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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 loan 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 about 40 basis points for HVCRE loans, indicating that a one percentage point increase in required capital raises loan rates by about 9.5 basis points.

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

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1 Introduction

How does the stringency of bank capital requirements affect the interest rates charged to borrowers? Requiring banks to increase equity funding, which has a higher required return than debt, could increase bank funding costs and cause borrowing to become more expensive for bank customers. However, the effects could be minimal if either cost increases do not pass through to borrowers, or if changes to capital structure have an offsetting effect on required returns (Modigliani and Miller, 1958). As much of the previous literature on this topic relies on calibrated models of bank funding, estimates of the likely costs of increased capital requirements vary widely, often reflecting different assumptions about this Modigliani-Miller offset (see Dagher et al. (2016) for a review).

This paper provides an empirical estimate of how changes in capital requirements impact bank loan rates using a quasi-experiment. Specifically, we use loan-level data from U.S. bank stress tests to identify how loan rates respond to a 50% increase in capital requirements for a subcategory of commercial real estate (CRE) loans. Using both a difference-in-differences (diff-in-diff) estimate exploiting variation in the time that a treated loan would be subject to the increased capital requirements, and a triple-difference approach additionally exploiting variation in whether a loan falls into a CRE loan category which is subject to the higher capital requirements, we demonstrate that increased capital requirements have a moderate effect on bank loan rates.

The planned increase in capital requirements was announced as part of the Basel III regulatory framework in a June 2012 Notice of Proposed Rulemaking. Bank regulators proposed designating non-1-4 family acquisition, development, and construction (ADC) loans without sufficient borrower contributed capital as "High Volatility Commercial Real Estate" (HVCRE) and increased the risk weight on these loans from 100% to 150%. As banks face a regulatory minimum ratio of total capital to risk weighted assets of 8 percent, this rule implies banks would need to fund 12 percent of an HVCRE loan with equity starting when the rule gets implemented in 2015, compared to 8 percent before 2015. 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. This enables us to identify the effect of the HVCRE rule with a diff-in-diff approach, comparing how the increased interest rate charged on high loan-to-value (LTV) loans varies by the exposure of the loan to the post-implementation period. Our headline result is that the increased capital requirement caused banks to raise interest rates on HVCRE loans by 38 basis points. Alternatively put, a 1 percentage point increase capital requirements results in about a 9.5 basis point increase in loan rates, an estimate around the middle of the range of values offered in the prior literature.

While the sample for our diff-in-diff specification is restricted to non-1-4 family ADC loans, the fact that not all CRE loan categories were subject by the rule 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 date 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. These triple-difference results indicate that we are picking up an effect that is due to the HVCRE rule instead of a general pricing relationship for long-maturity, high-LTV CRE loans.

The triple-difference results do not, however, rule out that there may be higher rates for long-maturity, high-LTV loans for other reasons specific to the non-1-4 family ADC market. To address this concern, we run a placebo test repeating our baseline diff-in-diff analysis for a sequence of placebo HVCRE announcement and implementation dates. The estimated effect size is maximized around when the placebo dates correspond with the real announcement and 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 treatment is orthogonal to the actual treatment. The placebo results thus demonstrate that the pricing of construction loans only interacts with maturity and LTV to the extent that it influences risk weighting under the HVCRE rule, instead of being a general pricing relationship.

The triple-difference approach and placebo tests confirm that our findings are restricted to the loan category and time period in which we should see effects. Yet, these results do not necessarily rule out some other development besides the HVCRE rule. For example, an increase in demand for long-maturity, high-LTV, non-1-4 family ADC loans following the rule's announcement would bias our results. We address this concern that we are not observing a supply response to the rule by exploiting variation across banks. Banks for whom risk-based capital constraints are slack should be less affected by the change in risk weights (see Greenwood et al. (2017)). Instead, it should be the banks closer to a risk based constraint which would need to raise 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 which are closer to their Tier 1 risk-based capital constraint. Given there is no reason to believe that demand would only increase for borrowers at banks closer to their risk-based constraint, we can more confidently claim our results are driven by a supply-side response to the HVCRE rule.

A final concern may be that our findings partly reflect an endogenous change in the composition of borrowers in response to the proposed rule. For example, if the rule increases the cost of high leverage borrowing, borrowers would be expected to try to raise more equity. If large experienced developers are more able to raise equity and reduce LTVs, then riskier borrowers might disproportionately take out loans more affected by the rule. In this situation, our estimates would reflect both the effect of the rule on bank funding costs, as well as the premium banks require from the riskier borrowers who are unable to raise equity. We find little support for this mechanism however. Treated loans actually have a lower, albeit insignificant, estimated probability of default. Furthermore, there was no evidence of a reduction in the share of ADC loans with a high LTV after the announcement of the HVCRE rule.

Our paper most relates to other work studying how capital requirements affect bank loan rates. In a review of this literature, Dagher et al. (2016) notes that the predicted impact of a one percentage point increase in capital requirements varies widely, ranging from around 2 basis points up to about 20 basis points. Our estimated effect of about 10 basis points for each percentage point increase in capital requirements puts us around the middle of that range. The lack of consensus partially reflects the fact that historically most estimates come from calibrated models of bank funding costs, with disparate assumptions about the strength of Modigliani and Miller (1958) offsets. Namely, papers estimating small effects on loan rates like Kashyap et al. (2010) 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. We advance this work by empirically estimating how interest rates respond to plausibly exogenous variation in capital requirements, thus eliminating the need to make assumptions about the extent of Modigliani and Miller (1958) offsets or loan rate pass through.[1]

The closest papers to ours within this literature use loan-level data to study the effects of changes in capital requirements for banks in Europe. Bridges et al. (2014), Gropp et al. (2018), Jiménez et al. (2017), and Basten and Koch (2015) all use bank-time variation to study how banks respond to changes in capital requirements.[2] Our paper has the advantage of using within bank-quarter variation in required capital across different loans, and thus has less risk of being biased by other bank level variables related to capital requirements.

Fraisse et al. (2015), Behn et al. (2016), and Benetton et al. (2017) all use within-bank variation in loan risk weights induced by the Basel II implementation of internal ratings-based capital requirements in Europe, and show that changes in capital requirements have large effects on loan rates or volumes. That we find more modest effects may be a result of the timing of the changes in capital requirements. Basel II was implemented near the height of the Global Financial Crisis in 2008, whereas the HVCRE rule went into effect late in the recovery from the Global Financial Crisis, and is likely more reflective of the banking environment in the current steady state. Consistent with this, the magnitude of our estimated effect is in line with Plosser and Santos (2018) who study changes in fees

[1] Kisin and Manela (2016) also estimates 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.

[2] Wallen (2017) similarly studies the relationship between bank capitalization and interest rates on U.S. syndicated loans.

on undrawn commitments following the increase in risk weights on longer-term unused commitments around the Basel I implementation in the early 1990's.

Finally, our paper also relates to the large literature studying how bank capital requirements affect bank loan volumes. A number of papers show 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). However, if demand for bank loans is relatively inelastic, the small effects on lending often identified in these empirical studies do not rule out the possibility of significant changes in bank funding costs and loan rates. An analysis of loan pricing is needed to get a full picture of how capital requirements affect the supply of bank credit.

The rest of the paper proceeds as follows. Section 2 provides background on the HVCRE rule. Section 3 describes our data and empirical strategy. Section 4 discusses the results, and Section 5 concludes.

2 Background on High Volatility Commercial Real Estate

Housing market distress played a central role in the early stages of the financial crisis. While mortgage losses, particularly through mortgage backed securities, are often emphasized, losses on CRE loans, particularly those for construction and land development, played an out-sized role in imposing losses on the banking sector. For example, Friend and Nichols (2013) show that 22.9% of banks with a heavy concentration in CRE ultimately failed, while only 0.5% of other banks failed.[3]

Motivated by these significant losses, when US bank regulators announced the new proposed rules for risk-weighted capital requirements, there was a particular emphasis on requiring banks to increase capital for risky ADC loans. As part of the new Basel III regulatory framework, regulators created a new loan category: High Volatility Commercial Real Estate (HVCRE). An HVCRE loan was defined as a credit facility to finance the

[3] A bank is considered concentrated in CRE if either ADC loans are at least 100% of risk-based capital or the total CRE portfolio is at least 300% of risk-based capital, in addition to a CRE loan growth criteria.

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 real estate's appraised "as completed" values, 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.[4] In order to require that banks hold capital commensurate with the elevated risk that these loans carry, the new rule set the risk weight on HVCRE loans at 150%, instead of 100% as it had been previously. The risk weight for other CRE loans, namely non-ADC CRE loans and ADC loans exempt from the HVCRE rule, remained at 100%.[5]

The initial proposed 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.[6] 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.[7]

[4] 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.

[5] 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`.

[6] 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)).

[7] 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 passed on May 24, 2018.

3 Data and Empirical Strategy

Data The primary data used in this paper comes from Schedule H.2 of the FR Y-14Q, which contains the loan-level data from 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.[8] The data includes the loan's interest rate, committed exposure, purpose (e.g., construction vs. acquisition), type (e.g., non-1-4 family vs. 1-4 family), dates of origination and maturity, as well as the zip code and appraised value of the property securing the loan. Banks report this microdata for all loans with a committed exposure above $1 million. Details on data cleaning and variable construction are in Appendix A.

