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

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Abstract

We investigate how capital requirements affect loan rates by studying the 50% increase in the risk weight for High Volatility Commercial Real Estate (HVCRE) loans under Basel III. Exploiting variation in loans' terms and exposure to the period after the rule's implementation, we find that a one percentage point increase in capital requirements raises loan rates by 8.5 basis points. Using a model of bank funding costs, we demonstrate the timing and scope of the HVCRE rule implies our estimate reflects the steady-state cost of capital requirements.

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JEL Classification: G21, G28, G38

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1 Introduction

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

This paper uses loan-level data from bank stress tests to investigate how loan rates responded to a new rule that increased capital requirements on high-leverage construction loans. While this change in requirements affected a relatively small volume of loans, the rule provides a particularly useful setting for studying the question at hand for two reasons. First, the variation created by the rule allows for a well-identified estimate of its effects. Our difference-in-differences approach exploits within-bank variation in capital requirements, allowing us to identify the effect on loan rates while controlling for bank-level confounders. Second, the timing of the rule allows us to identify the steady-state cost of capital requirements, as opposed to short-term costs relating to equity issuance. While most empirical studies examine

[1]Funding costs could be invariant to capital structure if the cost of using a more expensive funding source is offset by lower costs of debt and equity for better capitalized banks (Modigliani and Miller, 1958). However, various characteristics of the market—for example deposit insurance, the advantageous tax treatment of debt, and costs of equity issuance—are likely to cause equity funding to be comparatively costly.

[2]Changes in loan rates have been shown to affect spending by businesses (Gertler and Gilchrist, 1994; Ippolito et al., 2018) and households (Di Maggio et al., 2017; Wong, 2019).

periods when banks needed to raise capital, either to offset losses or to satisfy the newly implemented capital requirements, this is not the case for the HVCRE rule.[3] To make this point more concrete, we present a model where a bank's funding cost depends on both the required return to equity and a cost of adjusting equity. With this model, we show that the elasticity of loan rates with respect to capital requirements in our setting captures the steady-state cost of capital requirements.

To provide more detail on the rule, on June 7, 2012, U.S. bank regulators proposed a new set of rules for banks' risk-weighted capital requirements. Motivated by significant losses on construction loans during the crisis, part of the proposal sought to increase capital requirements for particularly risky acquisition, development, and construction (ADC) loans.[4] Non-1-4 family ADC loans without sufficient borrower contributed capital were deemed "High Volatility Commercial Real Estate" (HVCRE) and the risk weight on these loans increased from 100% to 150%. As banks face an 8 percent regulatory minimum ratio of total capital to risk weighted assets, this rule meant that banks would need to fund 12 percent of an HVCRE loan with equity once the rule went into effect in 2015, compared to 8 percent before 2015. Capital requirements for 1-4 family ADC loans, or other ADC loans with a sufficient down payment, stayed at 8 percent. Therefore, high-leverage ADC loans that have a greater portion of their term extending after 2015 are associated with higher average capital requirements.

The design of the HVCRE rule facilitates a difference-in-differences strategy to identify the effect of capital requirements on loan rates. Our treatment variables are

[3]The HVCRE rule was implemented well into the recovery from the financial crisis, at which point bank capital ratios had already recovered from crisis-era losses and risen to the new post-crisis equilibrium level. Furthermore, the HVCRE rule affected a small enough loan category that banks did not need to issue equity in response to the rule. Figure 1 shows that Tier 1 capital ratios stabilized by the passage of the HVCRE rule, and that banks had returned to distributing earnings, on net, rather than issuing new equity.

[4]The final rule states that: "Supervisory experience has demonstrated that certain acquisition, development, and construction loans ... present particular risks for which the agencies believe banking organizations should hold additional capital" (VIII.B.9). The text is available from the Federal Register here: `www.federalregister.gov/d/2013-21653/p-905`.

an indicator for whether the loan-to-value ratio (LTV) exceeds the threshold for a loan to be subject to higher capital requirements, and the exposure of the loan to the post-implementation period (the percent of the loan-life occurring after 2015). If capital is costly, banks should charge higher interest rates on high LTV loans that are more exposed to the period in which they have higher capital requirements.[5]

We find that the HVCRE rule raises interest rates on HVCRE loans by 34 basis points. Given that the rule increases required capital for an HVCRE loan by 4 percentage points (from 8 percent to 12 percent), the estimate implies an 8.5 basis point increase in loan rates per percentage point increase in capital. The magnitude of this effect is in line with the range of estimates coming from calibrated models (see Dagher et al. (2016) for a survey), but generally indicates lower costs of capital requirements than empirical papers studying Basel II regulations implemented around the time of the financial crisis (e.g. Benetton et al. (forthcoming)).

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

Second, we run a placebo test which demonstrates that the effects are timed with the rule. Specifically, we repeat our baseline diff-in-diff analysis for a sequence of placebo HVCRE announcement and implementation dates. The estimated effect is

[5]To graphically demonstrate the source of variation used in this study, Figure 2 shows how capital requirements vary by HVCRE status and time for four hypothetical loans.

maximized when the placebo dates correspond with the real announcement and implementation dates and falls to around zero as placebo dates move further away from the actual dates. This shows that loan pricing only interacts with maturity and LTV to the extent that it influences risk weights under the HVCRE rule.

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

How should we interpret this finding? While many papers try to identify the cost of higher capital requirements, the effect identified is dependent on the source of variation used in the paper. For example, estimates using cross-bank variation in capital requirements will reflect the ease of substitution between banks. Meanwhile, estimates using changes in aggregate capital requirements will likely reflect the cost of banks transitioning to a higher level of capitalization. We study an increase in capital requirements that affects all banks but, due to the small size of the treated market, had little influence on aggregate capital requirements. We present a model showing that the elasticity of loan rates with respect to capital requirements in this setting identifies the cost of equity funding at the margin as opposed to the temporary costs of transitioning to a higher level of capital.

That the estimated effect of the HVCRE rule arguably reflects the steady-state cost of equity financing is useful for two reasons. First, since banks' costs of debt and equity are not specific to a particular loan market, the estimated effect of the HVCRE rule is informative as to how capital requirements affect loan rates more generally. Second, measuring the steady-state cost of higher capital requirements is useful for assessing the costs and benefits of capital requirements. Indeed, the loan rate elasticity we identify is a key parameter in papers such as Miles et al. (2013) and Firestone et al. (2017) that seek to estimate the optimal level of capital requirements.

1.1 Related Literature

Our work is closely related to papers trying to estimate how capital requirements affect bank funding costs and loan rates. Most other estimates come from calibrated models. The literature suggests that a one percentage point increase in capital raises loan rates by somewhere between 2 to 20 basis points (Dagher et al., 2016). Much of the discrepancy in estimates reflects different assumptions about Modigliani-Miller effects.[6] By directly estimating how loan rates respond to capital requirements, we bypass many of the difficulties in forming calibrated estimates, such as uncertainty about Modigliani-Miller effects or the pass through of costs to borrowers.[7]

On the empirical side, several recent papers exploit within-bank variation in risk weights induced by the implementation of internal ratings-based capital requirements in Europe. These papers show that changes in capital requirements have

[6]The typical methodology in this literature is to estimate the required return on equity relative to debt for banks, and then assume a particular "Modigliani-Miller offset" reflecting the extent to which the higher cost of equity is offset by equity becoming safer as leverage declines. These parameters determine how changes in capital affect funding costs and, when combined with an assumption about rate pass-through, generate an estimated elasticity between capital and loans rates. The papers estimating small effects like Kashyap et al. (2010) generally have a high offset, while estimates at the higher end of the range, such as Slovik and Cournède (2011), tend to assume a low (or no) offset. Meanwhile, Baker and Wurgler (2015) present evidence the Modigliani-Miller offset could actually be negative.

[7]Kisin and Manela (2016) also estimate the cost of capital requirements from a calibrated model, but are able to avoid these sources of uncertainty. Instead of directly estimating the required returns on banks' funding sources, 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.

large effects on loan rates (Benetton et al., forthcoming) or volumes (Fraisse et al., 2020; Behn et al., 2016). These large effects may in part be driven by differences in the timing of implementation—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 crisis. Given that capital is more costly in crisis conditions (Carlson et al., 2013), there is a question of how these findings translate into more "normal times."[8]

Our contribution to this literature is to provide an estimate of the steady-state cost of capital requirements. Studies analyzing periods of stress find that capital is particularly costly partly because of either a temporarily high equity risk premium or because banks are needing to raise capital to offset losses. Similarly, studies analyzing broad-based changes in capital requirements find large effects partly due to banks needing to raise new capital to meet the requirements. Figure 1 shows that by the time the HVCRE rule was announced, banks' Tier 1 capital ratios had plateaued and banks were back to distributing capital to shareholders, on net, rather than raising capital. The model in Section 4 demonstrates that in such an environment, an estimate of the effects of capital requirements on loan rates reflects the long-run cost of *holding* capital, but not the short-term cost of *raising* capital.

Our work is also related to a broader literature studying how capital requirements affect lending policies, which generally focuses more on quantities than pricing. This work has shown 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 bank loan volumes (Peek and Rosengren, 1997; Gambacorta and Mistrulli, 2004; Aiyar et al., 2014). More recent papers have used cross-bank variation in capital requirements or capitalization and demonstrated that

[8] In a contemporaneous working paper, Plosser and Santos (2018) study how fees on loan commitments are affected by capital requirements. Consistent with capital being less costly in "normal times," the authors find modest changes in fees on undrawn commitments following the increase in risk weights from Basel I in the early 1990's.

tighter capital requirements induce a migration of lending to either less constrained banks (Basten, 2019; Gropp et al., 2019; Jiménez et al., 2017) or to non-banks (Irani et al., forthcoming).[9] However, it is not always straightforward to determine what changes in loan quantities mean for credit availability. A significant migration of credit across lenders could reflect either large shifts in credit supply or highly elastic demand (that is, low switching costs for borrowers). By studying the pricing dimension, our paper sheds further light on the magnitude of the effects of changes in capital requirements.

Finally, our paper is complementary to work assessing the optimal level of capital requirements. Miles et al. (2013), Cline (2016), Firestone et al. (2017), and Barth and Miller (2018) estimate the net benefits of higher capital requirements by evaluating the costs of higher loan rates relative to the benefits of less frequent crises. To estimate the costs of capital requirements, the authors rely on calibrated models of banks funding costs to determine how changes in capitalization would affect loan rates. Our contribution is to provide a well-identified empirical estimate of the steady-steady state cost of capital requirements.

The rest of the paper proceeds as follows. Section 2 describes our data, provides further background on the HVCRE rule, and discusses our empirical strategy. Section 3 presents the findings. Section 4 presents a simple model to aid the interpretation of the results. Section 5 concludes.

2 Data and Empirical Strategy

In this section, we review the data used in the paper. We then provide further details on the HVCRE regulation and on how we construct the treatment and exposure variables. Last, we review the empirical strategy used to identify the effect

[9]Notably, Basten (2019) examines the effect of the Counter-Cyclical Capital Buffer on mortgage pricing, finding that more constrained banks raise loan rates. Additionally, Auer and Ongena (2019) study how capital requirements in one loan category can affect lending in another loan category.

of the HVCRE rule.

2.1 Data

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

The data include key loan terms such as interest rate, loan size, dates of origination and maturity, and whether the loan rate is fixed or floating. The data also provide the purpose of the loan (e.g., land acquisition/development, construction, or renovation) and details on the property securing the loan, including the property's zip code, structure type (e.g, 1-4 family, multifamily, office, retail, or other), appraised value, and the basis for the appraised value (e.g, "as is" vs. "as stabilized"). Finally, banks provide their internal risk rating for the loan. This risk rating provides a summary measure of the assessed probability of default for a loan based on facility structure and borrower characteristics using a combination of statistical modeling and judgmental evaluation (Treacy and Carey, 2000).[11] Details on data cleaning and variable construction are in Appendix A.

2.2 Identifying HVCRE Loans

The initial proposed HVCRE rule was released in June 2012, to go into effect starting on January 1, 2015. The final rule, which was released in July 2013, mostly followed the initial proposal, although it allowed for additional exemptions for

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

[11]Banks report internal ratings using a bank-specific rating system. This internal rating is then mapped to a common scale using a concordance provided by the banks. This risk rating runs from (1)-(10), where (10) is the equivalent of a AAA-rated bond and (1) a D-rated bond.

agricultural loans and community development loans.[12] Critical for our empirical strategy, there was no grandfathering in of earlier originated loans. Namely, any ADC loan failing to meet the conditions to be exempt from HVCRE designation would be subject to a 50% increase in the amount of capital required to fund the loan starting on January 1, 2015. Therefore, 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.[13]

The rule defines an HVCRE loan as a credit facility to finance the acquisition, development, or construction of property unless the facility either finances the construction of a 1-4 family residential property, or the project meets certain requirements pertaining to borrower leverage. Specifically, a non-1-4 family ADC loan is *not* considered to be HVCRE if the following conditions hold: (i) the LTV ratio does not exceed supervisory limits, (ii) the borrower contributed capital in the form of cash, marketable assets, or out of pocket development expenses is at least 15% of the property's appraised "as completed" value, and (iii) the contributed capital is contractually required to remain in the project until the facility is sold, paid off, or converted to permanent financing.[14] Non-1-4 family ADC loans failing to meet these conditions were assigned a 150% risk weight. Meanwhile, the risk weight for other CRE loans, namely non-ADC CRE loans and ADC loans exempt from the HVCRE rule, remained at 100%.

