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Abstract

This paper examines the role of bank capital in decision-making by bank holding companies (BHCs) in the United States. Following Chami and Cosimano's (2001) call option approach to bank capital, BHCs optimally choose the amount of capital to insure the bank against becoming capital constrained in the future. We provide empirical support for this model, and find that a higher optimal level of capital leads to higher loan rates. Furthermore, higher loan rates result in lower amounts of lending. Thus, an increase in capital requirements is likely to lead to higher loan rates and a significant reduction in lending.

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I. Introduction

Given the prevalent regulatory focus on setting minimum capital ratios, especially in the aftermath of the subprime crisis, a key question to ask is: What, if any, is the role of capital in banks' decision-making? If policy is to have an influence on bank behavior, presumably to align it more closely to a social objective of reduced risk-taking, then it is crucial to understand the channels through which such a change in behavior might take place.

A considerable portion of the macro-theoretical literature, particularly pre-crisis, does not contemplate a meaningful role for bank capital. In most of these models, banks operate in a competitive environment in which the cost of raising equity is minimal. If financial frictions are present, they are represented by means of the financial accelerator introduced by Bernanke, Gertler and Gilchrist (1996, 1999), where a time-varying external finance premium follows from endogenous changes in the agency costs of lending. Furthermore, banking is characterized as being perfectly competitive (see also Kumhof et al., 2010), and therefore banks' decisions are never constrained by bank equity, since in such an environment additional equity can always be raised costlessly when needed.

In financial economics, a set of assumptions–such as the absence of frictions from taxation–lead to the well-known MM theorem that states that the capital structure of banks is irrelevant.[1] Thus, the MM theorem also implies that the financing of banks operations would not be constrained by bank equity. Moreover, as argued by Admati et al. (2013), an increase in bank capital, by lowering the bank's probability of default, might even lower the marginal cost of capital relative to other financing sources such as deposits or other debt. Furthermore, Admati and Hellwig (2014) argue that capital requirements should be raised, considering this low cost of capial.

On the other hand, the corporate finance literature has developed multiple environments in which the Modigliani-Miller Theorem does not hold. A recent study by Aiyar, Calomiris and Wieladek (2012) examines the effectiveness of capital regulation, which relies on bank equity being costly. It provides both a summary of conditions under which this is the case, as well as empirical evidence drawn from the United Kingdom experience since the adoption of Basel I. The conditions under which equity is relatively costly include: insufficient information about the bank's loan portfolio, favorable tax treatment of dividends, 'Too Big To Fail' (TBTF)[2], and

[1] See Chami, Cosimano and Fullenkamp (2001) for a proof of the Modigliani-Miller Theorem in a cash-in-advance dynamic stochastic general equilibrium (DSGE) economy.

[2] Gandhi and Lustig (forthcoming) provide evidence that the expected return on equity for the top 10% of

deposit subsidies through deposit insurance. By distinguishing between 'regulated' and 'unregulated' banks in the U.K., the study argues that the empirical results show that exogenous increases in capital requirements are associated with declines in lending among the regulated banks only, which implies that equity is costly.

A key empirical challenge in identifying a link between relative capital scarcity and loan supply is to isolate supply shocks from demand shocks. A common criticism of empirical work based on economywide data is the lack of convincing evidence that a change in supply has indeed been completely isolated from the change in demand for loans, and whether or not other financial institutions can easily replace bank financing.[3] The empirical solution then has often been to focus on events in which a 'natural' experiment leads to a decline in bank equity.[4]

Two papers which do include costly equity with an imperfectly competitive banking sector in a DSGE setting are Gerali et al. (2010) and Roger and Vlček (2011). Both find that negative shocks to bank capital have significant negative effects on investment and other real variables. In addition, Meh and Moran (2010) and Dib (2010) develop DSGE models in which the cost of raising equity by banks is determined endogenously. As a result, highly leveraged banks experience a relatively high cost of equity, and this financial friction has the potential to amplify the effects of economic shocks on the real economy.

