712
Loan to Value ratio	0.66	0.42	0.00	0.48	0.65	0.77	3.33	6712

This table reports the distribution of the loan-level variables used in our baseline sample of non-1-4 family ADC loans (top panel), control group of 1-4 family ADC loans (middle panel), and placebo sample of loans originated before the announcement of the HVCRE rule (bottom panel). N is the number of nonmissing observations for that variable. The variable σ(Δln(House Prices)) is the standard deviation of the annual change in house prices of the zip code of loan. Further information on variable construction can be found in the Appendix.

Online Appendix Table 2
Triple Difference Estimate: Placebo Sample

	Effect on Interest Rates (percentage points)							
	Sample of ADC Loans				Sample of CRE Loans			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
High LTV x Pct. HVCRE x Non-1-4 family ADC	-0.30	-0.34	-0.47*	-0.37	0.02	0.02	-0.08	-0.11
	(0.24)	(0.23)	(0.24)	(0.25)	(0.12)	(0.12)	(0.12)	(0.12)
High LTV x Pct. HVCRE	0.50*	0.47*	0.60*	0.45^{+}	0.16^{+}	0.10	0.19*	0.21**
	(0.23)	(0.23)	(0.24)	(0.24)	(0.09)	(0.09)	(0.09)	(0.08)
Pct. HVCRE	-0.19	-0.22	0.44	0.01	0.06	-0.00	0.68	0.32
	(0.14)	(0.14)	(0.75)	(0.75)	(0.10)	(0.10)	(0.50)	(0.48)
High LTV	-0.15	-0.16	0.14	0.10	0.05	0.02	0.66	0.72^{+}
	(0.11)	(0.11)	(0.56)	(0.55)	(0.05)	(0.05)	(0.42)	(0.41)
Non-1-4 family ADC x Pct. HVCRE	-0.21	-0.21	-0.03	0.13	-0.30**	-0.26**	-0.26*	-0.22*
	(0.14)	(0.14)	(0.14)	(0.15)	(0.09)	(0.08)	(0.10)	(0.10)
High LTV x Non-1-4 family ADC	0.07	0.07	0.13	0.14	-0.13^{+}	-0.11	-0.02	0.01
	(0.12)	(0.12)	(0.13)	(0.13)	(0.07)	(0.07)	(0.09)	(0.09)
Non-1-4 family ADC	2.47**	2.48**	2.21**	1.81**	0.43	0.40	0.61^{+}	0.23
	(0.67)	(0.67)	(0.69)	(0.68)	(0.35)	(0.34)	(0.34)	(0.33)
Loan controls	X	X	X	X	X	X	X	X
Qtr FE	X	X	X		X	X	X	
Controls $\times${Non-1-4 Fam ADC}	X	X	X	X	X	X	X	X
$\mathbb{1}_{\text{Fixed Rate}}\times${Pct. HVCRE; High LTV}		X				X		
Controls $\times${Pct. HVCRE; High LTV}			X	X			X	X
Bank-Qtr FE				X				X
R^2_a	0.246	0.247	0.253	0.315	0.337	0.339	0.346	0.392
No. banks	30	30	30	30	38	38	38	38
No. loans	8057	8057	8057	8057	34338	34338	34338	34338

This table reports coefficients from the following regression:

$$r_{i,b,t} = \beta(\text{High LTV}_{i,b,t} \times \text{Pct. HVCRE}_{i,b,t} \times \text{Non-1-4 family ADC}_{i,b,t}) + \gamma X_{i,b,t} + \tau_{b,t} + \varepsilon_{i,b,t},$$

for the sample of loans originated between January 1, 2010 and the announcement of the HVCRE rule. The variable $r_{i,b,t}$ is the interest rate on loan i from bank b at time t. The variable High LTV$_{i,b,t}$ is an indicator function taking the value of one if the loan to value ratio on the construction loan is above the HVCRE limit, the variable Pct. HVCRE$_{i,b,t}$ is the percentage of the life of the loan occurring after the announcement date, and the variable Non-1-4 family ADC$_{i,b,t}$ is an indicator for whether the loan is an ADC loan for a non-1-4 family property. $X_{i,b,t}$ is a vector of the loan level controls listed in Table 2 and Section 2.3, the lower order interaction of the treatment variables, and in some specifications the interaction of these variables with the loan controls. $\tau_{b,t}$ is a bank-quarter fixed effect. Columns (1)-(4) present the triple difference results for the sample of ADC loans, while columns (5)-(8) present the findings for the full sample of CRE loans. Columns (1) and (5) includes the set of controls and quarter fixed effects, columns (2) and (6) adds an interaction of the fixed rate dummy with High LTV$_{i,b,t}$ and Pct. HVCRE$_{i,b,t}$, columns (3) and (7) additionally includes interactions of the rest of the controls with the treatment variables, and columns (4) and (8) additionally includes bank-quarter fixed effects. Standard errors, in parentheses, are clustered at the bank-quarter level. +,*,** indicate significance at the 10%, 5%, and 1% levels, respectively.