We take the following steps to identify HVCRE loans in our sample. First,

[12]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)).

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

[14]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.

HVCRE loans must finance the acquisition, development, or construction of a non-1-4 family property. To identify whether a loan falls in the category subject to the HVCRE rule, we construct a dummy variable, Non-1-4 family $\text{ADC}_{i,b,t}$, that takes a value of 1 if a loan i at bank b at time t supports the construction of a non-1-4 family property.[15] Loans with a value of 1 for Non-1-4 family $\text{ADC}_{i,b,t}$ constitute the sample for our baseline diff-in-diff analysis, and serve as the treated category in our triple difference analysis.

Second, HVCRE loans must have either an LTV exceeding supervisory guidelines, or borrower contributed capital that is less than 15% of the value of the project. As data on borrower contributed capital is unavailable, we focus on the LTV requirement. We create a dummy variable, High $\text{LTV}_{i,b,t}$, indicating whether the loan's 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.[16] Construction loans are considered to have a high LTV if the LTV is above 0.80 unless the loan purpose is "Construction Other" and the property has non-zero and non-missing net operating income, 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 be HVCRE loans. In this case, our estimated effect of capital requirements on loan rates would be downward biased. In Section 3, we perform tests to analyze the likely size of this bias and find it to be small.

[15]These non-1-4 family ADC loans are loans whose "Loan Purpose" field is reported as "Construction Build to Suit/Credit Tenant Lease", "Land Acquisition & Development", or "Construction Other" and is not reported as being a 1-4 family residential construction loan.

[16]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.

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 January 1, 2015 and the maturity date divided by the number of days between the origination date and the maturity date.

2.3 Empirical Strategy

The basic empirical strategy is to study how the interest rate markup on high LTV construction loans varies by how long a 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 will therefore have a higher cost of funding for the bank if the life of the loan extends past January 1, 2015, when HVCRE loans have a 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 after the implementation date HVCRE loans have a cost of capital of $0.08 \times 1.5 \times r^e$. Non-HVCRE loans or HVCRE loans before the implementation date have a 100% risk weight and a cost of capital of $0.08 \times r^e$. Thus, a loan with a maturity M_i will have an average cost of capital:

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

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

2.3.1 Baseline Diff-in-Diff

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

The baseline specification is:

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

where $r_{i,b,t}$ is the loan's interest rate, High $\text{LTV}_{i,b,t}$ is an indicator for whether the loan's LTV exceeds the limit for the HVCRE rule, and Pct. $\text{HVCRE}_{i,b,t}$ is the percentage of the life of the loan occurring after the implementation date. We also include loan-level controls ($\text{X}_{i,b,t}$) and bank-quarter fixed effects ($\tau_{b,t}$). The loan-level controls include the non-interacted treatment variables, High $\text{LTV}_{i,b,t}$ and Pct. $\text{HVCRE}_{i,b,t}$, as well as controls for the following loan characteristics: the annual volatility of zip code level house prices, dummies for the risk rating of the loan, the natural logarithm of the committed exposure, property types dummies (Multifamily, Office, Retail or Other), loan purpose dummies (Land Acquisition/Development, Construction, or Renovation), dummies for the type of appraised value ("as is", "as completed," or "as stabilized"), as well as an indicator variable specifying whether the loan rate is fixed or floating. In our more parsimonious specifications, we include these controls linearly. In our preferred fully-interacted specifications, $X_{i,b,t}$ also includes the interactions of High $\text{LTV}_{i,b,t}$ and Pct. $\text{HVCRE}_{i,b,t}$ with the other controls. In some specifications, we also include core-based statistical area (CBSA)-quarter fixed effects as a control for local demand. Standard errors are clustered at the bank-quarter level.

We run this analysis for the sample of ADC loans that 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 (that is, loans missing the exemption for the HVCRE designation) require higher interest rates for loans more exposed to the period with higher capital requirements, consistent with the HVCRE rule increasing the cost of construction loans.

2.3.2 Triple Difference Methodology

A second, complementary approach exploits another source of variation: 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 effect of the HVCRE rule using the following triple difference specification:

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

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

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

2.3.3 Placebo Tests

Even if the baseline tests show a positive effect of the rule, there could be a concern that the estimates reflect a pricing function for non-1-4 family ADC loans that is independent of the rule. We address this concern with a placebo test, shifting the announcement to implementation window away from the actual one. For each placebo announcement date t', we construct a variable, Placebo Pct. $\text{HVCRE}_{i,b,t,t'}$, equaling the percentage of the life of the loan occurring after the placebo HVCRE implementation date $t' + k$, where k is the time between the real announcement and implementation dates of the HVCRE rule (938 days). We then estimate our diff-in-diff specification as before, but change the sample and the placebo variable. Specifically, we study loans originated between t' and $t' + k$ and use 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. If our findings are due to the HVCRE rule, then the effects should be maximized when correct announcement and implementation dates are used, and decline to zero as the placebo dates increasing depart from the actual dates.

2.3.4 Exploiting Heterogeneity in Banks' Capital Constraints

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

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

3 Empirical Analysis

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

3.1 Sample Properties

Table 1 presents summary statistics for the variables included in our regressions. The baseline sample includes 8,823 non-1-4 family ADC loans, coming from 31

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

bank holding companies. These loans were originated between the June 2012 announcement of the HVCRE rule and the January 2015 implementation. The top panel presents statistics for the whole sample, while the middle and bottom panels show statistics for the samples of loans with LTVs above and below the supervisory thresholds, respectively.[18]

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

Two additional variables also stand out as differing across the samples. First, HVCRE loans are more exposed to the post-implementation period, with 62 percent of the life of the loan, on average, occurring after January 1, 2015, compared to 55 percent for low LTV loans. This difference is largely attributable to longer terms at the upper end of the maturity distribution. Second, HVCRE loans are almost 20 percentage points more likely to have fixed interest rates. These variables and their interactions with High LTV and Pct. HVCRE variable are used as controls in the empirical tests.

3.2 Baseline Estimates

We present the main findings estimating the effect of the HVCRE rule in Table 2. Each column presents estimates from a diff-in-diff specification exploiting variation in loan LTV and the extent to which a loan is exposed to the period after the implementation of the HVCRE rule. The key variable of interest is the interaction between the indicator for if a loan's LTV qualifies it as HVCRE (High LTV)

[18] In Online Appendix Table 1, we also show summary statistics for 1-4 family construction loans and loans originated before the announcement of the rule. These additional groups of loans are used in the triple-difference estimation and placebo tests, respectively.

and the percentage of a loan's duration extending past the implementation date (Pct. HVCRE).

The most parsimonious specification in the first column just includes the treatment variables, loan controls, and time (quarter) fixed effects. The coefficient of 0.57 on the interaction term means that high LTV loans are expected to have interest rates that are 57bp higher if they are subject to the HVCRE rule for their entire life.

The estimated effect of the rule drops when we account for interactions between the controls and the treatment variables. The specification in column 2 additionally interacts the fixed rate dummy with Pct. HVCRE and High LTV, and the estimated effect of the HVCRE rule declines to 32bp. This decline is due to high LTV loans disproportionately having fixed interest rates. The effect in column 1 therefore reflects both the term premium required for lending at a fixed rate for a longer duration, and the higher capital requirements from making an HVCRE loan exposed to the post-implementation period. Consistent with this explanation, we show in Online Appendix Table 2 that adding an additional control for the term premium dampens the estimate in the first specification, but has little effect on the second through fourth specifications.[19]

Once the interaction with the fixed rate indicator is accounted for, the estimated effect of the HVCRE rule is not sensitive to the inclusion of other controls. The specification in the third column additionally includes interactions of the rest of the control variables with the treatment variables, and the coefficient of interest is little changed. The specification in the fourth column includes these interactions as well as bank-quarter fixed effects, and the estimate is little changed at 34 basis points. This 34 basis point effect found in the fully-interacted specification with bank-time fixed effects is our preferred estimate of the effect of the HVCRE rule.

[19]Specifically, Online Appendix Table 2 repeats the analysis from Table 2 but adds an additional control: the maturity-matched swap rate for fixed-rate loans or one-month dollar LIBOR for floating-rate loans. This control for the maturity-matched reference rate has only modest effects on estimates from specifications including the interactions of the treatment variables with the fixed rate dummy.

The last four columns estimate the same equations, but additionally include CBSA-quarter fixed effects. These fixed effects are useful for picking up changes in loan rates due to local loan demand, which should increase one's confidence that the estimates reflect changes in bank supply. The results are generally in line with the findings excluding the fixed effects, although the estimated effects of the HVCRE rule are modestly smaller and the standard errors are modestly higher. Nonetheless, the coefficient on the interaction term is still significant at the 5% level in every specification. Although this specification helps to rule out some demand-side stories for our findings, our preferred specification excludes these fixed effects, as there are over 2,000 unique CBSA-quarter observations and our sample includes fewer than 10,000 loans.

Our preferred estimate of the HVCRE rule has the rule raising loan rates by 34bp. To compare this effect to those in 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 4 percentage points. This means that a 1 percentage point increase in capital requirements raises loan rates by about 8.5 basis points.[20] In their survey of the literature, Dagher et al. (2016) notes that other estimates of this elasticity generally range between 2bp and 20bp, placing us on the lower end of the range of prior estimates.

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

3.3 Triple Difference Estimates

In our triple difference exercise, we study how the increase in interest rates for high LTV loans that are exposed to the post-implementation period differs between non-1-4 family ADC loans, which were subject to the rule, and other CRE loans, which were not. If the previous findings are due to a general pricing rule for all CRE loans, the triple difference approach should account for this effect.

Table 3 presents the triple difference results using 1-4 family ADC loans (columns 1-4) or non-ADC CRE loans (columns 5-8) as controls for how the interaction of High LTV$_{i,b,t}$ and Pct. HVCRE$_{i,b,t}$ influences the pricing of loans independent of the regulation. The coefficient on High LTV$_{i,b,t}$ $\times$ Pct. HVCRE$_{i,b,t}$ $\times$ Non-1-4 family ADC$_{i,b,t}$ then gives the estimated effect of the HVCRE rule.

The first four columns present estimates from the triple difference specification using the sample of ADC loans originated between the announcement and implementation of the HVCRE rule. The coefficient on High LTV$_{i,b,t}$ $\times$ Pct. HVCRE$_{i,b,t}$, reflecting the effect of these variables on the pricing of 1-4 family construction loans, is consistently negative, and is insignificant in specifications with fully interacted controls. Consequently, the estimated effect of the HVCRE rule is consistently higher in the triple difference specification than in the corresponding diff-in-diff specification. For the baseline specification with fully interacted controls and bank-quarter fixed effects, the estimated effect is 50bp, up from 34bp in the baseline diff-in-diff specification. The increase in estimates is larger in the other specifications.

One limitation of using 1-4 family construction loans as a control group is the limited sample size. The data include fewer than 2,000 1-4 family construction loans, and only about a tenth of them have an LTV above 0.8. This results in imprecise estimates, with standard errors about doubling relative to in the diff-in-diff specifications. The last four columns run the triple differences specification for the full sample of CRE loans, and thus uses non-ADC loans as a control category instead of only focusing on construction loans. For these non-ADC loans, we also find a negative interaction between LTV and exposure to the HVCRE period. The estimated effect of the rule in the specification with interacted controls and bank-quarter fixed effects is 51bp, similar to when 1-4 family construction loans were used as the control group. This effect is more precisely estimated due the much larger sample size, however the control category is also much more dissimilar to the treatment category than before.

The Online Appendix presents additional robustness checks for the triple-difference approach. We show that the results are robust to adding an additional control for the term premium in Online Appendix Table 3, and robust to including CBSA-quarter fixed effects in Online Appendix Table 4.

In short, the effect identified in the diff-in-diff methodology is unique to the one type of CRE loan for which the HVCRE rule applies. This indicates that the higher interest rates are due to the HVCRE rule, instead of reflecting a broader pricing formula for all CRE loans.

3.4 Placebo Test

So 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 only occurs in the category subject to the rule indicates that result is actually due to the rule, instead of some other factor affecting CRE loan rates. Nonetheless, one might be concerned that there is something specific to non-1-4 family ADC loans (besides the HVCRE rule) that induces higher interest rates on long-maturity, high LTV loans, and is thus not addressed in the triple difference approach. We address this concern with the placebo test discussed in Section 2.3, which repeats the primary methodology for a sequence of placebo HVCRE announcement and implementation dates.

Figure 3 plots how the coefficient in the diff-in-diff specification changes as we shift the window between announcement and implementation away from the actual dates. The x-axis indexes the placebo announcement date (t'), and the solid line shows the coefficient on Placebo Pct. $\text{HVCRE}_{i,b,t,t'} \times \text{High LTV}_{i,b}$ for the placebo regression corresponding with that announcement date. We can see that the coefficient from the placebo regression is maximized around when the placebo announcement date corresponds with the real announcement date. The estimated coefficient then declines to zero as the placebo announcement dates gets further from the real dates. If the primary findings were due high LTV loans with longer maturities always carrying a higher interest rate, then the coefficient on Placebo Pct. $\text{HVCRE}_{i,b,t,t'} \times \text{High LTV}_{i,b}$ would have remained positive, even as placebo dates moved further away from the real announcement and implementation dates.