Identifying HVCRE Loans Roughly three conditions have to hold for a loan to be subject to increased capital requirements: 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 which 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 Y-14Q data.[9] Construction loans are considered to have a high LTV if the LTV is above 0.80 unless

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

[9] 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.

the loan purpose is "Construction Other" and the property has non-zero and non-missing net operating income, 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 4, 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.

Empirical Strategy The basic empirical strategy is to study how the interest rate markup on high LTV construction loans varies 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 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:

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

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 ($\mathbb{1}_{\text{HVCRE loan}_i}$).

This facilitates a diff-in-diff approach to estimating the effect of the new 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 which occurs after the implementation date. Intuitively, a loan originated after the announcement of the HVCRE rule which 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 impacted 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 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, while Pct. 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 ($\tau_{b,t}$). 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 estimated probability of default, or the house price volatility in the zip code.

The variable $X_{i,b,t}$ includes the non-interacted treatment variables High $\text{LTV}_{i,b,t}$ and Pct. $\text{HVCRE}_{i,b,t}$, as well as the following loan level controls: the annual volatility of zip code level house prices, the logarithm of the committed exposure, as well as indicator variables specifying whether the loan rate is fixed or floating, whether the loan is for a multifamily property, whether the value used in LTV ratio corresponds to the "as completed" value, and whether the borrower is rated BBB or higher. 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.

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.

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

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

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 $X_{i,b,t}$ 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-HVCRE 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 are 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. Consequently, we treat this approach as a supplemental robustness check.

This triple-difference methodology addresses the concern that 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 were impacted 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.

4 Empirical Analysis

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 the same statistics for the sample of 1-4 family ADC loans originated during this period, which are used as the primary control group in the triple-difference specification. The bottom panel shows the statistics for the non-1-4 family ADC loans originated between January 2010 and the announcement date, which we use in one of our placebo tests. Here, we discuss properties of some of the key variables in our analysis.

Loans in the baseline sample have a median interest rate of about three percent and a median maturity of three years, resulting in about two thirds of the life of a typical loan extending after the implementation date. The median LTV is 0.63, with 16 percent of loans having an LTV above supervisory limits.

Characteristics of 1-4 family ADC loans and pre-announcement non-1-4 family ADC loans typically do not differ dramatically from the characteristics of loans in the baseline sample. The median interest rate in each of the control groups is a percentage point above the interest rate for the baseline sample of post-announcement non-1-4 family loans. This higher rate may partly reflect the fact that loans in the control groups have higher average estimated probabilities of default. Loans in the control groups also have somewhat shorter loan maturities and smaller loan sizes.

There are also notable differences in the propensity to make high LTV loans across the different samples. Although the median LTV is similar in the three samples, ranging from 0.63 to 0.67, only 10 percent of 1-4 family construction loans have an LTV above 0.8, whereas 21 percent of loans in the pre-announcement sample exceed supervisory limits. The high LTV share in the baseline sample is between these extremes at 16 percent.

Figure 1 demonstrates that there is little trend in the propensity to originate high-LTV, non-1-4 family ADC loans. High LTV originations constitute between 14 and 18 percent of the value of non-1-4 family ADC originations just about every quarter, with no visible change around the rule announcement. Figure 2 plots the average loan size and property valuation for new originations of non-1-4 family ADC loans over time. Each series shows a steady upward trend, but again there is little apparent change around the time of announcement. The disparity in the share of high LTV loans between the pre-announcement sample and the baseline sample seems to be attributable to low valuations for properties securing 2010 loans.

Figure 3 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 a clear shift in the distribution to lower LTVs after the announcement of the rule as has already been demonstrated. There is also evidence of bunching below the regulatory limit, with a fairly steep drop in the frequency of loans with an LTV above the limit. However, it is somewhat unclear whether this bunching increased as a result of the announcement of the rule. The pre-announcement sample has more loans just above and just below the limit, whereas the baseline sample has more density where the LTVs are comfortably below regulatory limits.

Main Results We present the main results for how the HVCRE rule impacted bank loan rates in Table 2. The first three columns 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 last four columns present the triple-difference estimates, expanding the sample to additionally include 1-4 family ADC loans (columns 4 & 5) and non-ADC CRE loans (columns 6 & 7), and testing for a differential effect on the non-1-4 family ADC loans which were impacted by the rule.

In the diff-in-diff specification, 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 0.59 on the interaction term. This means that a high LTV loan is expected to carry an interest rate which is 59 basis points (bp) higher as a result of the HVCRE rule.

The specification in the second column adds bank-quarter fixed effects, which do not meaningfully change the estimates. However, when we interact the loan controls with the two treatment variables in the third column, the magnitude of the effect drops to 38bp. This drop is predominantly due to the interaction of the fixed rate dummy with the variable Pct. HVCRE. Since fixed rate loans disproportionately have higher LTVs and are more expensive for longer maturities, this omitted variable likely biases the estimated coefficient on the interaction in the first two columns. Thus, the 38 basis point effect found in our fully-interacted specification is our preferred estimate of the effect of the HVCRE rule.

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 9.5 basis points.[10] 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 in the middle of the range of prior estimates.

While our results 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. 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.

The triple-difference approach is one attempt 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 which 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. We take the pricing of either 1-4 family ADC loans (columns 4 and 5) or non-ADC CRE loans (columns 6 and 7) as a control for how the interaction of High $\text{LTV}_{i,b,t}$ and Pct. $\text{HVCRE}_{i,b,t}$ would influence the pricing of CRE loans independent of the regulation. Our estimated effect of the rule on interest rates is then the additional magnitude of this interaction effect for the category of loans subject to the rule, given by the coefficient on High $\text{LTV}_{i,b,t} \times$ Pct. $\text{HVCRE}_{i,b,t} \times$ Non-1-4 family $\text{ADC}_{i,b,t}$.

[10]Banks face multiple and heterogeneous capital constraints, thus the proper denominator in this exercise is somewhat ambiguous. For example, a 50% increase in the 4.5% common equity tier 1 constraint means a 2.25 percentage points increase in required common. 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.

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 4 and 5 run the triple-difference specification for the sample of ADC loans originated between the announcement and implementation of the HVCRE rule. 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 virtually zero in both specifications. The coefficient on the triple interaction, however, is 0.67 in the specification with bank-quarter fixed effects and loan controls interacted with the non-1-4 family ADC dummy, and 0.40 in the fully-interacted specification, nearly identical to the coefficients of 0.62 and 0.38 found in the diff-in-diff specifications. Although the triple-difference approach substantiates the magnitude of the earlier findings, these estimates are imprecise due to the fact that the sample includes fewer than 2000 1-4 family construction loans, only about a tenth of which have an LTV above 0.8. As a result, the coefficient on the triple interaction is insignificant in the specification with the more thorough controls.

Columns 6 and 7 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 find a negative interaction between LTV and exposure to the HVCRE period. Consequently, the coefficients on the triple interaction are higher than before at 1.05 and 0.78. This difference is also more precisely estimated, as the sample size expands significantly compared to the specification with only construction loans. However, the control group is also more dissimilar to the treatment category than before, thus we would be hesitant to take this finding as an indication of a downward bias in the earlier estimates.

Placebo Test 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. For each placebo announcement date t', we construct a variable Placebo Pct. $\text{HVCRE}_{i,b,t,t'}$ which equals the percentage of the life of the loan maturing after the placebo HVCRE implementation date $t' + k$, where k is the number of days between the real announcement and implementation dates of the HVCRE rule (so 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 0.38 in our diff-in-diff specification, we would expect interest rates to be:

$$r_{i,b,t} = 0.38 \times (\text{High LTV}_{i,b,t} \times \text{Pct. HVCRE}_{i,b,t} \times \mathbb{1}_{t \text{ after HVCRE announcement}}) + \gamma X_{i,b,t} + \varepsilon_{i,b,t}, \quad (3)$$

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 should be:

$$\frac{\partial r_{i,b,t}}{\partial \text{Placebo Pct. HVCRE}_{i,b,t,t'}}\bigg|_{\text{High LTV=1}} = 0.38 \times \frac{\partial \text{Pct. HVCRE}_{i,b,t} \times \mathbb{1}_{t \text{ after HVCRE announcement}}}{\partial \text{Placebo Pct. HVCRE}_{i,b,t,t'}}.$$

Figure 4 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. $\text{HVCRE}_{i,b,t,t'} \times \text{High LTV}_{i,b,t}$ for the corresponding regression. We also plot 0.38 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 on the placebo regression under the assumption that the results are driven by the HVCRE rule. The estimate on the placebo regression is maximized around where 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 slightly negative for most dates after that.

Table 3 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. Again, as the rule was not known when these loans were originated, we should find no effects.

The estimated effects of the HVCRE rule are around zero for both the diff-in-diff and triple-difference placebo regressions. 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, which produced a coefficient of 0.38 in the baseline results, we recover a coefficient of 0.06 in the placebo sample. The coefficient on the triple-interaction term is negative and insignificant in the triple-differences specification comparing the pricing of 1-4 family construction loans to non-1-4 family ADC loans. When the control group includes non-ADC loans, the coefficient on the triple interaction is below 0.10, compared to being above 0.75 before.