Another argument refuting the effectiveness of capital requirements is that, even if one accepts that capital is relatively costly, and therefore capital scarcity could lead to a credit decline, in practice capital requirements are rarely binding, and thus capital constraints are not likely to bind or impact bank decisions. Based on the capital requirements currently imposed on bank holding companies (BHCs, hereafter) in the United States (Table 1), this would appear to be the case. As Table 2 shows, for the largest 250 BHCs[5] there are indeed sizable capital buffers above the regulatory minimum levels. In fact, these 250 BHCs turn out to be constrained by the regulatory constraints in fewer than 5% of the observations during any of the selected sample

financial institutions with marketable equity is about 8% lower than the smallest 10%. They argue that this follows from TBTF. This does not necessarily mean that equity financing is cheaper than bank debt and deposits since deposits are covered by deposit insurance.

[3]See Calomiris and Mason (2003) for a discussion of these arguments.

[4]See Khwaja and Mian (2008), Bernanke (1983), Bernanke and Lown (1991), Peek and Rosengren (1995) and Aiyar, Calomiris and Wieladek (2012) for examples of natural experiments used to study bank response to supply changes.

[5]We focus only on this sample out of 7,000 BHCs, since they account for 95% of total bank assets and well over 90% of total bank lending, as of 2013. Moreover, from a theoretical point of view, Corbae and D'Erasmo (2014) show in a dynamic framework of the banking industry that the lending decisions of only the largest banks have significant implications for amplifications of the business cycle.

periods.[6]

However, capital requirements could affect bank behavior even if they are not strictly binding. The theoretical model by Chami and Cosimano (2001) shows that optimal behavior by banks will lead them to maintain a buffer above the minimum required capital, to the extent that such a buffer would protect them against a future loan demand shock that might leave them capital constrained and therefore unable to provide loans at the unconstrained profit-maximizing level. Thus, capital—or, more specifically, equity—acts like a call option with its value derived from the possibility of the bank becoming capital-constrained in the future. Given that optimal capital decisions are undertaken simultaneously with the setting of lending rates, a shock to the conditions determining optimal capital will have a direct effect on lending rates and, through loan demand, on the market-clearing volume of loans. This model relies on two key assumptions: that bank equity is costly, and that there is market power in the banking industry.[7]

As in the case of the European call option, the value of equity is a function of its strike price and the volatility of the underlying asset. The strike price in this case is the difference between the volume of loans that can be supported by the bank's current equity holding, and the expected optimal level of loans. That is, the strike price is directly related to today's capital buffer; it is positively related to the current level of bank capital and negatively to the optimal (expected) amount of bank lending. An increase in the strike price - today's capital buffer increases - has a negative effect on the value of the real option. Increases in marginal revenue and decreases in marginal cost - both of which drive up the optimal loan volume relative to that which is supported by current capital - would have a positive impact on the desired amount of capital. Finally, the corresponding volatility of loan demand will also affect the value of, and therefore the desired volume of bank capital.[8]

In this paper, we provide an empirical test of the Chami-Cosimano model, estimating the bank's optimal capital choice and then tracing out its effects on loan supply. As in Aiyar, Calomiris and Wieladek (2012) we document that the bank's equity decision influences interest rates on loans, and through loan rates, the amount of lending by the bank. Thus, our results imply that an increase in capital requirements might come at a cost to society in the form of more expensive credit, which may or may not exceed the social benefit as argued by Admati and Hellwig (2014), which arises from a lower probability of default.

[6]We categorize a bank holding company as 'capital constrained' if it does not meet or exceed the 'well capitalized' requirement as shown in Table 1.

[7]The latter assumption has been verified empirically by many, including Claessens and Laeven (2004), Carb et al. (2009), Cosimano and McDonald (1998) and Roelands (2014a).

[8]Barnea and Kim (2014) also allow for endogenous choice of capital. However, they do not discuss an option value of capital since their banks hold capital because of private incentives rather than government regulations.

In this work the optimal capital choice is not solely dependent on supply of credit, since the real option argument does not rest on whether changes in bank equity arise from loan demand or supply. What matters is whether marginal revenue and/or cost are persistent, so that current information can be used to predict the strike price the bank is expected to face in the future. Also contrary to Aiyar et al. (2012), the real option approach implies convexity; therefore nonlinearities in the estimated optimal equity response are to be expected.