Not only does the coefficient from the placebo regression peak at the right date, but it also declines at about the rate that would be expected if the findings were driven by the HVCRE rule. To see this, note that if (1) gives the true pricing equation, then we would expect interest rates to be determined by:

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

where $\hat{\beta}$ and $\hat{\gamma}$ are regression coefficients and $\mathbb{1}_{t \text{ post announcement}}$ is an indicator for whether a 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, then banks would be unaware of the rule so the effect should not be priced in. Then if Placebo Pct. $\text{HVCRE}_{i,b,t,t'}$ only relates to interest rates to the extent that it correlates with Pct. $\text{HVCRE}_{i,b,t} \times \mathbb{1}_{t \text{ post announcement}}$, the coefficient on the interaction term in the placebo test should be:

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

This expected coefficient in the placebo regression is the dotted line in Figure 3.[21] We can see that the coefficients in the regressions for different placebo announcement dates closely follow what would be expected if the results were entirely due to the HVCRE rule: they are maximized at the true announcement date, decline as Placebo Pct. $\text{HVCRE}_{i,b,t,t'}$ increasingly departs from the actual exposure to the post-implementation period, and level off when the placebo dates are far enough off that Placebo Pct. $\text{HVCRE}_{i,b,t,t'}$ is orthogonal to Pct. $\text{HVCRE}_{i,b,t}$.

The expected coefficient is zero for two intervals. The first occurs when the placebo announcement date is more than 938 days before the real announcement date, as the sample for that regression is entirely composed of loans originated before banks were aware of the HVCRE rule. As expected, the coefficient in the placebo regression is about zero when the placebo announcement date is in early 2010. The expected coefficient is also zero for placebo announcement dates after 2015, as high LTV loans in this sample would be subject to the HVCRE rule for their entire duration, making the interaction with maturity irrelevant. We can see that the placebo coefficient achieves a minimum around January 1, 2015 and is negative for dates after that.

Table 4 provides more detail for the pre-announcement placebo findings. Each specification mirrors those from Table 2, except we use the sample of loans originated between January 1, 2010 and the HVCRE announcement date, and we use the real announcement date as the placebo implementation date.[22] Again, as the rule was not

[21]Specifically, the dotted line plots 0.34 times the coefficient from regressing Pct. $\text{HVCRE}_{i,b,t} \times \mathbb{1}_{t \text{ post announcement}}$ on Placebo Pct. $\text{HVCRE}_{i,b,t,t'}$.

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

known when these loans were originated, we should find no effects. The coefficients on the primary interaction terms are much smaller than in the main results. The preferred diff-in-diff specification with fully interacted controls and bank-quarter fixed effects, which produced a coefficient of 0.34 in the baseline results, produces a coefficient of 0.04 in the placebo sample. We similarly present triple difference estimates using the placebo sample in Table 5 of the Online Appendix. We find no evidence of an increase in loan rates for the treated loan category relative to other loan categories for loans originated before the rule was announced.

Overall, these placebo tests show that increase in loan rates identified in the main results are confined to the period in which the treatment variables affect capital requirements through the HVCRE rule. This indicates that the findings do not reflect a general pricing rule that exists independent of the HVCRE rule.

3.5 Heterogeneous Effects by Capital Constraints

While the placebo test shows that the increase in interest rates we find is specific to the period leading up to the implementation of the HVCRE rule, there may be a concern that some other development in the market for non-1-4 family ADC loans occurred at a similar time, such as in increase in demand for high LTV, longer maturity loans.[23] We address this concern by exploiting across-bank variation in proximity to risk-based capital constraints. If interest rates rose due to elevated demand, this effect would likely be similar across banks. However, if the increase in interest rates reflects higher risk weights on treated loans, this would matter most to banks with a binding risk-based capital constraint. Banks with a larger capital buffer, perhaps due to comparatively more binding non-risk-based constraints, would not

[23]Papers using loan-level data frequently use borrower-time fixed effects to control for demand (Khwaja and Mian, 2008). Unfortunately, while we have the borrower name in our data, the 8,823 observations in the baseline sample includes 7,441 unique names, with many of the repeated names being "Individual" or "Confidential". Hence, we lack the statistical power to use within-borrower variation. Note, we do show that our results are robust to including CBSA-quarter fixed effects, which account for location-specific changes in risk or demand.

need more capital on the margin to fund an HVCRE loan.

Table 5 presents the results from interacting the variables in our diff-in-diff specification with a dummy for whether the loan is from a bank closer than the median to its required Tier 1 capital ratio. The first four columns present results without CBSA-quarter fixed effects, while the last four columns present results with the fixed effects. We can see that the estimated effect of the HVCRE rule is almost entirely driven by more capital constrained banks. Looking at the coefficient on the interaction of High LTV$_{i,b,t}$ and Pct. HVCRE$_{i,b,t}$, we see that unconstrained banks react little to the HVCRE rule. These banks are estimated as changing interest rates by less than 15bp in each specification, with an estimated effect of 7bp in the preferred specification with fully interacted controls and bank-quarter fixed effects. In contrast, constrained banks are estimated as increasing interest rates by between 49bp and 65bp.[24]

3.6 Evaluating Potential Bias From Misclassification

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

[24]Table 6 of the Online Appendix presents results from interacting the variables in the triple difference specification with the capital constrained dummy. The results also show that the higher interest rates for treated loans in Table 3 are driven by banks that are closer to their minimum Tier 1 capital requirement. The effect of the HVCRE rule is smaller and insignificant for less capital constrained banks.

0.65 may be misclassified as having a low LTV.

Table 6 reports findings from our diff-in-diff specification dropping loans that are at a greater risk of being misclassified. The first four columns present results excluding loans with an LTV between 0.50 and the supervisory limit. Since LTV and borrower contributed capital are inversely related, loans with LTVs under 0.50 are unlikely to fail to meet the borrower contributed capital requirement.[25] Despite the sample size being reduced by over half, the coefficient estimates are similar to the main results in Table 2, generally rising a few basis points in specifications without bank-quarter fixed effects and falling a few basis points in the specification with them.

The last four columns restrict the sample to just construction loans for properties with no reported operating income. Unlike for land acquisition and development loans, where the appropriate supervisory limit is somewhat uncertain, we can be reasonably sure that these loans have a supervisory limit of 0.80. The sample size falls by over a third relative to the main table, but again the point estimates are little changed. The estimated effect of the HVCRE rule rises to 38bp in our preferred specification, compared to 34bp for the full sample. While this is consistent with a downward bias due to misclassification, it indicates that such a bias is small.

3.7 Effect on Loan Composition

In this subsection, we analyze how the rule affected the quantity and composition of lending. Faced with higher interest rates for high LTV bank loans, borrowers may choose to either reduce LTV or switch to financing from non-bank lenders.

[25]Recall that a loan is exempt from the rule if it has (1) an LTV not exceeding supervisory limits and (2) borrower contributed capital that is at least 15% of the completed value of the project. A loan may meet the first criterion but fail the second if the borrower makes a low investment but gets a favorable appraisal on the completed property. For example, if a construction project costs $9 million and produces a $10 million property, an LTV of 0.80 would correspond with a borrower contributed capital of 10%, making the loan fail the borrower contributed capital criterion. At an LTV of 0.50 however, the borrower would be contributing 40% of the competed value, and her loan would thus comfortably avoid being HVCRE.

Such a change in the composition of loans may influence the estimated effect of the rule—if the composition of borrowers endogenously changes in response to the rule, estimates may partially reflect changes in the risk characteristics of borrowers.

The direction of selection bias is ambiguous. On one hand, better quality borrowers may be more able to increase their equity contribution and avoid the HVCRE designation, implying treated loans come from riskier borrowers. On the other hand, higher funding costs may result in higher interest rates for strong borrowers and rationing for weaker borrowers, implying treated loans come from safer borrowers.

These possible changes in loan composition would be driven by a contraction in high LTV lending for a particular segment of the market. Contrary to this occuring, we find little evidence of a decline in high LTV lending due to the rule. Figure 4 shows that there was no decrease in the share of non-1-4 family ADC loans with a high LTV following the announcement of the rule. Since 2011, high LTV originations constitute between 10 and 20 percent of non-1-4 family ADC originations just about every quarter, with no visible change around the rule announcement. As we near the implementation date, meaning that newly originated loans would be more exposed to the rule, the high LTV share actually rises somewhat.

Furthermore, we see no evidence of capital constrained banks reducing high LTV lending relative to other banks. Given that banks closer to their minimum Tier 1 ratio are found to raise interest rates the most in response to the rule, one would expect that these constrained banks would originate fewer high LTV loans. Instead, Figure 5 shows that constrained banks generally are more prone to originate high LTV loans, and this does not change in the quarters following the announcement of the rule.

Although no change in the propensity to originate high LTV loans is obvious in the time series or in the cross-section of banks, it is possible that there are some changes at the margin. Even if most borrowers are willing to accept a higher interest rate to borrow at a high LTV, some borrowers who would demand a borderline LTV could opt for a lower LTV due to the rule. Figure 6 plots the distribution of LTVs relative to regulatory limits for both the sample of pre-announcement, non-1-4 family ADC loans and the baseline post-announcement sample. There is clearly bunching below the regulatory limit in the post-announcement sample, with the density falling by over half for the bin just above the limit. However, much of this bunching may not be a result of the HVCRE rule as the density also fell by over a third in the sample of loans originated before the rule was announced.[26]

Taken together, these figures suggest that the HVCRE rule may have induced some borderline loans to reduce LTVs to just under the threshold, but this effect was too small to notably affect the share of lending with a high LTV in aggregate. That the rule seemed to only induce a modest change in volumes for some marginal loans indicates that the rule was unlikely to have notably changed the composition of borrowers.

We also directly test whether loans more affected by the HVCRE rule differ in risk characteristics. Table 7 repeats the baseline diff-in-diff analysis, but uses loan risk measures as the dependent variable. In the first four columns, the dependent variable is the risk rating of the loan, which varies from (1)-(10), where (10) is the equivalent of a "AAA" rated bond and (1) a "D" rated bond. These internal risk ratings by banks incorporate the wide array of information available to banks, including information not included elsewhere in the data. As such, it presents the best summary measure of credit risk available for the loans in the sample. The coefficient on the interaction term is statistically and economically insignificant in

[26]The HVCRE LTV limits use supervisory thresholds that existed prior to the announcement of the HVCRE rule. Though crossing these thresholds previously did not affect risk weights, high LTV loans were still subject to higher scrutiny. This higher scrutiny above the thresholds could have contributed to the bunching below the supervisory thresholds before the rule. The null results in our placebo tests indicate that such effects do not influence our estimates.

every specification. If anything, treated loans are assessed as being somewhat safer, all else equal.

Columns (5)-(8) present results using zip code house price volatility as the dependent variable. Loans more affected by the HVCRE rule are originated in zip codes with more volatile house prices, but the effect is insignificant in all but the most parsimonious specification.

Finally, in Online Appendix Table 7, we repeat this analysis using more CRE-specific geographic measures. Using data from CBRE on commercial property metrics at the MSA-property type level, we show that treated loans do not differ in terms of cap rate (reflecting the required return to property investors) or vacancy rate (reflecting leasing frictions or possible over-supply in the segment).[27]

Overall, there is little evidence that indicates the increase in interest rates found in the diff-in-diff results reflect a change in the composition of loans. The share of loans with a high LTV did not change after the rule was announced, and risk characteristics on treated loans generally did not differ from those for control loans.

4 Interpreting the Results: Model and Discussion

In this section, we present a model of bank loan pricing to assist in the interpretation of our estimates. We show that the estimated effect of capital requirements on loan rates we identify reflects the cost of equity relative to debt after adjusting for Modigiliani-Miller effects. Since these factors are determined at the bank level, the effect generalizes to other loan categories. We conclude the section with a discussion of how our estimate of the cost of higher capital requirements relates to estimates of the benefits of capital requirement in the literature.

[27]Cap rate is defined as net operating income as a percent of property value, and thus measures the required return to property owners. Cap rates are higher for riskier property types, such as hotels, or in smaller, less liquid markets. Vacancy rates are the share of available space in an MSA-property type that is vacant.

4.1 Model and Results

Suppose that there is a continuum of banks, indexed by b, each originating several types of loans, indexed by i. Banks are monopolistically competitive, and maximize profits subject to CES demand in the spirit of Dixit and Stiglitz (1977). Let demand for loan type i for bank b at time t, denoted $L^b_{i,t}$, take the form:

$$L^b_{i,t} = L_i(\frac{r^b_{i,t}}{r_{i,t}})^{-\epsilon},$$

where $r^b_{i,t}$ is the interest rate offered for loan i, and $L_{i,t}$ and $r_{i,t}$ are the aggregate demand and market interest rate for that loan type, respectively.[28]

Banks fund their loan portfolio with a combination of deposits, D^b_t, and equity, E^b_t, where minimum equity is determined by risk-weighted capital requirements. Denoting $\omega_{i,t}$ as the amount of equity that must be used to fund a dollar of loan type i, bank b must then hold equity $E^b_t \geq \sum\limits_{i \in I} \omega_{i,t} L^b_{i,t}$, where I denotes the set of loan types.

If the total cost of funding a portfolio is homogeneous of degree one in equity and deposits, then the average cost of funding a dollar in loans will be a function $c(\bar{\omega})$ of the bank's capitalization, denoted $\bar{\omega}^b \equiv \frac{E^b}{\sum\limits_{i \in I} L^b_i}$. Banks then solve the maximization problem:

$$\begin{aligned} \underset{\{L^b_{i,t}, r^b_{i,t}\}}{\text{maximize}} \quad & \sum_{i \in I} L^b_{i,t} r^b_{i,t} - c\left(\frac{E^b_t}{\sum\limits_{i \in I} L^b_{i,t}}\right) \sum_{i \in I} L^b_{i,t} \\ \text{subject to} \quad & L^b_{i,t} = L_{i,t}(\frac{r^b_{i,t}}{r_{i,t}})^{-\epsilon} \; \forall i \in I \\ & E^b_t \geq \sum_{i \in I} \omega_{i,t} L^b_{i,t}. \end{aligned}$$

We assume $c'(\bar{\omega}) \geq 0$, meaning that equity is more costly than debt.[29] Substitut-

[28] This demand function can be microfounded with borrowers minimizing the cost of borrowing a CES composite of loans from a continuum of banks as in Gerali et al. (2010).