Heterogeneous Effects 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. For example, demand for longer-maturity, high-LTV loans could have risen around that time.

If interest rates rose due to demand, this effect would likely have a similar effect across banks. However, if the increase in interest rates reflects higher risk weights on treated loans, this would matter to some banks more than others. 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 HVCRE rule would not impact required capital.

In contrast, banks for whom 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 which 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 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 $\frac{\text{Common Equity Tier 1}}{\text{Risk Weighted Assets}}_{b,t} - 0.06 - \text{Surcharge}_b$, where Surcharge_b is the bank-specific surcharge over regulatory minimum capital requirements required of global systemically important banks.[11] Using this distance variable, we then construct a dummy variable, Capital Constrained_b, which takes a value of one if the bank's distance to the constraint is less than the median for the quarter. We then repeat our primary analysis, additionally including interactions with the dummy for whether the bank is close to its Tier 1 risk-based capital constraint.

Table 4 shows that the previous results are driven almost entirely by the banks which are closer to their Tier 1 capital constraint. The first two columns present the results of interacting our diff-in-diff specification with the capital constrained dummy. Looking at the coefficient on the interaction of the high LTV dummy and the percentage of the loan that extends beyond the implementation of the HVCRE rule, we see that unconstrained banks react little to the HVCRE rules. These banks are estimated as increasing interest rates by 14bp and 24bp in the specifications with and without the fully interacted controls. Estimates are either statistically insignificant or only marginally significant. In contrast, constrained banks are estimated as increasing interest rates by 49bp and 85bp in the specifications with and without the fully-interacted controls, with the difference from non-capital constrained banks being significant at the 10% and 1% level respectively.

The difference between capital constrained and unconstrained banks is starker when we test for heterogeneous effects in the triple difference specification. The coefficient on

[11] Since the surcharge is 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. However, results are little changed when the surcharge is taken to be either 0 or fully phased in. 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`

the quadruple interaction reflects the difference in the triple difference estimate between constrained and unconstrained banks. The estimate is over 85 basis points and significant at the 1% level in every specification.

In short, the increase in interest rates for non-1-4 family ADC loans demonstrated earlier in the paper is almost entirely driven by loans from banks for whom changes in risk weights would be expected to influence behavior.

Effects on Loan Composition While the bulk of the evidence points towards the HVCRE rule causing an increase in interest rates, there may still be a question as to whether or not 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 bias from this potential selection mechanism is ambiguous. On the one hand, better quality borrowers may be more able to raise equity and fund projects with an LTV which is low enough to avoid the higher interest rates that go with the HVCRE designation. This would mean that borrowers who take out loans which are more treated by the HVCRE rule would be to riskier than other high LTV 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.

We test for a change in the riskiness of borrowers in Table 5. Specifically, we repeat the previous diff-in-diff analysis replacing the loan interest rate with a measure of the riskiness of the loan. In the first two columns, the dependent variable is the bank's internally generated estimate of the loan's probability of default.[12] In the next two columns, the dependent variable is the loss given default rate, measuring the expected loss severity in the

[12] Banks that are subject to the advanced approach for regulatory capital must submit the advanced IRB parameter estimate for the loan's year-ahead probability of default. Banks that are not subject to the advanced approach for regulatory capital can report the probability of default estimate corresponding to the internal rating on the loan.

event of default. In the last two columns, the dependent variable is the volatility of house prices in the zip code of the property.

We find little evidence of a relationship between loan risk and the extent to which the loan is impacted by the HVCRE rule. High LTV loans which are more exposed to the post-implementation period have a lower estimated probability of default and lower expected losses in the event of default. However, the estimates are insignificant or barely significant in the fully interacted specification. In contrast, loans more impacted by the HVCRE rule are shown to be originated in zip codes with more volatile house prices, although the coefficients are also insignificant. Overall, there is little to indicate that the increase in interest rates found in our diff-in-diff results reflects elevated risk in treated loans.

Combined with the finding in Figure 1 that there was little change in the propensity to originate high-LTV, non-1-4 family ADC loans, the evidence generally points toward adjustments occurring in pricing as opposed to in the composition of lending.

Evaluating Bias From Measurement Error As few would expect capital requirements to be irrelevant to loan pricing, the contribution of this paper is in quantifying such an effect. For example, our finding that a one percentage increase in capital requirements leads to about a 10 basis points increase in loan rates can be a useful metric in calibrating models used to assess trade-offs from increased capital requirements or the interaction of capital requirements with other policies. Thus, it is important to assess the size of the downward bias due to potentially misclassifying some loans as untreated that are treated.

To understand this bias, consider a \$9 million project where the borrower contributes \$1 million and borrows the rest. If the appraised value of the property as of completion is \$10 million, the loan would have an LTV of 0.8, and would not exceed supervisory limits, but the borrower contributed capital would be only 10% of the value, below the 15% required to be exempt from the rule. It would take a \$1.5 million borrower contribution for this same loan to be exempt, and the LTV ratio would be 0.75 in this case.

Since we do not observe borrower contributed capital, some loans below the supervisory threshold are likely HVCRE loans. This would result in us underestimating the effects of the rule, as some of our control loans would be priced as HVCRE loans, diminishing the difference between treatment and control groups. To address this concern, we repeat the analysis dropping loans with LTVs which are below supervisory limits but not substantially so. The idea is that a construction loan with an LTV ratio of 0.75 is likely to have too small a down payment, whereas a loan with an LTV ratio under 0.50 is unlikely to be HVCRE and thus should be a safer control.

Table 6 presents the results from repeating the diff-in-diff and triple difference specifications, however excluding loans with an LTV between 0.50 and the supervisory limit.[13] The coefficients generally rise somewhat, as would be expected if we were excluding the low LTV loans which were more likely to be misclassified as non-HVCRE loans. However, the change in the estimated effect size is small. In our preferred fully interacted diff-in-diff specification, the estimated effect of 40 basis points is not meaningfully different from the previous estimate of 38 basis points. We also display results for the triple-difference specifications. In this case, we drop loans with an LTV above 0.50 from the control group as well. Dropping the loans with an intermediate LTV results in marginally higher estimates when 1-4 family ADC loans are the control category, and marginally lower estimates when non-ADC CRE loans are the control category. In both cases, the estimates are not substantially different from our baseline triple-difference estimates.

Generally, the robustness to excluding marginal loans indicates that the downward bias from the misclassifying HVCRE loans is likely to be small. The general takeaway that a one percentage point increase in capital requirements raises loan rates by about 10 basis points is unchanged.

[13] A 50% LTV is about the 25th percentile of the LTV distribution for non-1-4 family ADC loans in our baseline sample. This means we are dropping about 70% of low LTV loans from our baseline sample. Dropping loans with LTVs above 30% or 40% produces similar point estimates, although the standard errors rise as the sample size diminishes.

5 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 40 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.

These estimates imply that a one percentage point increase in required capital raises loan rates by about 9.5 basis points. This elasticity is around the middle of the middle range of existing estimates (see Dagher et al. (2016) for a review of this literature). This is generally consistent with Modigiliani Miller effects partially offsetting the effects of changes in funding composition on funding costs. Namely, calibrations assuming that funding costs are fixed will overstate the effects of capital regulation and estimates assuming that the only cost is a lost tax shield will understate the effects. To put our finding in the context of most the literature using calibrated models of bank funding, in Appendix B we relate our findings to the calibration in Miles et al. (2013). The elasticity of loan rates to capital requirements we find in our studies is consistent with a Modigiliani Miller offset of about 21%.

The estimate is also a useful input into an important policy question: what level of capital requirements is optimal? 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), our findings would generally be supportive of recent regulatory efforts to increase capital requirements. Further, the effect of the rule on interest rates may not imply social costs at all if the increased capital requirements decrease other socially costly distortions (Admati and Hellwig, 2014).

References

Admati, A. and M. Hellwig (2014). *The Bankers' New Clothes: What's Wrong with Banking and What to Do about It*. Princeton University Press.

Aiyar, S., C. W. Calomiris, and T. Wieladek (2014). Does macro-prudential regulation leak? evidence from a uk policy experiment. *Journal of Money, Credit and Banking 46*(s1), 181–214.

Bank of International Settlements (2010). An assessment of the long-term economic impact of stronger capital and liquidity requirements.

Basten, C. and C. Koch (2015). Higher bank capital requirements and mortgage pricing: Evidence from the countercyclical capital buffer (ccb). *BIS Working Papers No. 511*.

Behn, M., R. Haselmann, and P. Wachtel (2016). Procyclical capital regulation and lending. *The Journal of Finance 71*(2), 919–956.

Benetton, M., P. Eckley, N. Garbarino, L. Kirwin, and G. Latsi (2017). Capital requirements and mortgage pricing: Evidence from basel ii. *Working Paper*.

Bernanke, B. S., C. S. Lown, and B. M. Friedman (1991). The credit crunch. *Brookings papers on economic activity 1991*(2), 205–247.

Berrospide, J. M. and R. M. Edge (2010). The effects of bank capital on lending: What do we know, and what does it mean? *International Journal of Central Banking 6*(4), 5 – 54.