The prevailing empirical research on the impact of bank equity on lending is well illustrated by Berrospide and Edge (2010), (BE).[9] In this work a target equity capital ratio is hypothesized. It is then assumed that the actual capital ratio adjusts to this target using a partial adjustment model. The target level of equity capital is found to be dependent significantly on the size and diversification of bank assets, and loan charge-offs by the banking sector. The authors estimate a relatively quick adjustment of the capital ratio to its target, of about 36% per year. However, there is little evidence of the dependence of the target ratio on the marginal revenue and/or cost of loans. In particular, the return on assets (ROA) does not have a statistically significant effect on bank capital. To address whether or not bank capital has an impact on lending, they regress loan growth on the shortfall of bank equity, which is the difference between predicted and actual bank equity. They find a small yet significantly negative impact of this shortfall on bank commercial and industrial loan growth; a 0.25 percentage point increase in annual loan growth would result from a 1% increase in capital relative to its trend.

Based on results from our panel data regressions on the 250 largest BHCs in the U.S. over the period from 2001Q1 through 2014Q1, we provide support for the call option approach to the choice of capital, whereby BHCs choose their capital so as to optimize their flexibility in the face of uncertainty about future loan demand. To deal with endogeneity issues, due to the simultaneity of decisions on bank capital, loan rates and lending, we use a 2SLS approach. In the first stage, we estimate the target capital ratio, which is then used to create a capital surplus variable, on which (among other variables) the loan rate is regressed. Finally, the predicted loan rate from the second stage is used to estimate the interest rate semi-elasticity of loan demand.

Our main results on optimal capital decisions are as follows. First, capital ratios are negatively related to measures of the marginal cost of loans, including non-interest expenses and share of nonperforming loans. Second, since the 2007-2009 financial crisis, capital ratios have exhibited substantial persistence, being negatively affected by lagged changes in the capital ratio. Third,

[9] See also Bernanke and Lown (1991), Hancock and Wilcox (1993, 1994) and Berger and Udell (1994), Aiyar et al. (2012), Aiyar et al. (2014), and Berger and Bouwman (2014). Alternatively, Barnea and Kim (2014) examine peer groups to identify key assumptions of their banking model, and then see how a shock to bank credit would influence the model. As such, they are providing a calibration of these effects, and not an estimation of their model.

contrary to BE, we find that the main components of the ROA do influence bank capital. Fourth, while there is some consistency between our and the BE regression for the equity ratio, we find evidence in favor of the convexity of the bank capital's response to the marginal cost and/or revenue, consistent with the real option view of bank capital.

We follow a multi-step approach to assess the ultimate impact of capital on loan supply.

1. We examine how the target capital ratio, which follows from the initial capital ratio regressions, impacts the loan rate and how the loan rate influences lending. This way, we essentially follow a two-stage least squares approach, replacing the capital ratio with the deviation of the actual capital ratio from the target capital ratio when estimating the lending rate regression. We do this because banks simultaneously choose their capitalization and interest rate on loans, which determines the demand for loans by customers of the bank. We find a positive effect of interest and non-interest expenses and non-performing loans on loan rates of BHCs across all time periods examined. Consistent with a higher marginal cost of capital, we find that if a bank holds twice as much capital as targeted, it will raise loan rates by 23 to 27 basis points, or by around 10 percent.[10] Thus, if total risk-based capital requirements are increased from 8% to 10.5% (including the capital conservation buffer, introduced by Basel III), we can expect loan rates to rise by more than 4% (which corresponds to 7-8 basis points in our loan rate measure).

2. The final step is to regress the amount of bank loans on demand side variables including real GDP growth and inflation, as well as the predicted lending rate. Before the financial crisis, the interest rate semi-elasticity of loan demand appeared to be zero, but after the financial crisis, we find it to be significantly negative; a 10 basis point increase in loan rates would lead to a decrease in loan demand of about 5.3%. This is comparable to estimates by Aiyar et al. (2014), who find that a one-percentage point increase in U.K. capital requirements results in a 5.5% reduction in international lending by British banks over the time period 1999Q1 to 2006Q4.

As a robustness check we undertake panel vector autoregression (PVAR) estimations, which show quantitatively similar effects of capital on lending. A one-standard deviation (i.e. 2.2 percentage point) increase in the total risk-based capital ratio is likely to lead to an increase in loan rates of 8 to 12 basis points within the first two quarters. This translates into a drop in lending of 10% in the first quarter, and 5% in the second quarter, following the shock to capital.