[29] This assumption implies that banks want to minimize equity funding, making the second

ing in the constraints and taking the first-order condition with respect to $r^b_{i,t}$ gives the optimal loan rate for category i:

$$r^b_{i,t} = r(\omega_{i,t}, \bar{\omega}^b_t) = \frac{\epsilon}{\epsilon - 1}\left[c(\bar{\omega}^b_t) + c'(\bar{\omega}^b_t)(\omega_{i,t} - \bar{\omega}^b_t)\right]. \tag{3}$$

Now consider what is identified by the diff-in-diff specification. Suppose that a change in policy at time t' raises capital requirements for type H loans from $\omega_{H,t}$ to $\omega_{H,t'}$, while requirements for type L loans remain at the level previous required for H and L loans, meaning that $\omega_{H,t} = \omega_{L,t} = \omega_{L,t'}$. The diff-in-diff estimate of the effect of the rule will be:[30]

$$\begin{aligned} \beta^{\text{D-in-D}} &= [r(\omega_{H,t'}, \bar{\omega}_{t'}) - r(\omega_{L,t'}, \bar{\omega}_{t'})] - [r(\omega_{H,t}, \bar{\omega}_t) - r(\omega_{L,t}, \bar{\omega}_t)] \\ &= \frac{\epsilon}{\epsilon - 1} c'(\bar{\omega}_{t'})(\omega_{H,t'} - \omega_{H,t}), \end{aligned} \tag{4}$$

where the second line follows from substituting in (3) for each interest rate, and the equality of $\omega_{H,t}$, $\omega_{L,t}$ and $\omega_{L,t'}$.

This expression shows that the diff-in-diff estimate depends on the pass-through of costs to loan rates, $\frac{\epsilon}{\epsilon-1}$, the marginal cost of increasing equity funding after the capital requirements go into effect, $c'(\bar{\omega}_{t'})$, and the increase in capital requirements, $\omega_{H,t'} - \omega_{L,t'}$. This last term is known, as requirements increased from 8 percent to 12 percent. The 8.5 basis point increase in loan rates per percentage point increase in capital requirements is thus an estimate of $\frac{\epsilon}{\epsilon-1} c'(\bar{\omega}_{t'})$.

constraint hold with equality. Banks hold significant buffers in excess of their regulatory minimum capital requirements (Berger et al., 2008). ω_i should thus be thought of as a bank's internal required capital for a loan of type i. If banks set these internal requirements to maintain a constant buffer above minimum requirements, these would move 1-for-1 with minimum requirements, leaving our results unchanged.

[30] We drop the b superscript and ignore bank heterogeneity to simplify notation. If banks differ in funding costs, the diff-in-diff effect would depend on the expectation of $c'(\bar{\omega}^b_{t'})$ over the loans in the sample.

4.2 Special Case for $c(\bar{\omega})$

To better understand this expression, we calculate $c'(\bar{\omega}_{t'})$ for a particular case of a cost function. This derivation provides a clearer picture of how costly equity, Modigiliani-Miller offsets, and convex adjustment costs are manifested in the relationship between capital requirements and loan rates.

Suppose equity has a steady-state required rate of return:

$$rr_e(\bar{\omega}) = \xi\bar{\omega}^{-\mu} + rr_d,$$

where rr_d is the required return to debt, which we assume to be independent of capitalization due to deposit insurance. ξ is the premium required for equity when a bank is entirely equity funded, and μ is the Modigiliani-Miller offset, which parameterizes how rapidly the required return to equity declines as a bank becomes better capitalized.

Assume that banks also face adjustment costs $\Phi(\bar{\omega}_{t'} - \bar{\omega}_t)$ per dollar of lending when changing their level of capitalization away from its previous level. Let these adjustment costs be increasing and convex with $\Phi(0) = \Phi'(0) = 0$, and $\Phi''(\cdot) \geq 0$. While $rr_e(\bar{\omega})$ measures the steady-state cost of equity funding, $\Phi(\bar{\omega}_{t'} - \bar{\omega}_t)$ measures the cost of *raising* equity. This additional cost of accessing outside equity can be thought of as reflecting asymmetric information problems (Myers and Majluf, 1984) or underwriting fees (Altınkılıç and Hansen, 2000) associated with equity issuance.

Combining the cost of equity, cost of deposits, and cost of adjusting equity gives the cost of funding a dollar of loans as a function of a bank's capitalization:

$$c(\bar{\omega}_{t'}) = rr_d + (rr_e(\bar{\omega}_{t'}) - rr_d)\bar{\omega}_{t'} + \Phi(\bar{\omega}_{t'} - \bar{\omega}_t).$$

Under these assumptions, the marginal cost of equity funding is:[31]

$$c'(\bar{\omega_{t'}}) = (1-\mu)(rr_e(\bar{\omega}_{t'}) - rr_d) + \Phi'(\bar{\omega_{t'}} - \bar{\omega}_t). \tag{5}$$

This expression shows that the marginal cost of equity funding has two components. First, there is the steady-state cost of equity funding reflecting how much more expensive equity is than debt after adjusting for Modigiliani-Miller effects. The second effect is the short run cost of *raising* equity, which reflects costs of transitioning to the higher level of capitalization that becomes zero once that level of capitalization is met.

A merit of studying the HVCRE rule is that such adjustment costs are likely negligible. For one, HVCRE loans are only about 1% of bank loan portfolios, meaning the rule itself did little to affect aggregate capital requirements.[32] Second, as was shown in Figure 1, the rule went into effect at a time when aggregate capital was steady and banks were distributing earnings to shareholders on net, rather than raising new equity.

In short, while estimates of the effect of capital requirements on loan rates can reflect the cost of adjusting equity, our estimates likely reflect the steady-state cost equity funding. Absent broad-based changes in requirements pushing $\bar{\omega}_{t'}$ up, or significant losses pushing $\bar{\omega}_t$ down, it is likely that $\Phi'(\bar{\omega}_{t'} - \bar{\omega}_t) \approx \Phi'(0) = 0$.

[31]For simplicity, this analysis doesn't include a tax advantage of debt. If a bank faces a tax rate τ, it saves $\tau(1-\bar{\omega}_{t'})rr_d$ per dollar of loans by deducting interest expenses. Accounting for this would add an extra term τrr_d to the expression for $c'(\bar{\omega_{t'}})$ to account for the cost of the lost tax shield.

[32]More formally, $\frac{\partial \bar{\omega}^b}{\partial \omega_i}$ can be shown to be proportional to b's portfolio share in loan type i. Applying the implicit function theorem to the equation $\bar{\omega}^b - \frac{\sum_{j \in I} \omega_j L_j^b}{\sum_{j \in I} L_j^b} = 0$, we can show that

$$\frac{\partial \bar{\omega}^b}{\partial \omega_i} = \theta_i^b \frac{1 + (\omega_i - \bar{\omega}^b)\eta_i^{Dr} \frac{\partial r_i}{\partial \omega_i} \frac{1}{r_i}}{1 - \sum_{j \in I} (\omega_j - \bar{\omega}^b)\theta_j \eta_j^{Dr} \frac{\partial r_j}{\partial \bar{\omega}} \frac{1}{r_j}},$$

where θ_i^b is the fraction of lending that is of type i, and η_i^{Dr} is the elasticity of aggregate loan demand for loan type i to interest rates.

Combining (4) and (5), and noting that adjustment costs are about zero, our estimate identifies:

$$\beta^{\text{D-in-D}} \approx \underbrace{\epsilon/(\epsilon-1)}_{\text{Pass-through}} \times \underbrace{(1-\mu)}_{\substack{\text{M-M}\\ \text{Adjustment}}} \times \underbrace{(rr_e(\bar{\omega}) - rr_d)}_{\text{Equity Premium}}.$$

These three factors—the pass-through of costs to borrowers, the adjustment for Modigiliani-Miller offsets, and the higher cost of equity relative to debt—are the exact parameters that are estimated in papers such as Miles et al. (2013) and Firestone et al. (2017) that try to estimate the long-run costs of increasing capital. This equation indicates that our methodology identifies the steady-state cost of a change in capital requirements.[33]

4.3 Discussion

To get a sense of what our findings imply regarding the desirability of higher capital requirements, we compare the estimate of the marginal cost of capital requirements in our preferred specification (Specification 4 in Table 2) to the marginal benefits estimated by Firestone et al. (2017).[34] They note that FRB/US, a large-scale general equilibrium model of the US economy used by the Federal Reserve Board Staff, predicts that a 1bp increase in loan rates decreases the level of GDP by about 1.07bp. Combined with our estimated elasticity of loan rates with respect to capital requirements of 8.5bp, this implies that a one percentage point increase in capital requirements lowers GDP by about 9bp.

The benefit of higher capital is estimated as the reduction in the likelihood of a

[33] In addition to the direct effects that capital requirements have by increasing the cost of funding the targeted category, capital requirements can also have an indirect effect on the cost of equity. These indirect effects are likely negligible for HVCRE (we have shown in this section that capital requirements for HVCRE have little effect on aggregate capital requirements). However, a change in capital requirement for a larger category may be able to affect the marginal cost of equity, and thus affect the pricing of loans in other categories. This is discussed further in Appendix B.

[34] Note that higher borrowing costs may reflect the attenuation of distortions from government guarantees or the tax advantage of debt, in which case the costs of greater capital requirements would be private instead of social (Admati and Hellwig, 2014).

financial crisis from a 1 percentage point increase in capital, times the GDP loss due to a financial crisis. This makes the estimated net benefit of bank capital:

$$\text{Net Benefit} = \underbrace{\overbrace{\Delta\text{GDP}|\text{Crisis} \times \frac{\Delta\text{Pr(Crisis)}}{\Delta\text{Capital}}}^{\text{Marginal Benefit}}}_{\substack{\text{7bp-25bp} \\ \text{(Firestone et. al., 2017)}}} - \overbrace{\underbrace{\frac{\Delta\text{GDP}}{\Delta\text{Loan Rate}}}_{\substack{1.07 \\ \text{(FRB/US)}}} \underbrace{\frac{\Delta\text{Loan Rate}}{\Delta\text{Capital}}}_{\substack{\text{8.5bp} \\ \text{(this paper)}}}}^{\text{Marginal Cost}} .$$

Figure 7 plots the marginal benefits of higher capital from Firestone et al. (2017) at different levels of bank capitalization against the marginal cost implied by the estimates in this paper. We can see that the benefits of higher capital requirements are uncertain. Conservative estimates place the marginal benefit of a one percentage point increase in capital requirements (in terms of GDP) around 7bp, while the more aggressive estimates place the marginal benefit around 25bp.[35] With the most conservative estimate of the benefits, the costs of increasing capital just narrowly exceed the benefits, indicating current capital ratios are near their optimum. However, it is also possible that there are significant welfare gains to be made from increasing capital, with an optimal Tier 1 capital ratio closer to 20%.

5 Conclusion

Our paper studies the effect of a 50% increase in the amount of capital required to fund High Volatility Commercial Real Estate (HVCRE) 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 interest rates on treated loans by 34 basis points. We

[35] The conservative estimate assumes that financial crises cause only a temporary decline in the level of GDP and that other regulatory changes reduce the likelihood of financial crises, reducing the value of higher capital. The higher estimated benefit comes from assuming that financial crises permanently reduce the level of GDP.

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. The finding indicates that a one percentage point increase in capital requirements raises loan rates by about 8.5bp.

In a model with monopolistically competitive banks that face risk-based capital requirements, we show that the elasticity of loan rates with respect to risk weights in this particular setting reflects the steady-state cost of higher capital requirements (rather than transition costs). Although raising new capital is costly, it is a short-term cost. In the long run, the cost of higher capital reflects the cost of inside equity relative to debt. Under most estimates of the benefits in the literature, we find the benefits of increasing capital requirements from their current levels outweigh the costs. Under the most conservative estimate of the benefits, the costs of increasing capital just narrowly exceed the benefits, indicating current capital ratios are near their optimum. This wide range of optimal implied Tier 1 ratios suggests more research needs to be done in estimating the benefits of capital requirements.