Bridges, J., D. Gregory, M. Nielsen, S. Pezzini, A. Radia, and M. Spaltro (2014). The impact of capital requirements on bank lending. *Bank of England Working Paper No. 486*.

Carlson, M., H. Shan, and M. Warusawitharana (2013). Capital ratios and bank lending: A matched bank approach. *Journal of Financial Intermediation 22*(4), 663–687.

Dagher, J. C., G. Dell'Ariccia, L. Laeven, L. Ratnovski, and H. Tong (2016). Benefits and costs of bank capital. *IMF Staff Discussion Note No. SDN/16/04*.

Elliott, D. J. (2010). *A further exploration of bank capital requirements: effects of competition from other financial sectors and effects of size of bank or borrower and of loan type*. Washington: Brookings Institution.

Fraisse, H., M. Le, and D. Thesmar (2015). The real effects of bank capital requirements. *HEC Paris Research Paper No. FIN-2013-988.*.

Friend, Keith, H. G. and J. B. Nichols (2013). An analysis of the impact of the commercial real estate concentration guidance. *Board of Governors of the Federal Reserve System (U.S.)*.

Gambacorta, L. and P. E. Mistrulli (2004). Does bank capital affect lending behavior? *Journal of Financial intermediation 13*(4), 436–457.

Greenwood, R., S. G. Hanson, J. C. Stein, and A. Sunderam (2017). Strengthening and streamlining bank capital regulation. *Brookings Papers on Economic Activity Conference Drafts*.

Gropp, R., T. Mosk, S. Ongena, and C. Wix (2018). Banks response to higher capital requirements: Evidence from a quasi-natural experiment. *The Review of Financial Studies*.

Jiménez, G., S. Ongena, J.-L. Peydró, and J. Saurina (2017). Macroprudential policy, countercyclical bank capital buffers, and credit supply: evidence from the spanish dynamic provisioning experiments. *Journal of Political Economy 125*(6), 2126–2177.

Kashyap, A. K., J. C. Stein, and S. Hanson (2010). An analysis of the impact of "substantially heightened" capital requirements on large financial institutions. *Working Paper*.

Kisin, R. and A. Manela (2016). The shadow cost of bank capital requirements. *The Review of Financial Studies 29*(7), 1780–1820.

Miles, D., J. Yang, and G. Marcheggiano (2013). Optimal bank capital. *The Economic Journal 123*(567), 1–37.

Modigliani, F. and M. H. Miller (1958). The cost of capital, corporation finance and the theory of investment. *The American economic review 48*(3), 261–297.

Peek, J. and E. S. Rosengren (1997). The international transmission of financial shocks: The case of japan. *The American Economic Review 87*(4), 495.

Plosser, M. and J. Santos (2018). The cost of bank regulatory capital. *Federal Reserve Bank of New York Staff Reports Staff Report No. 853*.

Slovik, P. and B. Cournède (2011). Macroeconomic impact of basel iii. *Working Paper 844, OECD Economics Department*.

Wallen, J. (2017). The effect of bank capital requirements on bank loan rates. *Working Paper*.

Appendix A: Data Appendix

The data from the Y-14Q Schedule H.2 was downloaded on January 2, 2018 from the Wholesale Data Mart, which is maintained by staff at the Federal Reserve Bank of Chicago.[14] We clean the raw Y-14Q download by dropping observations that have missing values for any variables we require for our analysis, so the 5-digit zip code of the property (MDRM K453), the "loan purpose" (MDRM G073), the line reported on the FR Y-9C (MDRM K449), or the loan's interest rate (MDRM 7889), committed exposure (MDRM G074), interest rate variability category (MDRM K461), maturity date (MDRM 9914), or origination date (MDRM 9912). We also drop extreme observations, with interest rates below zero or above 25 percent, times to maturity below 0 or above 30 years, or negative committed exposures. Further, we drop observations not relevant to our analysis, such as observations with originations prior to 2010 or loans that are not identified as "fixed" or "floating," with regard to their interest rate variability category. 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). We

[14] 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`.

drop observations for which both value at origination and current value are missing or if the implied loan to value ratio is negative. Loan interest rates, loan to value ratios, loan probabilities of default (MDRM G082), and loan losses given default (MDRM G086) are then winsorized at the 1% level.

The data is reported quarterly; however, since we are interested in the loan characteristics as of origination, we use data from the first time a loan appears in the panel. For a given bank holding company, loans are identified by their "loan number" (MDRM G063). We however 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. The Y-14Q data collection began in the Fall of 2011, so the first appearance of a loan generally corresponds to the quarter of origination in the baseline sample of loans originated between the June 2012 rule announcement and the January 2015 implementation. The placebo sample of loans includes loans originated prior to the announcement of the rule and is thus more reliant on data which is reported after the time of origination. For example, loans originated in 2010 likely do not appear in the data until 2011. A consequence of this is that interest rates on floating rate loans at the time of observation may differ from interest rates at the time of origination. However, from 2010 through 2015 the bank prime rate reported in the H.15 was flat at 3.25% and the 1 month LIBOR never deviated significantly from the 0.25% IOER rate, so any error in measuring interest at origination for these floating rate loans should be minimal.

A loan is designated as non-1-4 family ADC if it has designated loan purpose of either (1) Construction Build to Suit/Credit Tenant Lease, (2) Land Acquisition & Development, or (3) Construction Other and has a line reported on FR Y9-C that is not equal to "1-4 family residential construction loans originated in domestic offices." These "1-4 family residential construction loans" are instead used as a control group in our triple-difference specification.

We define an HVCRE loan as a non-1-4 family ADC loan where the LTV on the loan exceeds 0.75 for loans for the purpose of "land acquisition and development", 0.8 for other ADC loans with no reported net operating income, and 0.85 for other ADC loans with non-zero and non-missing net operating income, reflecting the supervisory limits for land development, construction and property improvement loans respectively. We believe this is the closest indicator for whether a loan would be classified as HVCRE available with the data available to us. The date of the HVCRE rule implementation was January 1, 2015, so the exposure variable for our baseline regression is constructed as the percent of the loan that matures after this date, using the observed maturity and origination dates.

For computing the standard deviation of annual changes in house prices by zip code, we download data from the Federal Housing Finance Agency on Annual House Price Indexes by five-digit zip code.[15] We compute the standard deviation of the given year-over-year change in house prices. We then merge the data by zip code into our loan-level dataset. Our baseline controls are a "fixed" vs. "floating" indicator, the natural log of the loan's committed exposure, the standard deviation of annual changes in house prices by zip code, an indicator for whether the loan's value basis (MDRM K456) is denoted as "as completed," an indicator for whether the property type (MDRM K451) is designated as "Multi-family for Rent (including low income housing)," and an indicator as to whether the internal rating (MDRM G080) by the bank of the borrower is "BBB" or higher. Notice, in cases where the loan's value basis is missing, we set the indicator to be zero rather than dropping these observations. We similarly treat missing observations as zeros for the property type and rating indicators, although there are far few missing cases for these variables.

We also merge in data from the Call Reports (FFIEC 031 and 041) aggregated to the bank-holding company level by quarter. 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 Call Report, 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 Common Equity Tier 1 constraint, we assume the G-SIB surcharge (as of January 2017 ratios) and Capital Conservation buffers are half-way phased in throughout our sample. We note that the constraint itself only differs for

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

banks subject to the G-SIB surcharge. That is, the constraint is 4.5% plus half of the phase in of the 2.5% capital conservation buffer (so 5.75% 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 the Common Equity Tier 1 capital (RCFA P859) relative to the bank's total risk-weighted assets (RCFD A223) in percentage terms less the bank-specific capital constraint in percentage terms.

Appendix B: Derivation of the Modigliani-Miller Offset and Calibration to Miles et. al. (2013)

Most of the existing literature that attempts to estimate how changes in bank capital requirements would impact loan rates takes the following approach: take an estimate of the required returns on bank equity and debt and then make an assumption about the degree to which Modigliani-Miller effects offset changes in the composition of funding. This produces an estimate of how a change in the composition of funding effects funding costs. If changes in funding costs pass through to borrowers, this estimate also provides the expected change in loan rates for bank borrowers.

In this section, we invert this methodology and instead use our empirical estimate of the elasticity between loan rates and capital requirements and use it to back out the Modigliani-Miller offset.

Note that the weighted average funding cost for a firm can be written as

$$
\begin{aligned}
WACC &= R_e \frac{E}{E+D} + R_d \frac{D}{E+D}(1-\tau) \\
&= (R_e - R_d)\frac{E}{E+D} + \tau R_d \frac{E}{E+D} + R_d(1-\tau),
\end{aligned}
$$

where R_e and R_d are the costs of equity and debt, τ is the tax rate, and $\frac{E}{D+E}$ and $\frac{D}{E+D}$ is the percentage of bank funding from equity and debt, respectively. The effect of increasing capital requirements is seen in the first two terms: first it causes a shift in the composition of funding towards a more expensive funding source ($R_e - R_d > 0$), second it causes a bank to shift funding away from tax deductible debt, reducing the value of this tax shield.