[10] Our measure of loan rates, which is underestimated, since we calculate it as the quarterly ratio of interest income to total loans, averaged roughly 1.7% to 2.4% over selected sample periods (see Table 2).

The remainder of the paper is organized as follows. The main features of the Chami-Cosimano theoretical model and its implications for empirical estimation are presented in Section 2. The data and empirical results are presented and discussed in Section 3, with the robustness checks reported in Section 4. Section 5 concludes.

II. Bank Capital Decisions

If there is persistence in either the marginal revenue and/or cost of loans, then the bank is able to predict the amount of loans to be issued in the future. As a result, a forward looking bank would want to choose enough capital to reduce the chance of the capital constraint binding on their loan decisions. Chami and Cosimano (2001, 2014) prove that the marginal value of bank capital is equal to the shadow price of this constraint. This shadow price is zero when the constraint does not bind. However, the shadow price is linearly related to the spread between the optimal amount of loans issued by the bank and the level of loans at which the capital constraint just binds. Thus, the bank treats capital as a real call option as in Merton (1974).[11]

To implement the bank's capital decision Chami and Cosimano (2001, 2014) prove that there is a critical shock to loan demand, ε_κ, such that beyond this level the bank is capital constrained and consequently, the bank loses profits. This critical value is

$$\varepsilon_\kappa = 2 \cdot (L_\kappa - L_0), \tag{1}$$

where L_κ is the level of loans at which the bank becomes capital constrained, and L_0 is the expected level of loans next period.

This expected level of loans is such that the expected marginal revenue of loans equals its marginal cost, since banks are assumed to have some monopoly power (Claessens and Laeven, 2004; Carb et al., 2009; Cosimano and McDonald, 1998; Roelands, 2014). The Chami and Cosimano model assumes that the marginal cost is measured by non-interest expense, c^L, and by the expense of financing the loans, r^K, while the linear demand curve leads to the marginal revenue, $l_0 - 2 \cdot l_1 \cdot r^L + l_2 \cdot Y + \varepsilon^L$. Here, l_0, l_1 and l_2 are positive constants, r^L is the loan rate and Y is a set of measures (specified in the empirical section) of economic activity. Consequently,

[11]Chami and Cosimano dealt with the capital constraints of Basel I and II. Roelands (2014b) extends this analysis to the liquidity coverage ratio added under Basel III. (7). A shorter time period is used in estimating the capital asset ratio to minimize a bias that may result from a likely anticipation of an increase in capital requirements after the financial crisis and passage of Basel III.

the optimal quantity of loans and the optimal loan rate during any given time period are given by

$$L = \frac{1}{2} \cdot \left[l_0 + l_2 \cdot Y + \varepsilon^L - c^L - r^K \right] \tag{2}$$

and

$$r^L = \frac{1}{2l_1} \cdot \left[\left(l_0 + l_2 \cdot Y + \varepsilon^L \right) + c^L + r^K \right]. \tag{3}$$

Thus, persistence in interest and non-interest expense as well as economic activity allow the bank to forecast future expected loan demand. If we rewrite the optimal loan rate in terms of the marginal costs of equity (r^K) and deposits ($r^D + c^D$, i.e. the interest rate and non-interest expenses on deposits),

$$r^L = \frac{1}{2 \cdot l_1} \cdot \left(l_0 + l_2 \cdot Y + \varepsilon^L \right) + \frac{1}{2} \left[\left(1 - \frac{K}{A} \right) \cdot \left(r^D + c^D \right) + c^L + \frac{K}{A} \cdot r^K \right], \tag{4}$$

we see that in the case of $r^K > \left(r^D + c^D \right)$, the optimal loan rate depends positively on the capital-to-asset ratio $\frac{K}{A}$. Thus, we expect the loan rate to increase with capital, which causes the quantity of loans to decrease with capital (Cosimano and Hakura, 2011).