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

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

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

Table 2
Baseline Diff-in-Diff

	Effect on Interest Rates (percentage points)							
	No CBSA Fixed Effects				CBSA-Qtr Fixed Effects			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
High LTV x Pct. HVCRE	0.57**	0.32**	0.32**	0.34**	0.47**	0.27*	0.27*	0.30**
	(0.12)	(0.11)	(0.11)	(0.10)	(0.12)	(0.12)	(0.11)	(0.11)
Pct. HVCRE	-0.15**	-0.33**	-1.10	-1.11	-0.05	-0.25**	-0.17	-0.22
	(0.05)	(0.06)	(0.86)	(0.85)	(0.06)	(0.06)	(0.93)	(0.92)
High LTV	-0.18*	-0.15*	1.92**	1.76**	-0.11	-0.09	2.08**	1.88**
	(0.08)	(0.07)	(0.66)	(0.66)	(0.08)	(0.08)	(0.72)	(0.71)
Loan controls	X	X	X	X	X	X	X	X
Qtr FE	X	X	X		X	X	X	
$\mathbb{1}_{\text{Fixed Rate}} \times$ {Pct. HVCRE; High LTV}		X				X		
Controls $\times$ {Pct. HVCRE; High LTV}			X	X			X	X
Bank-Qtr FE				X				X
CBSA-Qtr FE					X	X	X	X
R_a^2	0.352	0.372	0.379	0.457	0.414	0.430	0.439	0.497
No. banks	31	31	31	31	31	31	31	29
No. loans	8823	8823	8823	8823	7853	7853	7853	7829

Notes: This table reports coefficients from the following regression:

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

where $r_{i,b,t}$ is the interest rate on loan i from bank b at time t. The variable High LTV$_{i,b,t}$ is an indicator function taking the value of one if the LTV on the construction loan is above the HVCRE limit, and the variable Pct. HVCRE$_{i,b,t}$ is the percentage of the life of the loan occurring after the implementation date. $X_{i,b,t}$ includes the following loan-level controls: the annual volatility of zip code level house prices, the natural logarithm of the committed exposure, property types dummies (Multifamily, Office, Retail or Other), risk rating dummies, loan purpose dummies (Land Acquisition/Development, Construction, or Renovation), appraised type dummies ("as is", "as completed" or "as stabilized"), as well as an indicator variable specifying whether the loan rate is fixed or floating. $X_{i,b,t}$ also includes the treatment variables and in some specifications the interaction of these variables with the loan controls. $\tau_{b,t}$ is a bank-quarter fixed effect. Each column presents coefficients from the difference-in-difference specification for the sample of non-1-4 family ADC loans originated between the announcement and implementation of the HVCRE rule. Column (1) includes the set of controls and quarter fixed effects, column (2) adds an interaction of the fixed rate dummy with High LTV$_{i,b,t}$ and Pct. HVCRE$_{i,b,t}$, column (3) additionally includes interactions of the rest of the controls with the treatment variables, and column (4) additionally includes bank-quarter fixed effects. Columns (5)-(8) present results from identical specifications, except additionally include CBSA-quarter fixed effects. Standard errors, in parentheses, are clustered at the bank-quarter level. +,*,** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 3
Triple Difference Estimates

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

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

Table 4
Baseline Diff-in-Diff: Placebo Sample

	Effect on Interest Rates (percentage points)							
	No CBSA Fixed Effects				CBSA-Qtr Fixed Effects			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
High LTV x Pct. HVCRE	0.20^{+}	0.14	0.11	0.04	0.13	0.09	0.04	-0.00
	(0.11)	(0.10)	(0.12)	(0.11)	(0.14)	(0.13)	(0.15)	(0.15)
Pct. HVCRE	-0.40**	-0.45**	0.51	0.15	-0.25**	-0.30**	1.41^{+}	1.01
	(0.08)	(0.09)	(0.77)	(0.77)	(0.09)	(0.09)	(0.83)	(0.83)
High LTV	-0.08	-0.09	-0.11	0.07	-0.02	-0.02	0.41	0.43
	(0.05)	(0.05)	(0.62)	(0.63)	(0.07)	(0.07)	(0.75)	(0.78)
Loan controls	X	X	X	X	X	X	X	X
Qtr FE	X	X	X		X	X	X	
$\mathbb{1}_{\text{Fixed Rate}}\times$\{Pct. HVCRE; High LTV\}		X				X		
Controls$\times$\{Pct. HVCRE; High LTV\}			X	X			X	X
Bank-Qtr FE				X				X
CBSA-Qtr FE					X	X	X	X
R^2_a	0.251	0.253	0.260	0.329	0.316	0.318	0.323	0.382
No. banks	29	29	29	29	29	29	29	24
No. loans	6712	6712	6712	6712	5840	5840	5840	5812

Notes: This table reports coefficients from the following regression:

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

for the sample of loans originated between January 1, 2010 and the announcement of the HVCRE rule. All other variables are as in Table 2. The variable $r_{i,b,t}$ is the interest rate on loan i from bank b at time t. The variable High LTV$_{i,b,t}$ is an indicator function taking the value of one if the LTV on the construction loan is above the HVCRE limit, and the variable Pct. HVCRE$_{i,b,t}$ is the percentage of the life of the loan occurring after the announcement date. $X_{i,b,t}$ is a vector of the loan-level controls, the two treatment variables, and in some specifications the interaction of these variables with the loan controls (controls are listed in Table 2 and Section 2.3). $\tau_{b,t}$ is a bank-quarter fixed effect. Each column presents coefficients from the difference-in-difference specification for the sample of non-1-4 family ADC loans originated between the announcement and implementation of the HVCRE rule. Column (1) includes the set of controls and quarter fixed effects, column (2) adds an interaction of the fixed rate dummy with High LTV$_{i,b,t}$ and Pct. HVCRE$_{i,b,t}$, column (3) additionally includes interactions of the rest of the controls with the treatment variables, and column (4) additionally includes bank-quarter fixed effects. Columns (5)-(8) present results from identical specifications, except additionally include CBSA-quarter fixed effects. Standard errors, in parentheses, are clustered at the bank-quarter level. +,*,** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 5
Heterogeneous Effects By Distance to Capital Constraints

	Effect on Interest Rates (percentage points)							
	No CBSA Fixed Effects				CBSA-Qtr Fixed Effects			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Capital Constrained								
x High LTV x Pct. HVCRE	0.52^{+}	0.60*	0.51*	0.43*	0.59*	0.64*	0.59*	0.44^{+}
	(0.31)	(0.25)	(0.22)	(0.20)	(0.30)	(0.26)	(0.23)	(0.23)
x Pct. HVCRE	-0.04	-0.04	-0.05	-0.01	-0.02	-0.02	-0.06	0.09
	(0.11)	(0.11)	(0.11)	(0.11)	(0.12)	(0.11)	(0.11)	(0.12)
x High LTV	-0.29^{+}	-0.31*	-0.23^{+}	-0.24^{+}	-0.36*	-0.36*	-0.30^{+}	-0.24
	(0.16)	(0.15)	(0.14)	(0.13)	(0.17)	(0.16)	(0.16)	(0.15)
High LTV x Pct. HVCRE	0.13	-0.06	0.01	0.07	-0.00	-0.13	-0.06	0.05
	(0.21)	(0.18)	(0.16)	(0.15)	(0.20)	(0.18)	(0.15)	(0.15)
Pct. HVCRE	-0.14^{+}	-0.30**	-1.64^{+}	-1.68^{+}	-0.03	-0.21*	-0.47	-0.51
	(0.08)	(0.08)	(0.90)	(0.89)	(0.08)	(0.08)	(1.07)	(1.04)
High LTV	0.04	0.05	2.19**	2.05**	0.15	0.15	2.26**	2.05*
	(0.12)	(0.11)	(0.72)	(0.72)	(0.12)	(0.12)	(0.85)	(0.83)
Loan controls	X	X	X	X	X	X	X	X
Qtr FE	X	X	X					
$\mathbb{1}_{\text{Fixed Rate}}$ Interactions		X				X		
Fully Interacted Controls			X	X			X	X
Bank-Qtr FE				X				X
CBSA-Qtr FE					X	X	X	X
R_a^2	0.301	0.318	0.330	0.415	0.367	0.381	0.396	0.458
No. banks	30	30	30	30	30	30	30	28
No. loans	7628	7628	7628	7628	6703	6703	6703	6679

Notes: This table reports coefficients from the following regression:

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

where Capital $\text{Constrained}_{i,b,t}$ 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 $r_{i,b,t}$ is the interest rate on loan i from bank b at time t. The variable High $\text{LTV}_{i,b,t}$ is an indicator function taking the value of one if the LTV on the construction loan is above the HVCRE limit, and the variable Pct. $\text{HVCRE}_{i,b,t}$ is the percentage of the life of the loan occurring after the implementation date. $X_{i,b,t}$ is a vector of the loan-level controls, the three treatment variables, and in some specifications the interaction of these variables with the loan controls (controls are listed in Table 2 and Section 2.3). $\tau_{b,t}$ is a bank-quarter fixed effect. Each column presents coefficients from the difference-in-difference specification for the sample of non-1-4 family ADC loans originated between the announcement and implementation of the HVCRE rule. Column (1) includes the set of controls and quarter fixed effects, column (2) adds an interaction of the fixed rate dummy with High $\text{LTV}_{i,b,t}$ and Pct. $\text{HVCRE}_{i,b,t}$, column (3) additionally includes interactions of the rest of the controls with the treatment variables, and column (4) additionally includes bank-quarter fixed effects. Columns (5)-(8) present results from identical specifications, except additionally include CBSA-quarter fixed effects. Standard errors, in parentheses, are clustered at the bank-quarter level. +,*,** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 6
Tests for Bias from Potential Misclassification of Treatment

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

Notes: This table reports coefficients from the following regression:

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

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

Table 7
Estimated Effect on Risk Characteristics

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

Notes: This table reports coefficients from the following regression:

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

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

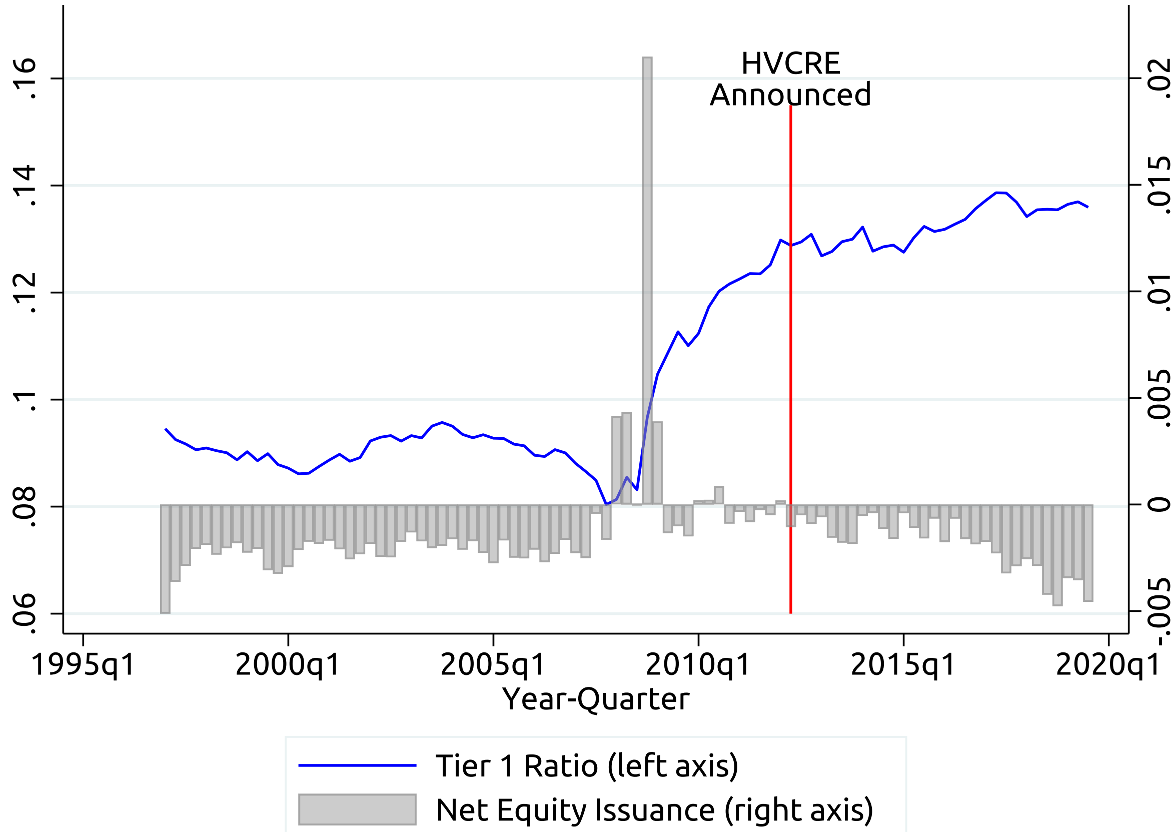

Figure 1: Bank Capital Raising

Notes: This figure plots banks' quarterly net equity issuance and Tier 1 capital, both as a percent of risk-weighted assets. Net equity issuance is the difference between stock sales and capital distributions, aggregated across all of the banks. Stock sales include: the sale and conversions of perpetual preferred stocks and common stocks as wells as the sale of treasury stock. Capital distributions include cash dividends and the purchase of treasury stock. Tier 1 capital and risk-weighted assets are both aggregated across banks. All measures computed in this figure are derived from the FR Y9-C form, and banks are those that report on the form FR Y9-C.