Assuming that R_e is a function of $\frac{E}{E+D}$ and differentiating $WACC$ with respect to $\frac{E}{E+D}$ shows how bank funding costs respond to changes in capitalization.

$$
\begin{aligned}
\frac{\partial WACC}{\partial(\frac{E}{E+D})} &= R_e - R_d + \frac{E}{E+D}\frac{\partial R_e}{\partial(\frac{E}{E+D})} + \tau R_d \\
&= (1 - MM_{offset})(R_e - R_d) + \tau R_d,
\end{aligned} \tag{4}
$$

where $MM_{offset} = \frac{\frac{E}{E+D}\frac{\partial R_e}{\partial(\frac{E}{E+D})}}{R_e - R_d}$ is the percentage of the increase in funding cost from switching from debt to equity (excluding the tax shield) which is offset by a reduction in required returns. Different assumptions about this term underlie much of the heterogeneity in estimates in the literature. For example, Kashyap et al. (2010) argue that this offset is around 100%, and thus that capital requirements mostly matter due to tax treatments. Other calibrations such as Slovik and Cournède (2011) and Bank of International Settlements (2010) assume that this offset is 0, and thus find that changes in capital requirements are more costly.

Following Miles et al. (2013), assume $R_e - R_d = 9.85\%$ and $R_d = 5\%$.[16] We set $\tau = .35$. Thus, if the MM_{offset} is 0, then a 1% increase in capital will raise funding costs by 9.85bp due to the switch to a more expensive funding source and an additional 1.75bp due to lost

[16] Slovik and Cournède (2011) and Elliott (2010) estimate that $R_e - R_d \approx 12.5\%$, we take the lower estimate to reflect lower ROEs following the crisis. The 5% estimated cost of funds may seem high given deposit rates at the time, however we assume decreases in debt mostly come from longer term debt. The Moody's Baa corporate bond yield averaged around 5% over the sample period.

tax shield. Assuming that changes in bank funding costs pass through directly to loan rates, this would mean that the HVCRE rule, which increased equity requirements on effected loans 8% to 12%, would be expected to increase loan rates by about 46bp ($4 \times (9.85 + 1.75)$) instead of the 38bp we find.

This gap may reflect several factors: attenuation bias in our econometric specification due to not having an exact measure of HVCRE treatment, incorrect calibration of the components of funding costs, or non-binding capital constraints for some of our sample to name a few. However, if we assume the difference is due to Modigliani and Miller (1958) effects, we can get a sense of the degree of offset from reductions in R_e. Substituting our estimated elasticity between loan rates and capital requirements of 9.5bp in for $\frac{\partial WACC}{\partial(\frac{E}{E+D})}$ in (4) implies that $MM_{offset} \approx 21\%$.[17]

Figures and Tables

[17]The equation is $9.5 = (1 - MM_{offset})9.85 + 1.75$.

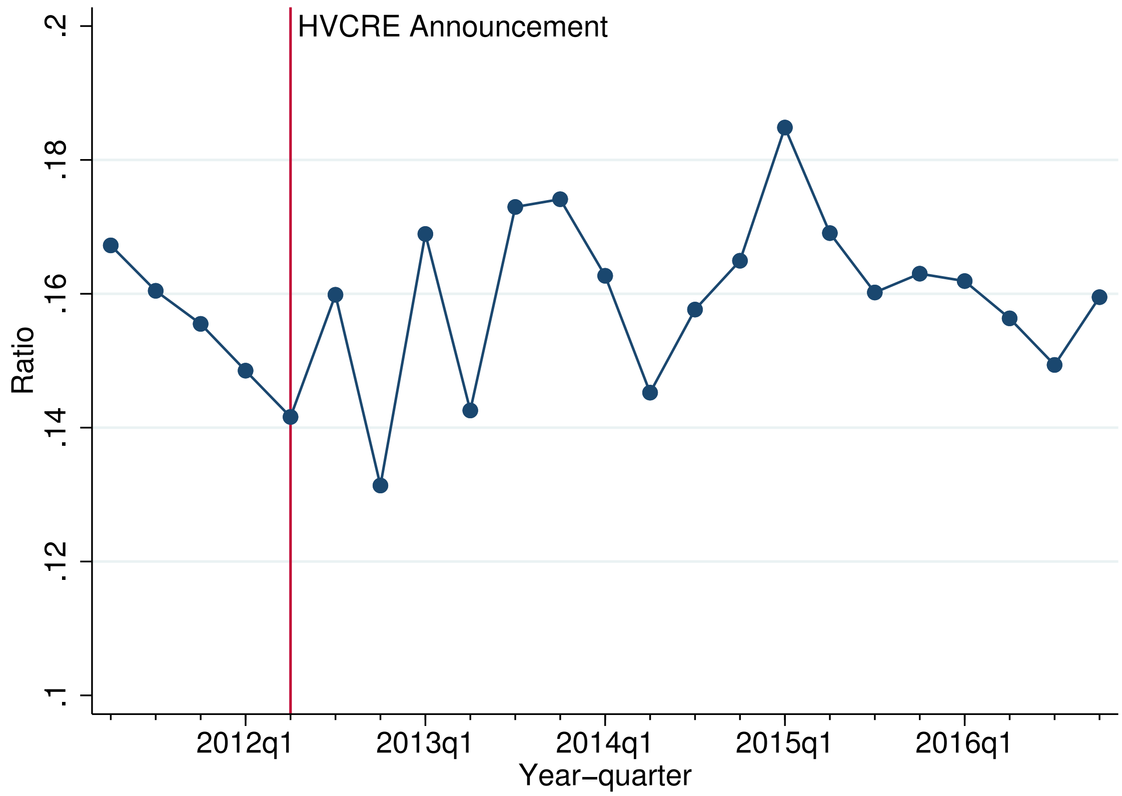
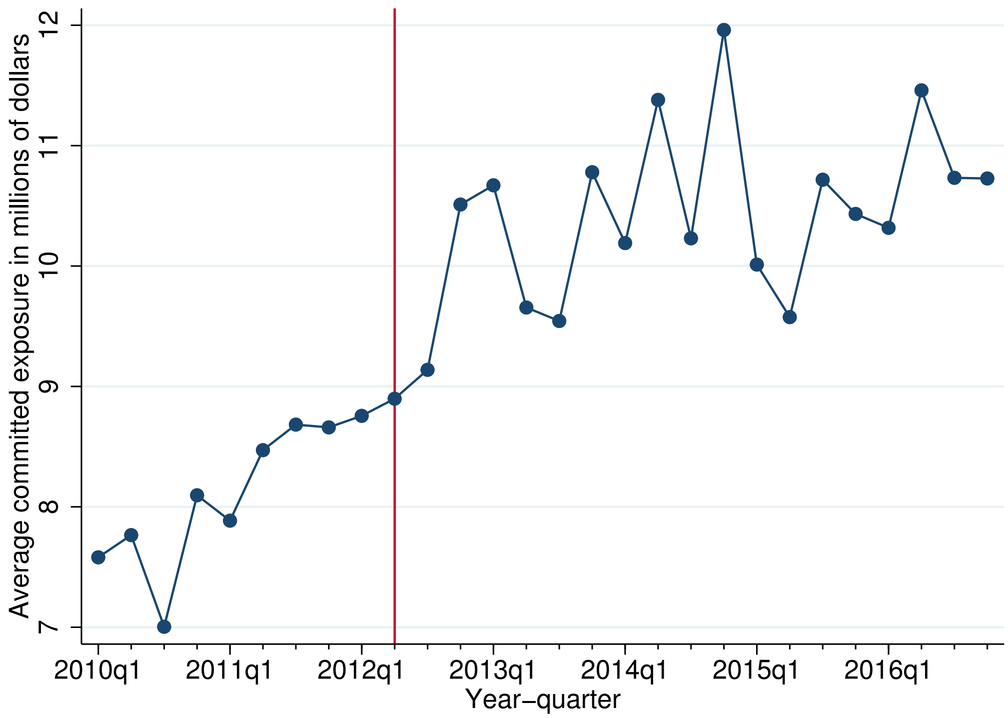
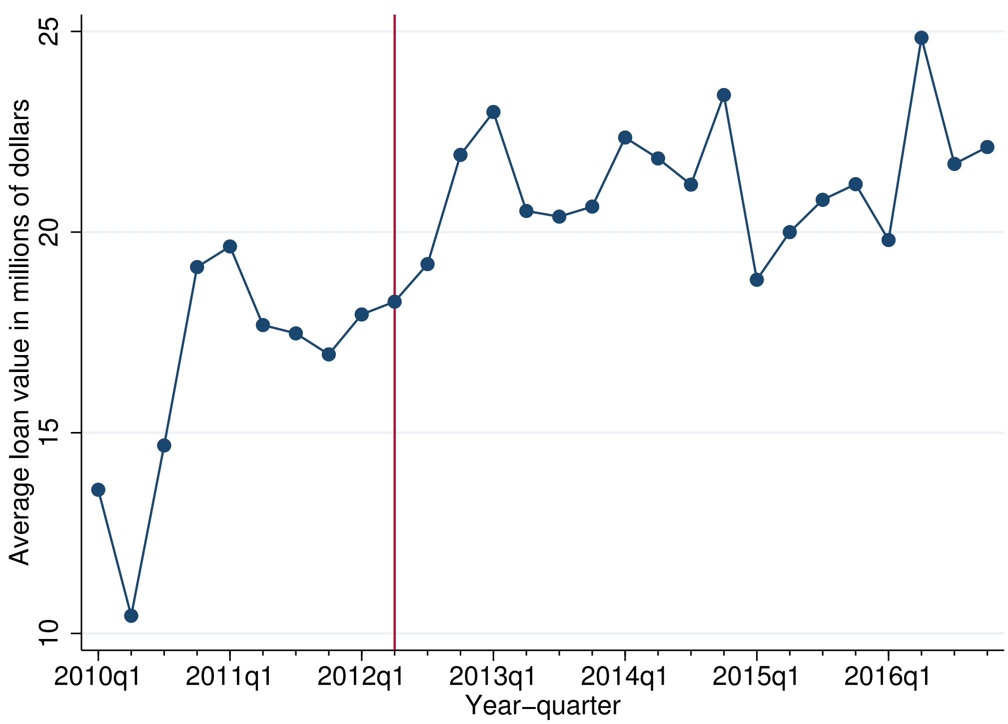


Figure 1: Percent of Non-1-4 Family Residential ADC Newly Committed Exposures Classified as HVCRE

This figure displays the percent of new non-1-4 family residential ADC committed exposures that we classify as HVCRE by quarter in our sample from 2011:Q3 through 2016:Q4.