If the quantity of expected loans is below critical value L_κ, then any capital in excess of the regulatory requirement would not have economic value since the capital constraint is not binding. The option, on the other hand, would have marginal value $\frac{1}{l_1 \cdot \kappa}$ when the shock to loan demand is above its critical value. Here, l_1 is the impact of the loan rate on loan demand, and κ is the percentage of assets which must be held as bank equity. As a result the value of bank equity, K, is given by

$$K_T = \frac{2}{l_1 \cdot \kappa} \cdot \left(L_\kappa - L_T \right)^+ ,$$

where T is the time at which the constraint binds. Consequently, bank capital acts like a European call option with strike price $\frac{2}{l_1 \cdot \kappa} \cdot L_\kappa$ and expiration date T.[12]

If unanticipated loans follow a log-normal distribution given expected lending, then the current value of capital is given by the Black-Scholes formula

$$K_0 = \frac{2}{l_1 \kappa} \left[L_0 N\left(d_1\right) - e^{-rT} L_\kappa N\left(d_2\right) \right], \tag{5}$$

$$\text{with} \quad d_1 \doteq -a + \sigma\sqrt{T} = \frac{\ln\left(\frac{L_0}{L_\kappa}\right) + \left(r + \frac{1}{2}\sigma^2\right) T}{\sigma\sqrt{T}}$$

[12] The 2 occurs because a linear demand for loans leads to marginal revenue of one-half of demand. The linear demand curve for loans is used for simplicity. If one wanted a more general loan demand function, then the results would be derived using implicit function theorem. While this assumption may be more realistic it does not impact the empirical hypothesises tested here.

$$\text{and} \quad d_2 \doteq -a = \frac{\ln\left(\frac{L_0}{L_\kappa}\right) + \left(r - \frac{1}{2}\sigma^2\right)T}{\sigma\sqrt{T}}.$$

Here r is the risk free rate, $N(d_1)$ is the probability that the shock is below d_1 for a standard normal distribution, and σ is the standard deviation of loan shocks. See Appendix A for the derivation.

We can use the properties of the Black-Scholes European call option pricing formula to determine the effect of a change in the amount of loans on the value of bank capital. It is well known that the value of an option is positively related to the present value of the underlying asset (expected loans, L_0) and negatively to the strike price (the amount of loans at which the bank becomes capital constrained, L_κ). However, in this case the expected value of loans not only affects the option value of capital directly (positively), but also indirectly through the strike price. As shown in Appendix A, the direct effect dominates the indirect effect, and thus, bank capital increases in value as a bank expects to lend more.

Another well-known property of the value of an option is that it is convex in both the underlying asset and the strike price.[13] Consequently, as bank capital becomes larger we should expect a smaller negative effect of change of bank equity, interest expenses and non-interest expenses. Thus, the option view of bank capital can be represented by the following empirical model of the capital-to-asset ratio, which captures the above nonlinearities:

$$\begin{aligned} \frac{K_t}{A_t} &= a_0 + \left(-a_1 + a_2\frac{K_{t-1}}{A_{t-1}}\right)\Delta\frac{K_{t-1}}{A_{t-1}} + \left(-a_3 + a_4\frac{K_{t-1}}{A_{t-1}}\right)r^D_{t-1} \\ &\quad + \left(-a_5 + a_6\frac{K_{t-1}}{A_{t-1}}\right)c^L_{t-1} + \left(a_7 + a_8\frac{K_{t-1}}{A_{t-1}}\right)Y_{t-1} + a_9 \cdot X_{t-1} + \upsilon^K_t. \end{aligned} \tag{6}$$

Here all the coefficients a are positive (with the possible exceptions of a_7 and a_8, depending on the way in which the different measures of the aggregate economy affect loan demand), and X is a set of controls. Depending on the specification, these controls include the natural log of total assets to control for bank size, the ratio of loan loss provisions relative to total loans and its interaction with the lagged capital ratio, lending standards, loan growth, a volatility index (to measure economic uncertainty), and the liability-to-asset ratio of nonfinancial businesses. In addition to the controls, each regression in this paper uses BHC-fixed effects. Finally, υ^K_T is an error term.