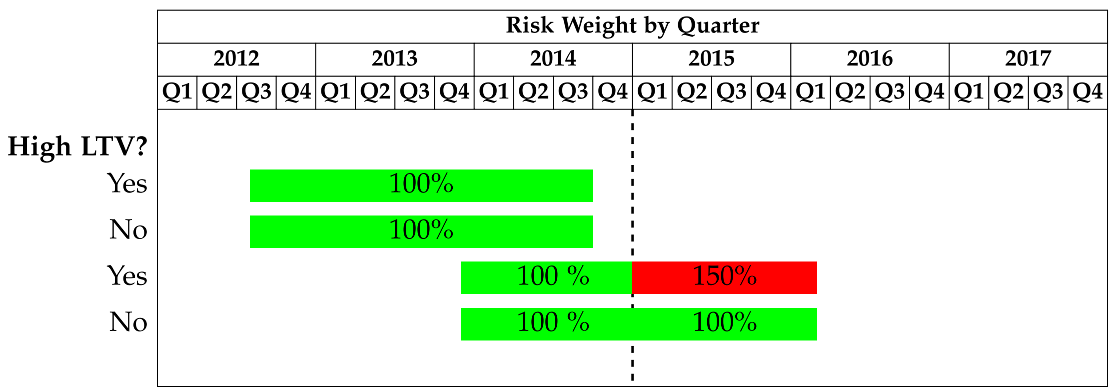

Figure 2: Sources of Variation

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

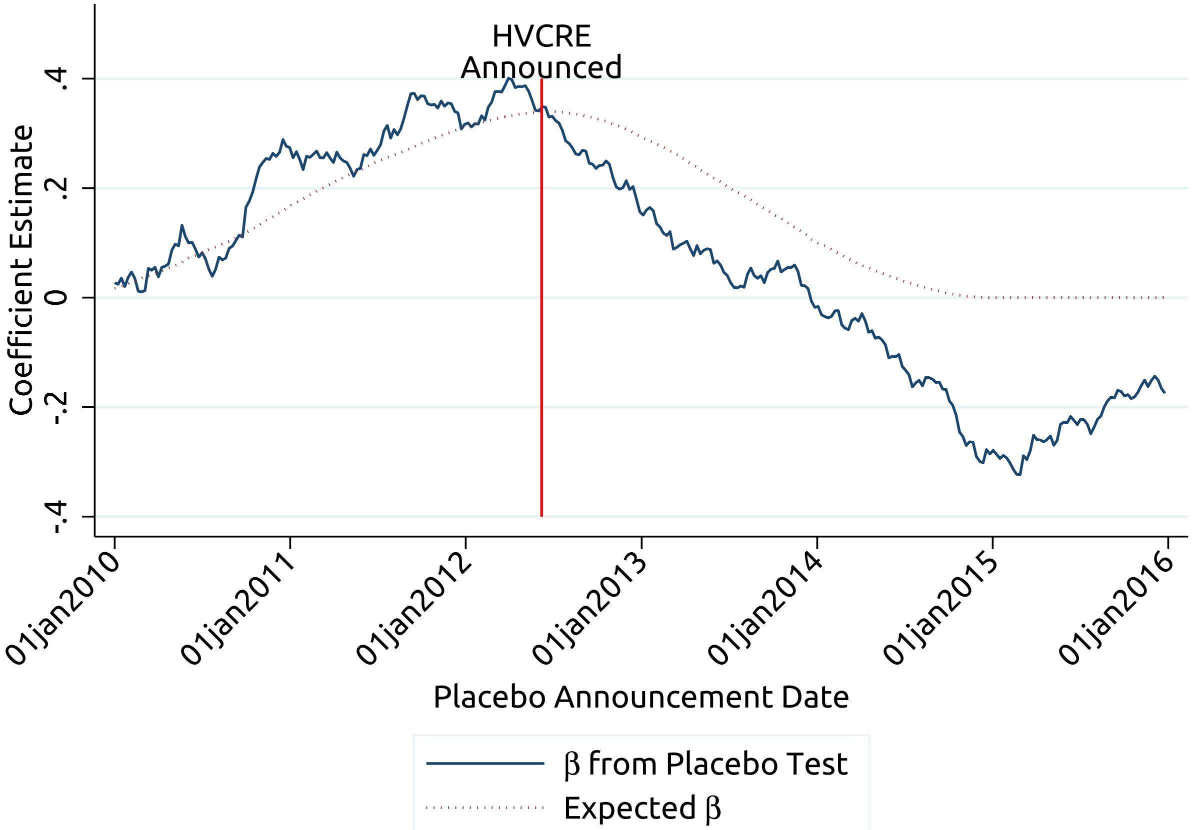

Figure 3: Regression Coefficients By Placebo Announcement Date

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

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

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

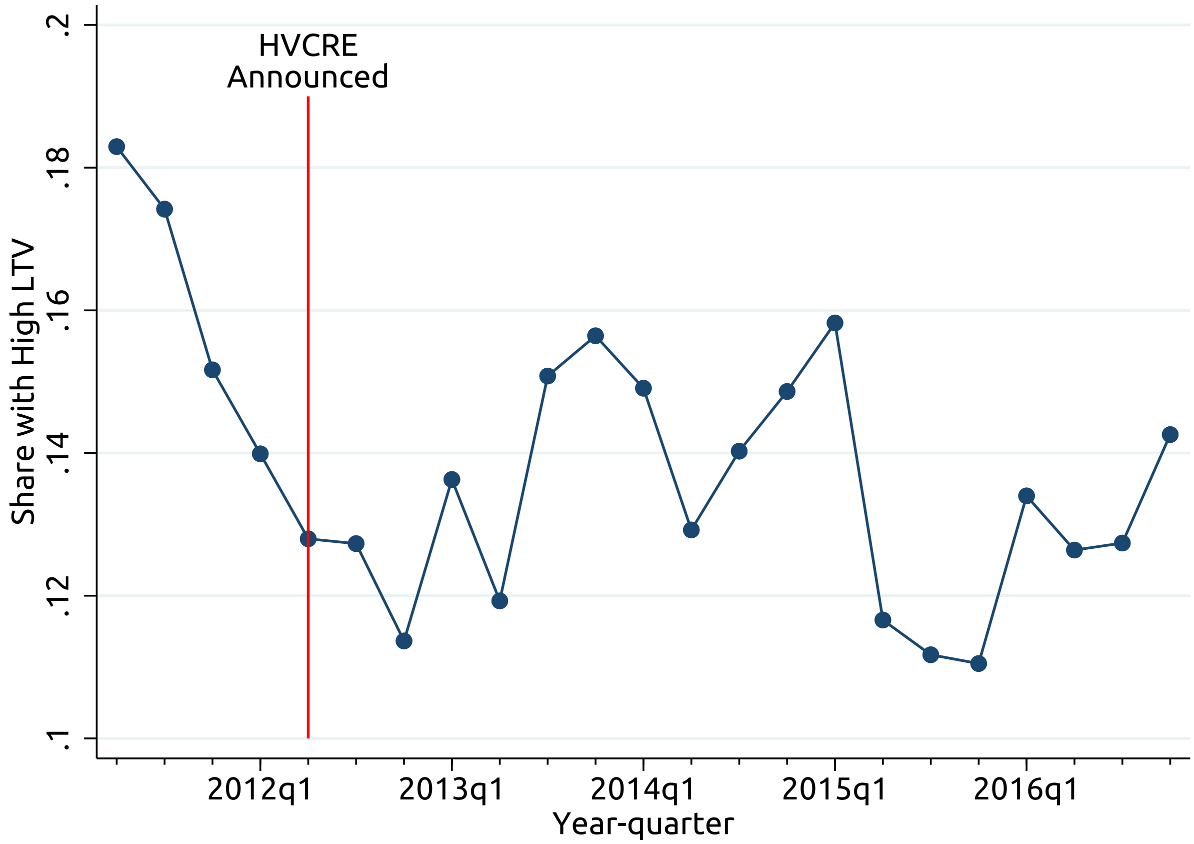

Figure 4: Percent of Newly Originated Non-1-4 Family ADC Loans with a High LTV

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

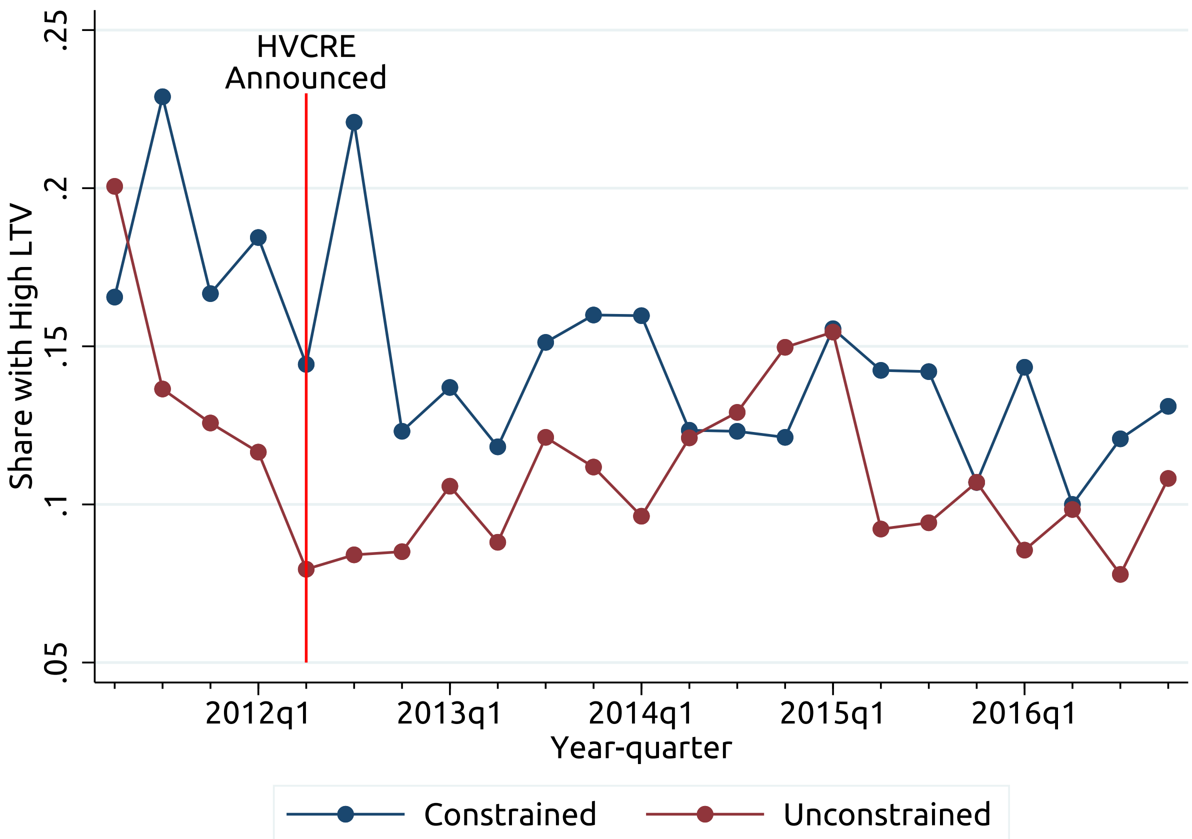

Figure 5: Percent of Newly Originated Non-1-4 Family ADC Loans with a High LTV, by Proximity to Minimal Capital Ratios

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

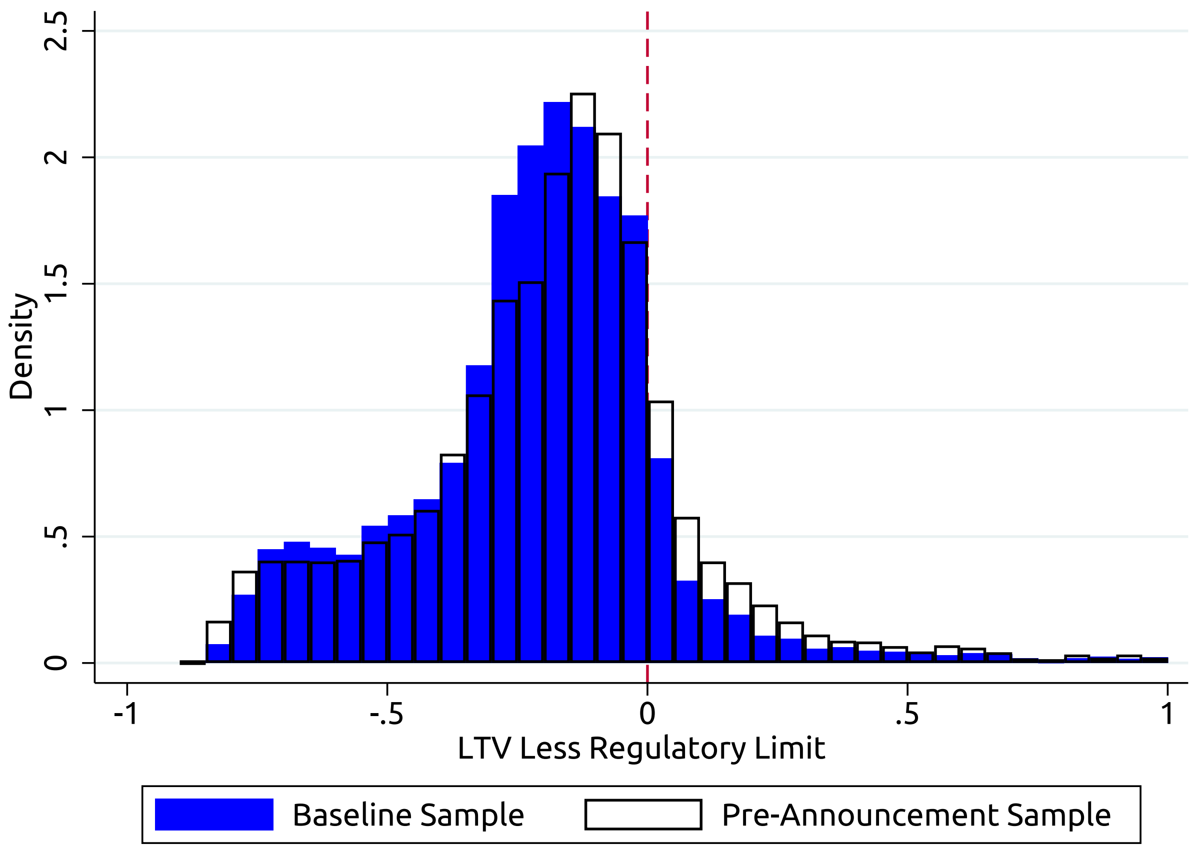

Figure 6: Density of LTV Less Regulatory Limit

Notes: This figure displays the distribution of the difference between the LTV 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. The dashed line denotes the boundary beyond which loans exceed the supervisory limit. Values above 1 are suppressed due to a long right tail in the LTV distribution.