(a) Average Loan Size



(b) Average Loan Value

Figure 2: Average Loan Size and Value on New Commitments over Time

The first subfigure shows the average committed exposure in millions of dollars by quarter from 2010:Q1 through 2016:Q4. The second subfigure shows the average loan value in millions of dollars by quarter. Valuations and committed exposures are winsorized at the 1% level for this figure.

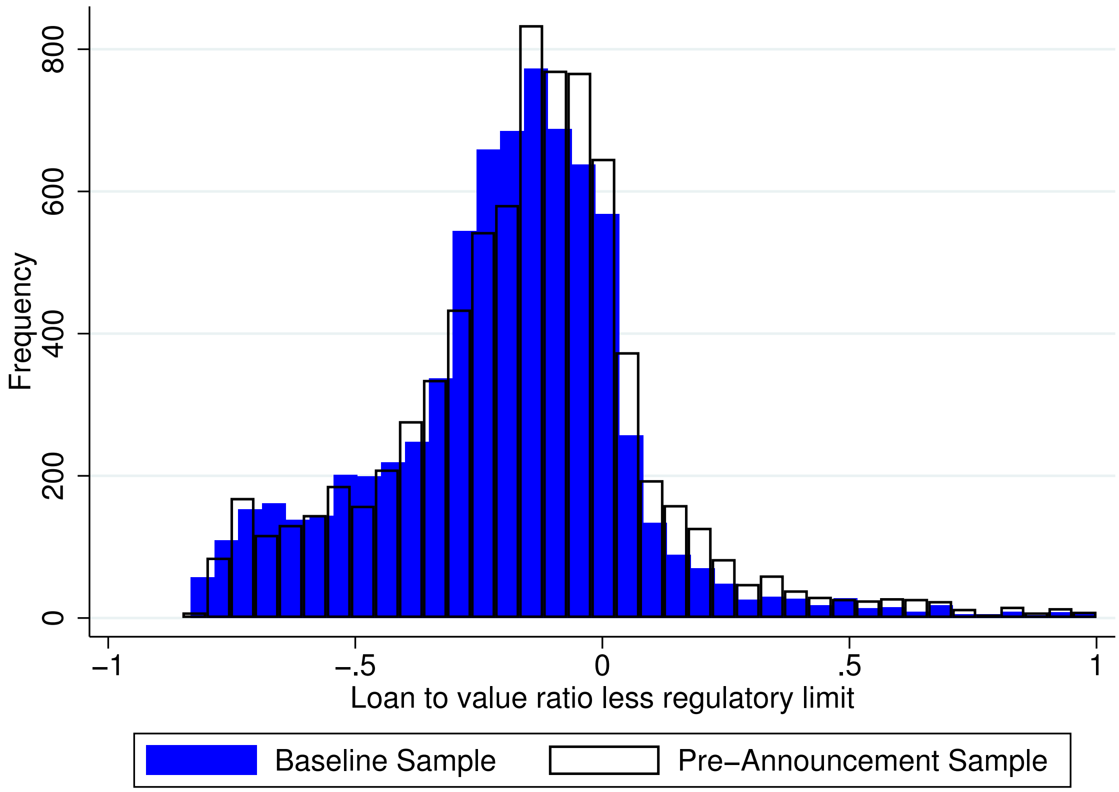


Figure 3: Density of Loan to Value Ratios Relative to Regulatory Limit

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.

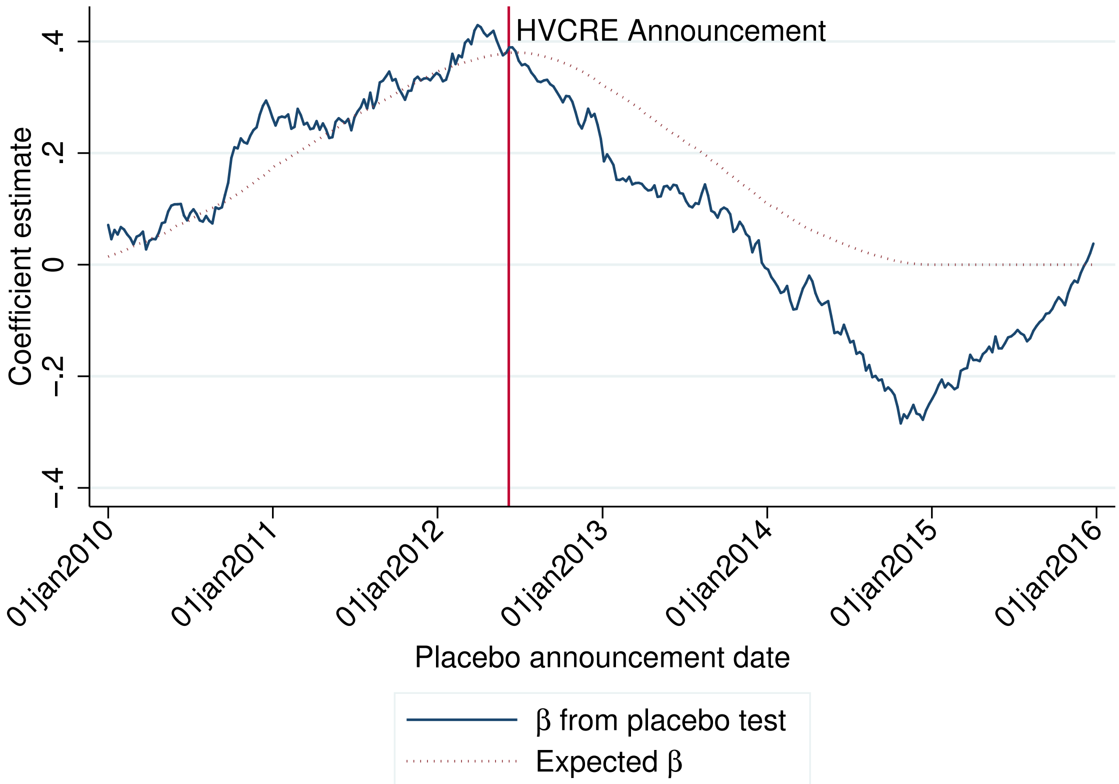


Figure 4: Actual and Counterfactual Regression Coefficients By Placebo Announcement Date

This figure plots the regression coefficient from a placebo test that we repeat weekly through our sample from January, 1, 2010 to Debember 23, 2016 (the solid line), as well as a counterfactual estimate that reflects the expected coefficient from this test were only the HVCRE rule driving our results (the dotted line).

Our baseline specification is: $r_{i,b,t} = \beta(\text{High LTV}_{i,b,t} \times \text{Pct. HVCRE}_{i,b,t}) + \gamma X_{i,b,t} + \tau_{b,t} + \varepsilon_{i,b,t}$, 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. The variable $X_{i,b,t}$ is a vector of the loan-level controls listed in the text, the lower order interaction of the treatment variables, and in some specification the interaction of these variables with the loan controls. The variable $\tau_{b,t}$ is a bank-quarter fixed effect.

To construct our placebo estimate ("β from placebo test"), for each placebo announcement date t', we construct a variable Placebo Pct. HVCRE$_{i,b,t,t'}$ which equals the percentage of the life of the loan maturing after the placebo HVCRE implementation date $t' + k$, where k is the number of days between the real announcement and implementation dates of the HVCRE rule (so 938 days). We then estimate our diff-in-diff specification for loans originated between t' and $t' + k$ as before, but using Placebo Pct. 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. The x-axis indexes the placebo announcement date (t'), and the solid line shows the coefficient on Placebo Pct. HVCRE$_{i,b,t,t'}$ $\times$ High LTV$_{i,b,t}$ for the corresponding regression.

To construct the dotted line ("Expected β"), we construct an indicator, $\mathbb{1}_{t \text{ after HVCRE announcement}}$, for whether the loan was originated after the announcement of the HVCRE rule and accounts for the fact that banks would be unaware that high LTV loans maturing after January 1, 2015 would carry a higher risk weight and thus shouldn't be priced. The dotted line plots 0.38 times the coefficient from regressing Pct. HVCRE$_{i,b,t}$ $\times$ $\mathbb{1}_{t \text{ after HVCRE announcement}}$ on Placebo Pct. 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.