The optimal loan rate is positively related to the capital ratio as in (4) so that we obtain an

[13] Hull (2006, Chapter 16) demonstrates that the convexity property of European call options is true for any well defined probability distribution. Thus, the empirical specification below holds in general, while the lognormal assumption is used to obtain the explicit Black-Scholes formula in (5).

empirical model for the loan rate,

$$r_t^L = b_0 + b_1 \frac{\left(\frac{K_t}{A_t} - \widehat{\frac{K_t}{A_t}}\right)}{\widehat{\frac{K_t}{A_t}}} + b_2 r_t^D + b_3 c_t^L + b_4 Y_t + b_5 X_t + \upsilon_t^r, \tag{7}$$

where the coefficients b are all positive (with the possible exception of b_4), the target capital ratio, $\widehat{\frac{K_t}{A_t}}$, follows from the regression of the capital ratio, (6), and υ_t^r is an error term. With this setup, we can address the probable endogeneity issue between bank loan rates and capital, which arises since banks decide on both simultaneously. Thus, we can think of (6) as a first-stage regression, using the interaction terms of the capital ratio with each of the main independent variables in the loan rate regression as instruments through the target capital ratio, $\widehat{\frac{K_t}{A_t}}$, in (7), the second-stage regression.

Finally, the empirical model for real loan demand is

$$\ln\left(\frac{L_t}{P_t}\right) = l_0 + l_1 \widehat{r_{t-1}^L} + l_2 Y_{t-1} + l_3 X_{t-1} + \upsilon_t^L. \tag{8}$$

Here, P_t is the GDP deflator at time t, the interest rate semi-elasticity of loan demand, l_1, is negative, and the desired loan rate, $\widehat{r_t^L}$, is based on its empirical model, (7), and υ_T^L is an error term. Again, since loan rates and the quantity of loans are simultaneously determined, we instrument for the loan rate with the capital surplus variable, the deposit rate and the marginal cost of lending.

The model is kept simple to illustrate the key idea that endogenous bank capital acts as a real call option for the bank. If one were to allow for a nonlinear demand curve, then we would not have an explicit expression, as in (1), for the critical shock to capital at which the capital constraint binds. However, one would have qualitative information on the effect of exogenous variables such as the deposit rate and non interest expenses. This means we would know how these changes influence the strike price and the option value of capital in (5). Thus, the key empirical hypothesis (6) for our empirical work is still true.

We could also include more explicit relations between the capital asset ratio and the cost of deposits and other financial funding. Barnea and Kim (2014) for example assume that the interest rate on deposits is negatively related to the ratio of capital to risk weighted assets, capturing the market discipline effect of higher equity on the cost of financing the firm. This relationship is part of the Modigliani and Miller argument and would mitigate the effect of the capital asset ratio on the loan rate in (4). Depending on the strength of this relationship, we would be less likely to accept our empirical model (7).

Finally, the risk associated with loans could be made explicit as in Barnea and Kim (2014) in which bank equity is used as a buffer to meet unanticipated loan losses. In addition, this risk is positively related to the loan rate to capture the well-known, Stiglitz and Weiss (1981), adverse selection concept. This would raise the margin between the loan rate and the marginal cost of funding. We include this effect in our empirical model by including controls for nonperforming loans in our empirical model (6) and (7).

III. Data and Results

A. Data

Whenever possible, we use data at the institutional level. For the bank-specific variables we use bank holding company (BHC) data from the Federal Reserve Bank of Chicago.[14] We use data at the holding company level rather than the commercial bank level since critical decisions regarding bank capital are generally made at the holding company level (Ashcraft, 2008). The data set ranges from 2001Q1 through 2014Q1. We use the 250 largest BHCs as of 2013Q1, which were responsible for over 90% of total bank lending in the United States in 2013. For more details, see Roelands (2014a).

The BHC database primarily provides data on balance sheet and income statement items. Unfortunately, this does not include (marginal) interest rates. As an approximation for the interest rate on loans, we calculate the ratio of total interest income to total loans. Whenever we discuss the 'loan rate' throughout the next sections, we refer to this approximation. Since interest income is measured per quarter, and we think of interest rates as annualized, one may want to multiply this ratio by 4 to get a closer approximation of annualized interest rates. A problem not as easy to fix, however, is that by its nature, this ratio does not have much variation compared to marginal interest rates (quarterly averages across the BHCs range from 1.5% to 2.8% for our measure of loan rates), due to the fact that interest income includes interest payments received on older loans which may have been issued at different (fixed) rates than the current marginal interest rate. This issue is likely to lead to low coefficient estimates in regressions where the loan rate is the dependent variable.

[14] More specifically, we use data from the forms FR Y-9C and FR Y-9LP.