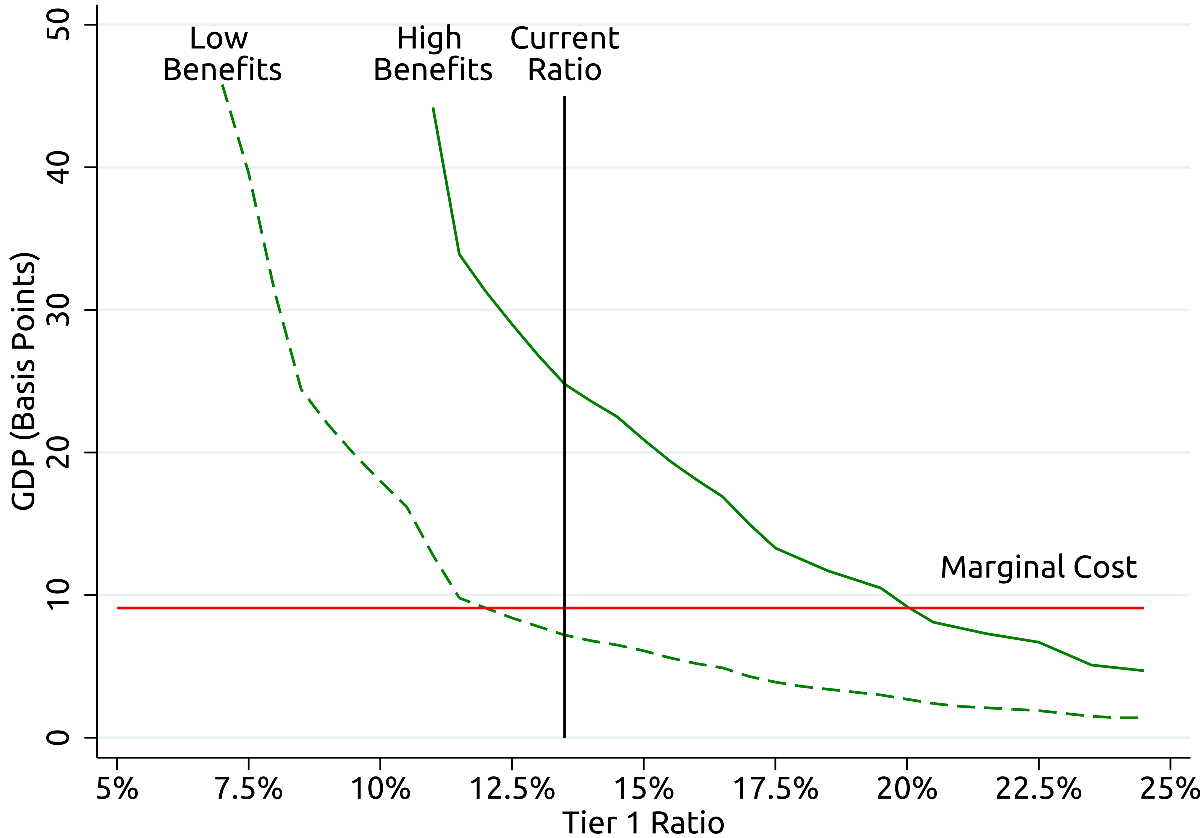

Figure 7: Marginal Costs and Benefits of Higher Capital Requirements

Notes: This figure displays estimates of the marginal benefit of higher capital requirements in terms of less frequent financial crisis and the marginal cost of capital requirements in terms of lower GDP from higher loan spreads. Estimates of the marginal benefits of capital requirements come from Firestone et al. (2017). The estimated cost of capital requirements is the 8.5bp elasticity of loan rates with respect to capital requirements estimated from the diff-in-diff specification times the -1.07 elasticity of GDP with respect to loan spreads estimated by Firestone et al. (2017).

Appendix

A Data Appendix

The data from the Y-14Q Schedule H.2 was downloaded on April 26, 2019 from the Wholesale Data Mart, which is maintained by staff at the Federal Reserve Bank of Chicago.[36] We clean the raw Y-14Q download by dropping observations that have missing values for any variables we require for our analysis. This includes "loan purpose" (MDRM G073), the line reported on the FR Y-9C (MDRM K449), interest rate (MDRM 7889), committed exposure (MDRM G074), interest rate variability category (MDRM K461), maturity date (MDRM 9914), origination date (MDRM 9912), 5-digit zip code of the property (MDRM K453), and the type of appraised value (MDRM K456). We also drop extreme observations: interest rates below zero or above 25 percent, times to maturity below 0 or above 30 years, and negative committed exposures. In addition, we drop missing or negative observations for the risk rating of the loan, or loans in zipcodes not matching to the house price data.

Risk rating is a standardized version of the internal rating of the loan (MDRM G080). This rating takes the internal risk rating using a particular bank's scale, and maps the rating to a common scale (e.g. A, BB, or BBB) provided by the bank. When multiple ratings are provided for a loan, which occurs if an internal rating category spans multiple external categories, we take the minimum risk rating.

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

[36]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.

are winsorized at the 1% level.

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

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

To compute the house price volatility in the zip code, we take the standard deviation of annual house price changes. This variables uses data from the Federal Housing Finance Agency zip code level House Price Index.[37] We compute the standard deviation of the given year-over-year change in house prices between 1990 and 2011 and merge this by zip code with our loan-level dataset. The standard deviation of annual house price changes is winsorized at the 1% level. For the broader geographic controls, a core-based statistical area (CBSA) in our data is either the actual CBSA, or the county for counties not in a CBSA.

We also merge in quarterly bank-holding company level data on capitalization from the FR Y-9C. In the few cases in which a loan origination occurs in a quarter when subsidiaries of the bank holding company did not file a Y-9C form, we drop these observations from our heterogeneous effects analysis, but not from our baseline or placebo analysis. Our results are basically unchanged if we drop these observations from our baseline and

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

placebo analyses.

In calculating the bank-level measure of the distance from the tier 1 capital constraint, we assume the G-SIB surcharge (as of January 2017) and Capital Conservation buffers are half-way phased in.[38] That is, the constraint is 6% plus half of the phase in of the 2.5% capital conservation buffer (so 7.25% total) for most banks in our sample, with an extra half of 2.5% (due to the G-SIB surcharge) for JP Morgan Chase & Co. (RSSDID 1039502) and Citigroup Inc. (RSSD ID 1951350), 2% for Bank of America Corporation (RSSD ID 1073757), DB USA Corporation (RSSD ID 2816906), and HSBC North America Holdings Inc. (RSSD ID 3232316), 1.5% for Wells Fargo & Company (RSSD ID 1120754) and The Goldman Sachs Group, Inc. (RSSD ID 2384403), and 1% for Morgan Stanley (RSSD ID 2162966), State Street Corporation (RSSD ID 1111435), Bank of New York Mellon Corporation (RSSD ID 3587146), Santander Holdings USA, Inc. USA (RSSD ID 3981856). We compute the distance from the constraint as Tier 1 capital (BHCK 8274) relative to the bank's total risk-weighted assets (BHCK A223) less the bank-specific capital constraint.

A couple of additional data sources are used as robustness checks in the appendix. As an additional control for the term premium, we add the maturity-matched reference rate to the specification. This variable takes the value of one-month dollar LIBOR for floating rate loans, and the maturity-matched swap rate for fixed rate loans. The maturity-matched swap rate linearly imputes between LIBOR and the two-year swap rate for fixed-rate loans with a term under two years, and linearly imputes between relevant swap rates for longer-term loans. For example, the reference rate for a fixed-rate loan with a 4.5 year term would be an average of the 4 and 5 year swap rate at the time of origination. Finally, we also use data from CBRE Econometric Advisors on vacancy rates and cap rates by property type and MSA. These data provide another way of assessing differences in risks for treated loans. Properties in the Y-14 data are matched on property-types and MSA using an MSA-zip code crosswalk from CBRE.

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

B Effects of a general change to capital requirements:

In Section 4, we show that our difference-in-differences estimate reflects the marginal cost of increasing equity funding times a mark-up. The particular setting of the HVCRE rule makes this marginal cost likely to reflect steady-state costs of equity funding. Here, we discuss what an estimate of the effect of capital requirements on loan rates can say about a change in capital requirements more generally, and how the effects of a change in requirements for other types of loans could have different effects.

Differentiating (3) with respect to a particular category's capital requirement shows how changing capital requirements for loan type i affects loan rates for category j:

$$\frac{\partial r_j^b}{\partial \omega_i} = \begin{cases} \frac{\epsilon}{\epsilon - 1}\left[c'(\bar{\omega}^b) + \frac{\partial \bar{\omega}^b}{\partial \omega_i} c''(\bar{\omega}^b)(\omega_i - \bar{\omega}^b)\right], \text{ for } i = j \\ \frac{\epsilon}{\epsilon - 1}\left[\qquad\qquad \frac{\partial \bar{\omega}^b}{\partial \omega_i} c''(\bar{\omega}^b)(\omega_j - \bar{\omega}^b)\right], \text{ for } \neq j. \end{cases} \tag{6}$$

In general, changes in risk weights affect pricing through two mechanisms. First, there is the direct effect: loans in the targeted category need to be funded with more equity. This is captured by the term $c'(\bar{\omega}^b)$, which reflects how much more costly equity is than debt. Equation (4) shows that this is the term reflected in our diff-in-diff estimate. Note that the costs of debt and equity are determined at the bank level, so the magnitude of this effect is common across different categories. Therefore, even though our methodology only studies the effect of changes in capital requirements for a small loan category, the findings are informative as to the effects of capital requirements for other categories.

Second there is an indirect effect: changes in capital requirements may influence the marginal cost of equity relative to debt by changing the bank's aggregate capitalization. Unlike the direct effect, which only influences the treated category, this change in the cost of equity will have broader consequences. If higher risk weights for one category makes equity comparatively more costly at the margin, all loan types with significant capital requirements will become more expensive to fund.

In short, our estimated effect of capital requirements on loan rates captures the direct effect of the capital requirements on the cost of funding a loan, not the indirect effect on equity costs.[39] While the HVCRE rule likely had minimal indirect effects (as $\frac{\partial \bar{\omega}^b}{\partial \omega_i} \approx 0$ —see footnote 32), other changes in capital requirements might have more prominent indirect effects. A broad-based change in capital requirements, or a change for a loan category that comprises a larger share of banks' portfolios, would have more influence on capital holdings in aggregate. In the presence of convex adjustment costs, this could result in a more significant increase in loan rates, at least in the short run as banks transition to the higher level of capitalization.

[39] Note that the direction of this effect is ambiguous. On one hand, higher capital requirements might make banks safer, reducing the cost of equity, and making loans with higher capital requirements cheaper to fund. On the other hand, adjustment costs can make higher capital requirements for one category increase the cost of funding loans in other categories.

Online Appendix

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

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

Notes: 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 non-missing observations for that variable. The variable σ(Δln(House Prices)) is the standard deviation of the annual change in house prices of the zip code of loan. Further information on variable construction can be found in the Appendix.

Online Appendix Table 2
Diff-in-Diff Also Controlling for the Term Premium

	Effect on Interest Rates (percentage points)							
	No CBSA Fixed Effects				CBSA-Qtr Fixed Effects			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
High LTV x Pct. HVCRE	0.26*	0.24*	0.26*	0.29**	0.20+	0.21+	0.26*	0.29*
	(0.10)	(0.11)	(0.11)	(0.10)	(0.11)	(0.12)	(0.12)	(0.11)
Pct. HVCRE	-0.37**	-0.36**	-1.27	-1.37	-0.27**	-0.28**	-0.45	-0.56
	(0.05)	(0.06)	(0.87)	(0.86)	(0.06)	(0.06)	(0.94)	(0.93)
High LTV	-0.11	-0.11	1.90**	1.78**	-0.05	-0.05	2.13**	1.91**
	(0.07)	(0.07)	(0.65)	(0.64)	(0.08)	(0.08)	(0.70)	(0.69)
Loan controls	X	X	X	X	X	X	X	X
Qtr FE	X	X	X		X	X	X	
$\mathbb{1}_{\text{Fixed Rate}}\times$\{Pct. HVCRE; High LTV\}		X				X		
Controls$\times$\{Pct. HVCRE; High LTV\}			X	X			X	X
Bank-Qtr FE				X				X
CBSA-Qtr FE					X	X	X	X
R^2_a	0.387	0.387	0.394	0.471	0.440	0.440	0.450	0.508
No. banks	31	31	31	31	31	31	31	29
No. loans	8823	8823	8823	8823	7853	7853	7853	7829

Notes: This table reports coefficients from the following regression:

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

where $r_{i,b,t}$ is the interest rate on loan i from bank b at time t. The variable High LTV$_{i,b,t}$ is an indicator function taking the value of one if the LTV on the construction loan is above the HVCRE limit, and the variable Pct. HVCRE$_{i,b,t}$ is the percentage of the life of the loan occurring after the implementation date. $X_{i,b,t}$ includes the same loan-level controls as in Table 2, as well as an additional control for the maturity-matched reference rate. This reference rate is one-month dollar LIBOR at the time of origination for floating rate loans and the maturity-matched swap rate for fixed rate loans. Maturity-matched swap rates are linearly imputed between available quotes. $X_{i,b,t}$ also includes the treatment variables and in some specifications the interaction of these variables with the loan controls. $\tau_{b,t}$ is a bank-quarter fixed effect. Each column presents coefficients from the difference-in-difference specification for the sample of non-1-4 family ADC loans originated between the announcement and implementation of the HVCRE rule. Column (1) includes the set of controls and quarter fixed effects, column (2) adds an interaction of the fixed rate dummy with High LTV$_{i,b,t}$ and Pct. HVCRE$_{i,b,t}$, column (3) additionally includes interactions of the rest of the controls with the treatment variables, and column (4) additionally includes bank-quarter fixed effects. Columns (5)-(8) present results from identical specifications, except additionally include CBSA-quarter fixed effects. Standard errors, in parentheses, are clustered at the bank-quarter level. +,*,** indicate significance at the 10%, 5%, and 1% levels, respectively.