Table 1
Summary Statistics for Loan Variables in the Different Samples

	Baseline sample of non-1-4 family ADC loans							
	Mean	Std	min	p10	p50	p90	max	N
Interest rate (percentage points)	3.32	1.06	1.50	2.18	3.03	5.00	6.15	7516
Percent maturing after January 1, 2015	0.57	0.35	0.00	0.00	0.67	0.96	1.00	7516
High LTV (1 if LTV exceeds supervisory max)	0.16	0.36	0.00	0.00	0.00	1.00	1.00	7516
Standard deviation of annual change in house prices of zip code of loan	7.57	3.02	1.89	3.91	7.23	11.47	24.64	7516
Loan probability of default (percentage points)	1.44	1.52	0.00	0.26	1.09	2.50	11.66	5338
Loan loss given default (percentage points)	31.78	12.95	3.00	10.00	35.00	44.00	60.00	5339
Committed exposure at origination ($ millions)	10.49	13.46	0.26	1.20	4.80	28.57	68.17	7516
Time to maturity at origination (yrs.)	4.88	5.73	0.04	1.00	3.00	10.98	29.96	7516
Floating rate (0) or fixed (1)	0.15	0.36	0.00	0.00	0.00	1.00	1.00	7516
Loan to Value ratio	0.66	0.48	0.02	0.25	0.63	0.87	3.87	7516
	Sample of 1-4 family construction loans							
	Mean	Std	min	p10	p50	p90	max	N
Interest rate (percentage points)	4.01	0.90	2.21	2.88	4.00	5.25	6.19	1754
Percent maturing after January 1, 2015	0.41	0.36	0.00	0.00	0.40	0.91	1.00	1754
High LTV (1 if LTV exceeds supervisory max)	0.10	0.30	0.00	0.00	0.00	1.00	1.00	1754
Standard deviation of annual change in house prices of zip code of loan	8.05	2.80	2.13	4.40	8.03	11.45	41.10	1754
Loan probability of default (percentage points)	2.22	3.22	0.03	0.26	1.07	5.37	21.20	1194
Loan loss given default (percentage points)	24.98	13.31	5.00	5.00	26.00	40.00	60.00	1195
Committed exposure at origination ($ millions)	4.38	6.28	0.08	0.55	1.94	10.50	38.00	1754
Time to maturity at origination (yrs.)	2.17	3.11	0.02	1.00	1.47	3.00	30.00	1754
Floating rate (0) or fixed (1)	0.16	0.37	0.00	0.00	0.00	1.00	1.00	1754
Loan to Value ratio	0.68	0.65	0.00	0.14	0.67	0.80	5.11	1754
	Sample of loans originated before announcement							
	Mean	Std	min	p10	p50	p90	max	N
Interest rate (percentage points)	4.07	1.21	1.53	2.51	4.00	5.62	7.25	7874
Percent maturing after June 7, 2012	0.40	0.37	0.00	0.00	0.37	0.92	1.00	7874
High LTV (1 if LTV exceeds supervisory max)	0.21	0.41	0.00	0.00	0.00	1.00	1.00	7874
Standard deviation of annual change in house prices of zip code of loan	7.19	2.96	1.77	3.70	6.82	11.10	27.57	7874
Loan probability of default (percentage points)	6.72	20.31	0.00	0.38	1.27	9.00	100.00	2728
Loan loss given default (percentage points)	30.40	13.01	0.00	14.00	33.00	44.00	50.00	2777
Committed exposure at origination ($ millions)	7.90	9.57	0.38	1.20	3.87	20.60	50.00	7874
Time to maturity at origination (yrs.)	3.32	4.37	0.00	0.45	2.00	7.00	30.00	7874
Floating rate (0) or fixed (1)	0.11	0.31	0.00	0.00	0.00	1.00	1.00	7874
Loan to Value ratio	0.67	0.37	0.02	0.26	0.65	0.95	2.66	7874

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 "s.d. of Δhouse prices of loan zip code" 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 Appendix A.

Table 2
Effect of HVCRE Rule on Loan Rates

	Effect on Interest Rates (percentage points)						
	Sample of Non-1-4 Family ADC Loans			Sample of ADC Loans		Sample of CRE Loans	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
High LTV x Pct. HVCRE	0.59**	0.62**	0.38**	-0.08	-0.04	-0.35**	-0.25*
	(0.12)	(0.11)	(0.11)	(0.22)	(0.23)	(0.10)	(0.11)
x Non-1-4 family ADC				0.67*	0.40	1.05**	0.78**
				(0.26)	(0.26)	(0.16)	(0.15)
Pct. HVCRE	-0.29**	-0.22**	-0.41	-0.22+	-0.75	-0.27**	-0.60
	(0.07)	(0.07)	(0.63)	(0.13)	(0.62)	(0.07)	(0.45)
High LTV	-0.20**	-0.20**	2.02**	0.10	1.67**	0.35**	0.73+
	(0.08)	(0.06)	(0.56)	(0.15)	(0.49)	(0.07)	(0.39)
Non-1-4 family ADC				-0.76+	-0.76+	0.44	0.26
				(0.43)	(0.39)	(0.32)	(0.31)
x Pct. HVCRE				0.00	0.06	-0.04	0.12+
				(0.11)	(0.12)	(0.07)	(0.07)
x High LTV				-0.28+	-0.14	-0.59**	-0.49**
				(0.16)	(0.16)	(0.10)	(0.10)
Loan controls	X	X	X	X	X	X	X
Time FE	X						
Bank-Time FE		X	X	X	X	X	X
Controls×{HVCRE,High LTV}			X		X		X
Controls×{Non-1-4 Fam ADC}				X	X	X	X
R_a^2	0.366	0.448	0.464	0.457	0.471	0.448	0.466
No. banks	31	31	31	31	31	36	36
No. loans	7516	7516	7516	9270	9270	31592	31592

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. The variable $X_{i,b,t}$ is a vector of the loan-level controls listed in the text, the lower order interaction of the treatment variables, and in some specification the interaction of these variables with the loan controls. The variable $\tau_{b,t}$ is a bank-quarter fixed effect. Columns (1)-(3) present 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 (4) and (5) present the triple-difference results for the sample of ADC loans, while columns (6) and (7) present the findings for the full sample of CRE loans. Standard errors, in parentheses, are clustered at the bank-quarter level. +,*,** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 3
Effect of HVCRE Rule on Loan Rates: Placebo Sample

	Effect on Interest Rates (percentage points)						
	Sample of Non-1-4 Family ADC Loans			Sample of ADC Loans		Sample of CRE Loans	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
High LTV x Pct. HVCRE	0.13	0.13	0.06	0.29	0.28	0.08	0.05
	(0.10)	(0.11)	(0.09)	(0.24)	(0.25)	(0.09)	(0.09)
x Non-1-4 family ADC				-0.15	-0.17	0.07	0.02
				(0.27)	(0.26)	(0.12)	(0.11)
Pct. HVCRE	-0.56**	-0.55**	-1.24+	-0.32+	-0.94	-0.36**	-0.55
	(0.10)	(0.11)	(0.72)	(0.16)	(0.66)	(0.12)	(0.54)
High LTV	0.01	0.03	0.82	0.07	0.72	0.09	0.18
	(0.05)	(0.05)	(0.58)	(0.10)	(0.51)	(0.06)	(0.36)
Non-1-4 family ADC				2.88**	3.02**	1.07**	1.11**
				(0.71)	(0.74)	(0.30)	(0.31)
x Pct. HVCRE				-0.24	-0.19	0.03	0.01
				(0.16)	(0.15)	(0.07)	(0.07)
x High LTV				-0.06	-0.02	-0.12	-0.09
				(0.13)	(0.12)	(0.08)	(0.08)
Loan controls	X	X	X	X	X	X	X
Time FE	X						
Bank-Time FE		X	X	X	X	X	X
Controls×{HVCRE,High LTV}			X		X		X
Controls×{Non-1-4 Fam ADC}				X	X	X	X
R_a^2	0.241	0.287	0.293	0.277	0.281	0.372	0.380
No. banks	29	29	29	31	31	37	37
No. loans	7874	7874	7874	9309	9309	40836	40836

This table reports coefficients from the following regression

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

for the sample of loans originated between January 1, 2010 and the announcement of the HVCRE rule. The variable Pct. $\text{HVCRE}_{i,b,t}$ is the percentage of the life of the loan occurring after the announcement date. All other variables are as in Table 2: $r_{i,b,t}$ is the interest rate on loan i from bank b at time t, 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 Non-1-4 family $\text{ADC}_{i,b,t}$ is an indicator for whether the loan is an ADC loan for a non-1-4 family property. The variable $X_{i,b,t}$ is a vector of the loan-level controls listed in the text, the lower order interaction of the treatment variables, and in some specification the interaction of these variables with the loan controls. The variable $\tau_{b,t}$ is a bank-quarter fixed effect. Columns (1)-(3) present coefficients from the difference-in-difference specification for the sample of non-1-4 family ADC loans. Columns (4) and (5) present the triple-difference results for the sample of ADC loans, while columns (6) and (7) present the findings for the full sample of CRE loans. Standard errors, in parentheses, are clustered at the bank-quarter level. +,*,** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 4
Heterogeneous Effects By Distance to Capital Constraints