As mentioned earlier, the regulatory requirements for capital ratios are shown in Table 1.[15]Table 2 provides an overview of three observed capital ratios over the pre-crisis (2001Q1-2007Q2), crisis (2007Q3-2009Q2) and post-crisis (2009Q3-2014Q1) periods, as well as over the full sample period. Figure 1 provides more detailed distributions of the three capital ratios over the three sub-periods. As it turns out, very few BHCs are actually capital constrained at any point in time. We see that the distributions over the periods before and during the crisis are quite similar. However, after the crisis, the distributions shifted to the right, with many BHCs holding much more capital than required. This is not only consistent with the Chami-Cosimano argument of optimal holding of buffers of capital - enabling banks to absorb future shocks that would put downward pressure on their capital ratios - but may also reflect more cautious behavior by BHCs after the financial crisis, as well as the anticipation of higher capital requirements in the future, as a result of Basel III regulatory reforms.

Measures of conditions in the rest of the economy, including real gross domestic product, the GDP deflator, the NASDAQ Volatility Index (VIX)[16], and indebtedness of nonfinancial businesses (total liabilities relative to total assets) are taken from the Federal Reserve Economic Data (FRED). A measure of aggregate lending standards is taken from the Senior Loan Officer Opinion Survey from the Federal Reserve Board. The specific series we use measures the "net percentage of domestic respondents tightening standards on commercial & industrial loans to large and medium-size businesses."

B. Results

The results relating to the first-stage regression for the capital ratio (6) are presented in Table 3. The three capital ratios used are the total risk-based capital ratio (Total RBC), the tier 1 risk-based capital ratio (Tier 1 RBC) and the equity-to-asset ratio. The risk-based capital ratios measure capital relative to risk-weighted assets (according to regulations), while the equity-to-asset ratio equals equity relative to total (unweighted) assets.

Consistent with the theory presented in Section 2, the capital ratios of BHCs depend negatively on factors affecting the strike price. All three measures of the capital ratio depend negatively on their own lagged change, average non-interest expenses ($\frac{NonIntExp_{it-1}}{Liabilities_{it-1}}$), and the ratio of non-

[15]The regulatory capital ratios we use are both risk-based, i.e. the denominator is risk-weighted assets, rather than total assets. Tier 1 capital is a component of total capital and consists mostly of equity. In our estimations we also use the equity-to-asset ratio (not risk-based), for which no regulatory requirements were imposed over the sample period considered in this paper.

[16]Data on the S&P 500 VIX is not available prior to December 2007.

performing loans ($\frac{NonPerfLoans_{it-1}}{Loans_{it-1}}$).

Capital ratios also respond to macroeconomic variables, including the lagged quarterly growth rates of gross domestic product ($\Delta \ln (GDP_{t-1})$) and the consumer price index ($\Delta \ln (CPI_{t-1})$). With tighter lending standards, banks tend to demand less capital reflecting greater confidence in the quality of loans issued. The VIX, reflecting overall market uncertainty, has no significant impact on any of the capital measures.

In addition, the results are consistent with convexity in each of the components of the strike price, as the interaction of each variable with the lagged capital ratio has a positive and often significant coefficient. That is, each of the responses of capital to factors determining the strike price will weaken as the capital ratio increases. This evidence of convexity provides additional support for the option value approach to bank capital.

Most of these results hold up over the pre-crisis period, as presented in Table 4. Although the autocorrelative nature of capital ratios, as well as the importance of lending standards, have become insignificant, the explanatory power (as measured by the adjusted R^2) is slightly higher than over the entire sample period. We use the coefficient estimates from Table 4 to predict capital ratios for the second stage regressions relating to the loan rate. The reason for this is that we do not want our target capital ratios to be affected by either a crisis period nor the anticipation of higher capital requirements as part of Basel III and Dodd-Frank immediately after the crisis.