Online Appendix Table 3

Triple Difference Estimates Also Controlling for the Term Premium

	Effect on Interest Rates (percentage points)							
	Sample of ADC Loans				Sample of CRE Loans			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
High LTV x Pct. HVCRE x Non-1-4 family ADC	0.67**	0.64**	0.62**	0.46*	0.42**	0.42**	0.38**	0.41**
	(0.20)	(0.20)	(0.21)	(0.21)	(0.13)	(0.13)	(0.13)	(0.12)
High LTV x Pct. HVCRE	-0.41*	-0.40*	-0.36*	-0.19	-0.16+	-0.15	-0.08	-0.06
	(0.17)	(0.17)	(0.18)	(0.17)	(0.10)	(0.10)	(0.10)	(0.09)
Pct. HVCRE	-0.27*	-0.29*	-0.61	-1.23	-0.53**	-0.54**	-0.42	-0.71
	(0.12)	(0.13)	(0.76)	(0.80)	(0.06)	(0.06)	(0.56)	(0.53)
High LTV	0.24*	0.23*	2.01**	1.91**	0.21**	0.21**	0.66+	0.65*
	(0.09)	(0.09)	(0.54)	(0.55)	(0.06)	(0.07)	(0.35)	(0.33)
Non-1-4 family ADC x Pct. HVCRE	-0.13	-0.12	-0.23+	-0.13	0.18*	0.19*	0.04	0.10
	(0.12)	(0.12)	(0.13)	(0.13)	(0.07)	(0.07)	(0.08)	(0.07)
High LTV x Non-1-4 family ADC	-0.35**	-0.34**	-0.23+	-0.18	-0.31**	-0.31**	-0.26**	-0.21*
	(0.12)	(0.12)	(0.12)	(0.11)	(0.09)	(0.09)	(0.09)	(0.08)
Non-1-4 family ADC	-0.09	-0.08	-0.05	-0.74	-0.06	-0.06	-0.01	-0.30
	(0.47)	(0.47)	(0.47)	(0.49)	(0.38)	(0.38)	(0.38)	(0.36)
Loan controls	X	X	X	X	X	X	X	X
Qtr FE	X	X	X		X	X	X	
Controls $\times$ {Non-1-4 Fam ADC}	X	X	X	X	X	X	X	X
$\mathbb{1}_{\text{Fixed Rate}} \times$ {Pct. HVCRE; High LTV}		X				X		
Controls $\times$ {Pct. HVCRE; High LTV}			X	X			X	X
Bank-Qtr FE				X				X
R^2_a	0.417	0.417	0.423	0.498	0.426	0.426	0.430	0.488
No. banks	31	31	31	31	36	36	36	36
No. loans	10860	10860	10860	10860	32280	32280	32280	32280

Notes: 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 LTV on the construction loan is above the HVCRE limit, the variable Pct. HVCRE$_{i,b,t}$ is the percentage of the life of the loan occurring after the implementation date, and the variable Non-1-4 family ADC$_{i,b,t}$ is an indicator for whether the loan is an ADC loan for a non-1-4 family property. $X_{i,b,t}$ is a vector of the loan-level controls, the lower order interactions of the treatment variables and in some specifications the interaction of these treatment variables with the loan controls. The controls are those are listed in Table 2 as well as an additional control for the maturity-matched reference rate. This reference rate is one-month dollar LIBOR at the time of origination for floating rate loans and the maturity-matched swap rate for fixed rate loans. Maturity-matched swap rates are linearly imputed between available quotes. $\tau_{b,t}$ is a bank-quarter fixed effect. Columns (1)-(4) present the triple difference results for the sample of ADC loans, while columns (5)-(8) present the findings for the full sample of CRE loans. Columns (1) and (5) include the set of controls and quarter fixed effects, columns (2) and (6) add an interaction of the fixed rate dummy with High LTV$_{i,b,t}$ and Pct. HVCRE$_{i,b,t}$, columns (3) and (7) additionally include interactions of the rest of the controls with the treatment variables, and columns (4) and (8) additionally include bank-quarter fixed effects. Standard errors, in parentheses, are clustered at the bank-quarter level. +,*,** indicate significance at the 10%, 5%, and 1% levels, respectively.

Online Appendix Table 4
Triple Difference Estimates with CBSA-Quarter Fixed Effects

	Effect on Interest Rates (percentage points)							
	Sample of ADC Loans				Sample of CRE Loans			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
High LTV x Pct. HVCRE x Non-1-4 family ADC	1.12**	0.82**	0.76**	0.61**	0.83**	0.58**	0.49**	0.49**
	(0.23)	(0.23)	(0.22)	(0.22)	(0.14)	(0.13)	(0.12)	(0.12)
High LTV x Pct. HVCRE	-0.64**	-0.53**	-0.47*	-0.32+	-0.31**	-0.24*	-0.15	-0.12
	(0.19)	(0.20)	(0.20)	(0.19)	(0.09)	(0.09)	(0.09)	(0.08)
Pct. HVCRE	-0.01	-0.26*	0.11	-0.08	-0.23**	-0.51**	-0.68	-0.78
	(0.11)	(0.12)	(0.75)	(0.80)	(0.06)	(0.06)	(0.55)	(0.53)
High LTV	0.43**	0.36**	1.84**	1.75**	0.30**	0.26**	0.83*	0.71*
	(0.10)	(0.10)	(0.53)	(0.54)	(0.06)	(0.07)	(0.33)	(0.31)
Non-1-4 family ADC x Pct. HVCRE	-0.07	-0.00	-0.10	-0.16	0.08	0.20**	0.08	0.09
	(0.11)	(0.11)	(0.13)	(0.12)	(0.07)	(0.07)	(0.08)	(0.07)
High LTV x Non-1-4 family ADC	-0.54**	-0.46**	-0.29*	-0.21+	-0.45**	-0.36**	-0.28**	-0.22**
	(0.13)	(0.13)	(0.13)	(0.12)	(0.09)	(0.09)	(0.09)	(0.08)
Non-1-4 family ADC	-0.53	-0.58	-0.57	-0.42	0.32	0.04	0.09	-0.17
	(0.52)	(0.51)	(0.51)	(0.51)	(0.36)	(0.37)	(0.37)	(0.35)
Loan controls	X	X	X	X	X	X	X	X
Qtr FE	X	X	X		X	X	X	
Controls $\times$ {Non-1-4 Fam ADC}	X	X	X	X	X	X	X	X
$\mathbb{1}_{\text{Fixed Rate}} \times$ {Pct. HVCRE; High LTV}		X				X		
Controls $\times$ {Pct. HVCRE; High LTV}			X	X			X	X
Bank-Qtr FE				X				X
CBSA-Qtr FE	X	X	X	X	X	X	X	X
R^2_a	0.454	0.468	0.475	0.532	0.421	0.441	0.445	0.496
No. banks	31	31	31	30	36	36	36	35
No. loans	9901	9901	9901	9882	31128	31128	31128	31115

Notes: This table reports coefficients from the following regression:

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

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

Online Appendix Table 5

Triple Difference Estimate: Placebo Sample

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

Notes: This table reports coefficients from the following regression:

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

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

Online Appendix Table 6

Heterogeneous Effects Capital Constraints: Triple Difference

	Effect on Interest Rates (percentage points)							
	Sample of ADC Loans				Sample of CRE Loans			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Capital Constrained								
x High LTV x Pct. HVCRE x Non-1-4 ADC	0.94*	1.22**	1.06**	1.11**	0.65+	0.65*	0.67*	0.52*
	(0.43)	(0.40)	(0.38)	(0.37)	(0.34)	(0.31)	(0.29)	(0.26)
x High LTV x Pct. HVCRE	-0.38	-0.63+	-0.54	-0.68*	-0.15	-0.11	-0.17	-0.07
	(0.34)	(0.33)	(0.34)	(0.33)	(0.20)	(0.20)	(0.20)	(0.18)
High LTV x Pct. HVCRE x Non-1-4 ADC	0.27	-0.12	-0.07	-0.26	0.37	0.17	0.09	0.11
	(0.26)	(0.26)	(0.26)	(0.24)	(0.23)	(0.21)	(0.20)	(0.19)
High LTV x Pct. HVCRE	-0.15	0.08	0.10	0.32+	-0.22+	-0.16	-0.04	-0.03
	(0.20)	(0.20)	(0.20)	(0.17)	(0.13)	(0.14)	(0.13)	(0.13)
Lower Order Interactions	X	X	X	X	X	X	X	X
Controls	X	X	X	X	X	X	X	X
Controls x Non-1-4 ADC	X	X	X	X	X	X	X	X
{Pct. HVCRE; High LTV; Capital Constrained}								
x $\mathbb{1}_{\text{Fixed Rate}}$		X				X		
x Controls			X	X			X	X
Qtr FE	X	X	X		X	X	X	
Bank-Time FE				X				X
R^2_a	0.369	0.382	0.389	0.470	0.359	0.379	0.383	0.444
No. banks	30	30	30	30	32	32	32	32
No. loans	9509	9509	9509	9509	26072	26072	26072	26072

Notes: 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 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. $X_{i,b,t}$ 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 LTV$_{i,b,t}$ is an indicator function taking the value of one if the LTV on the construction loan is above the HVCRE limit, Pct. HVCRE$_{i,b,t}$ is the percentage of the life of the loan occurring after the implementation date, and 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. $\tau_{b,t}$ is a bank-quarter fixed effect. Columns (1)-(4) present the results for the sample of ADC loans, while columns (5)-(8) 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.

Online Appendix Table 7
HVCRE Rule and Market Risk Characteristics

	Cap Rate (%)				Vacancy Rate (%)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
High LTV x Pct. HVCRE	-0.02	-0.04	-0.00	-0.01	-0.13	0.10	0.35	0.20
	(0.06)	(0.06)	(0.06)	(0.06)	(0.37)	(0.36)	(0.38)	(0.39)
Pct. HVCRE	0.13**	0.17**	-0.21	-0.02	0.63**	0.87**	-0.88	-0.90
	(0.04)	(0.04)	(0.38)	(0.39)	(0.19)	(0.21)	(2.43)	(2.41)
High LTV	-0.01	-0.02	0.27	0.39	-0.09	-0.14	4.74*	5.95*
	(0.05)	(0.04)	(0.32)	(0.34)	(0.28)	(0.28)	(2.28)	(2.30)
Loan controls	X	X	X	X	X	X	X	X
Qtr FE	X	X	X		X	X	X	
$\mathbb{1}_{\text{Fixed Rate}} \times$\{Pct. HVCRE; High LTV\}		X				X		
Controls$\times$\{Pct. HVCRE; High LTV\}			X	X			X	X
Bank-Qtr FE				X				X
R^2_a	0.288	0.289	0.296	0.333	0.534	0.535	0.541	0.554
No. banks	31	31	31	31	31	31	31	31
No. loans	5769	5769	5769	5769	5769	5769	5769	5769

Notes: This table reports coefficients from the following regression:

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

where Risk measure$_{i,b,t}$ is the risk measure on loan i from bank b at time t, coming from market-property type data from CBRE . The variable High LTV$_{i,b,t}$ is an indicator function taking the value of one if the LTV on the construction loan is above the HVCRE limit, and the variable Pct. HVCRE$_{i,b,t}$ is the percentage of the life of the loan occurring after the implementation date. $X_{i,b,t}$ is a vector of the loan-level controls, the two treatment variables, and in some specifications the interaction of these variables with the loan controls (controls are those listed in Table 2). $\tau_{b,t}$ is a bank-quarter fixed effect. Each column presents coefficients from the difference-in-difference specification for the sample of non-1-4 family ADC loans originated between the announcement and implementation of the HVCRE rule. In columns (1)-(4), the risk measure is the cap rate for properties in the same market and property type as the property securing the loan, reflecting the required (unlevered) return to property owners from holding a property in a given market. In columns (5)-(8), the risk measure is the vacancy rate for the given property type in the market. Columns (1) and (5) include the set of controls and quarter fixed effects, columns (2) and (6) add an interaction of the fixed rate dummy with High LTV$_{i,b,t}$ and Pct. HVCRE$_{i,b,t}$, columns (3) and (7) additionally include interactions of the rest of the controls with the treatment variables, and columns (4) and (8) additionally include bank-quarter fixed effects. Standard errors, in parentheses, are clustered at the bank-quarter level. +,*,** indicate significance at the 10%, 5%, and 1% levels, respectively.