	Effect on Interest Rates (percentage points)					
	Non-1-4 Family ADC Loans		Sample of ADC Loans		Sample of CRE Loans	
	(1)	(2)	(3)	(4)	(5)	(6)
Capital Constrained						
x High LTV x Pct. HVCRE	0.61**	0.35+	-1.02+	-1.24**	-0.33	-0.28
	(0.21)	(0.19)	(0.53)	(0.47)	(0.22)	(0.23)
x High LTV x Pct. HVCRE x Non-1-4 ADC			1.80**	1.66**	1.12**	0.86**
			(0.57)	(0.50)	(0.31)	(0.30)
x Pct. HVCRE	0.19	0.11	0.51+	0.74**	-0.05	-0.24*
	(0.13)	(0.12)	(0.30)	(0.25)	(0.13)	(0.12)
x High LTV	-0.21	-0.17	0.15	0.50	0.15	0.15
	(0.13)	(0.13)	(0.37)	(0.34)	(0.16)	(0.16)
x Pct. HVCRE x Non-1-4 ADC			-0.39	-0.62**	0.33*	0.36**
			(0.27)	(0.23)	(0.13)	(0.12)
x High LTV x Non-1-4 ADC			-0.41	-0.70*	-0.46*	-0.41+
			(0.38)	(0.35)	(0.21)	(0.21)
x Non-1-4 ADC			0.08	0.56**	-0.09	-0.06
			(0.17)	(0.14)	(0.09)	(0.08)
High LTV x Pct. HVCRE	0.24+	0.14	0.40	0.59*	-0.20	-0.09
	(0.14)	(0.15)	(0.33)	(0.28)	(0.16)	(0.16)
High LTV x Pct. HVCRE x Non-1-4 ADC			-0.18	-0.51	0.40+	0.25
			(0.34)	(0.31)	(0.21)	(0.21)
Pct. HVCRE	-0.33**	-0.23	-0.52*	-0.65	-0.28**	-0.46
	(0.10)	(0.67)	(0.21)	(0.65)	(0.10)	(0.47)
High LTV	-0.08	2.21**	0.15	1.56**	0.29*	0.58
	(0.09)	(0.58)	(0.25)	(0.48)	(0.12)	(0.43)
Pct. HVCRE x Non-1-4 ADC			0.29	0.37*	-0.18*	0.00
			(0.19)	(0.15)	(0.09)	(0.08)
High LTV x Non-1-4 ADC			-0.18	0.27	-0.35*	-0.25+
			(0.25)	(0.20)	(0.15)	(0.15)
Non-1-4 ADC			-0.40**	-0.61	0.07	0.13
			(0.12)	(0.38)	(0.06)	(0.30)
Loan controls	X	X	X	X	X	X
Bank-Time FE	X	X	X	X	X	X
Controls×{HVCRE,High LTV, Capital Constrained}		X		X		X
Controls×{Non-1-4 Fam ADC}				X		X
R^2_a	0.449	0.465	0.426	0.477	0.445	0.467
No. banks	30	30	30	30	32	32
No. loans	6899	6899	8551	8551	28726	28726

This table reports coefficients from the following regression:

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

where Capital $\text{Constrained}_{i,b,t}$ 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 $X_{i,b,t}$ includes loan level controls, lower order interactions of the four primary explanatory variables, and the interaction of these variables with the loan controls. All other variables are as in Table 2: $r_{i,b,t}$ is the interest rate on loan i from bank b at time t, 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, Pct. $\text{HVCRE}_{i,b,t}$ is the percentage of the life of the loan occurring after the implementation date, and Non-1-4 family $\text{ADC}_{i,b,t}$ is an indicator for whether the loan is an ADC loan for a non-1-4 family property. The variable $\tau_{b,t}$ is a bank-quarter fixed effect. Columns (1)-(2) present coefficients for the sample of non-1-4 family ADC loans originated between the announcement and implementation of the HVCRE rule. Columns (3) and (4) present the results for the sample of ADC loans, while columns (5) and (6) present the findings for the full sample of CRE loans. Standard errors, in parentheses, are clustered at the bank-quarter level. +,*,** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 5
Estimated Effect on Risk Characteristics

	Effect on Riskiness of Loans					
	Probability of Default		Loss Given Default		House Price Volatility	
	(1)	(2)	(3)	(4)	(5)	(6)
High LTV x Pct. HVCRE	-0.51*	-0.42+	-1.89+	-0.49	0.40	0.35
	(0.21)	(0.23)	(1.14)	(1.06)	(0.37)	(0.34)
High LTV	0.53**	0.30	2.10*	-14.44*	-0.14	1.33
	(0.19)	(1.27)	(0.81)	(7.13)	(0.26)	(1.73)
Pct. HVCRE	-0.19+	-0.57	1.24	5.49	-0.56**	1.36
	(0.10)	(1.62)	(0.75)	(6.55)	(0.20)	(1.68)
Loan controls	X	X	X	X	X	X
Bank-Time FE	X	X	X	X	X	X
Controls×{HVCRE, High LTV}		X		X		X
R_a^2	0.287	0.289	0.614	0.617	0.090	0.096
No. banks	26	26	26	26	31	31
No. loans	5338	5338	5339	5339	7516	7516

This table reports the estimated coefficient from estimating

$$\text{Riskiness}_{i,b,t} = \beta(\text{High LTV}_{i,b,t} \times \text{Pct. HVCRE}_{i,b,t}) + \gamma X_{i,b,t} + \tau_{b,t} + \varepsilon_{i,b,t}, \quad (5)$$

where $\text{Riskiness}_{i,b,t}$ is a measure of the riskiness of loan i from bank b at time t, $\text{High LTV}_{i,b,t}$ 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 $\text{Pct. HVCRE}_{i,b,t}$ is the percentage of the life of the loan occurring after the implementation date. The variable $X_{i,b,t}$ is a vector of the loan-level controls listed in the text, the lower order interaction of the treatment variables, and in some specification the interaction of these variables with the loan controls. The variable $\tau_{b,t}$ is a bank-quarter fixed effect. In columns (1) and (2), the dependent variable is the expected year-ahead probability of default of the loan. In columns (3) and (4), the dependent variable is the expected loss given default. In columns (5) and (6), the dependent variable is the house price volatility in the zip code of the property. Standard errors, in parentheses, are clustered at the bank-quarter level. +,*,** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 6
Robustness to Excluding Loans with LTVs Between 0.50 and Supervisory Limit

	Effect on Interest Rates (percentage points)						
	Sample of Non-1-4 Family ADC Loans			Sample of ADC Loans		Sample of CRE Loans	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
High LTV x Pct. HVCRE	0.64**	0.60**	0.40**	-0.02	-0.16	-0.22*	-0.16
	(0.14)	(0.13)	(0.12)	(0.32)	(0.33)	(0.11)	(0.11)
x Non-1-4 family ADC				0.61+	0.55	0.94**	0.73**
				(0.36)	(0.36)	(0.18)	(0.17)
Pct. HVCRE	-0.38**	-0.24*	-0.58	-0.24	-1.33	-0.45**	-0.90
	(0.11)	(0.11)	(0.86)	(0.23)	(0.86)	(0.08)	(0.59)
High LTV	-0.27**	-0.25**	3.24**	0.01	2.61**	0.23**	0.94*
	(0.09)	(0.08)	(0.60)	(0.21)	(0.53)	(0.08)	(0.39)
Non-1-4 family ADC				-1.58**	-1.39**	-0.42	-0.56
				(0.58)	(0.51)	(0.45)	(0.41)
x Pct. HVCRE				-0.02	-0.11	0.01	0.12
				(0.20)	(0.21)	(0.10)	(0.10)
x High LTV				-0.24	-0.19	-0.53**	-0.45**
				(0.23)	(0.23)	(0.12)	(0.12)
Loan controls	X	X	X	X	X	X	X
Time FE	X						
Bank-Time FE		X	X	X	X	X	X
Controls×{HVCRE,High LTV}			X		X		X
Controls×{Non-1-4 Fam ADC}				X	X	X	X
R_a^2	0.371	0.471	0.496	0.459	0.481	0.420	0.436
No. banks	30	30	30	30	30	35	35
No. loans	3272	3272	3272	3954	3954	11630	11630

This table replicates the findings from table 2, except the sample excludes loans with an LTV between 0.50 and the supervisory maximum. It reports coefficients from the 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. The variable $X_{i,b,t}$ is a vector of the loan-level controls listed in the text, the lower order interaction of the treatment variables, and in some specification the interaction of these variables with the loan controls. The variable $\tau_{b,t}$ is a bank-quarter fixed effect. Columns (1)-(3) present 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 (4) and (5) present the triple-difference results for the sample of ADC loans, while columns (6) and (7) present the findings for the full sample of CRE loans. Standard errors, in parentheses, are clustered at the bank-quarter level. +,*,** indicate significance at the 10%, 5%, and 1% levels, respectively.