Table 5 shows the results for the loan rate (i.e. the ratio of interest income over total loans). The first explanatory variable included is a measure of 'capital surplus' ($\frac{CR_{it}-\widehat{CR}_{it}}{\widehat{CR}_{it}}$), calculated as the percentage excess of the observed capital ratio over its target level as estimated from the first stage regression in Table 4. The results indicate that a 1 percentage point capital surplus[17] will lead to an increase in the optimal loan rate that ranges from 11 basis points (equity-to-asset ratio) to 27 basis points (tier 1) per quarter, or 44 to 108 basis points, respectively, in terms of annualized interest rates. In the context of Basel III, including the capital conservation buffer, total risk-based capital requirements are increasing from 8% to 10.5%, or a 31.25 percent increase in the requirement. Therefore, if a bank will increase its total risk-based capital by 31 percent relative to its target ratio prior to the financial crisis, we can expect to see an increase in loan rates of $0.3125 \times 22.8 = 7.125$ basis points (quarterly), or $0.3125 \times 22.8 \times 4 = 28.5$ basis points (annualized). Considering that loan rates averaged 1.7% (under the quarterly measure)

[17] When $\frac{CR_{it}-\widehat{CR}_{it}}{\widehat{CR}_{it}} = 1$, this means that the actual capital ratio, CR, is twice as large as the desired capital ratio, $\widehat{CR}$.

over the 2009Q3-2014Q1 sample period, the higher requirements can be expected to result in roughly a 4-5 percent (= 0.07125/1.7) increase in loan rates. Clearly, this shows that when BHCs hold more capital than they desire, they charge higher loan rates. These results provide evidence that the Modigliani-Miller Theorem does not hold, as banks' holdings of capital do appear to have an impact on prices.

Beyond their impact on desired capital, an increase in interest expenses tends to exert upward pressure on loan rates (Table 5). A 100 basis point increase in the interest rate on debt leads to roughly a 130 basis point increase in the loan rate. Beyond its importance regarding capital ratios, non-interest expenses seem to have no significant effect on loan rates. The non-performing loan ratio, on the other hand, has a significant, negative (albeit small) impact on loan rates. A tightening of lending standards tends to lower lending rates slightly, as banks may be rationing loans to more creditworthy borrowers who require lower risk premia, and therefore lower loan rates. Finally, an uptick in overall market uncertainty, and with it a potential drop in borrower creditworthiness, tends to increase loan rates.

As a final step in the estimation, Table 6 presents the results of the loan demand regression, (8). The target loan rate estimated from the total risk-based capital specifications in Table 5 is included as a regressor.[18] Over the entire sample period, which appears to be mainly driven by the pre-crisis period, the interest rate semi-elasticity of loan demand is extremely small, though statistically significantly larger than zero. Since 2007Q3, however, this semi-elasticity has become significantly negative. This finding is consistent with Cosimano and Hakura (2011), who found that the loan rate semi-elasticity of loan demand faced by largest U.S. banks was relatively small before the the crisis, and became larger after the crisis.

During and after the financial crisis, a 100 basis point increase in the (quarterly) loan rate results in a 54 percent drop in the quantity of loans demanded. Keep in mind that during this period, our measure of loan rates averaged between 1.7 and 2%, and a 100 basis point increase thus implies that interest rates increased by more than 50%.[19]Combining this with the results in Table 5, raising total risk-based capital requirements from 8% to 10.5%, and the subsequent increase in loan rates by 7.125 basis points is likely to result in approximately a 4% reduction in lending ($= 0.07125 \times (-0.538)$).

[18]The other two specifications from Table 5 yield virtually identical results.

[19]Replacing the dependent loan rate variable by $4 \times \frac{\widehat{IntInc_{it-1}}}{Loans_{it-1}+Securities_{it-1}}$ (a closer approximation of 'annualized' loan rates) results in a point estimate of -0.135, leaving the estimates on the other coefficients unchanged. Under this interpretation, a 100 basis point increase in annualized loan rates results in a 13.5% reduction in real lending.

Loan demand also depends negatively on real GDP growth, which is consistent with consumption smoothing. If people smooth their consumption, they would do so by borrowing during times of low or negative income growth (in this case real GDP growth), and by saving (or paying off debt) during good times. Finally greater market uncertainty, as reflected by the VIX, slightly reduces loan demand.

IV. Robustness

This section presents a series of robustness checks. First, we check whether the initial results presented in the previous section hold up if we consider only the post-crisis period to estimate optimal capital ratios and loan rates. Second, we use a panel vector autoregression (PVAR) analysis to examine the order in which banks make their decisions regarding capital, interest rates and lending.

A. Results After the Financial Crisis

As mentioned in Section 1, Berrospide and Edge (2010) find a positive relationship between capital surplus[20] and BHC loan growth. In contrast, the Chami and Cosimano (2001) theory and our empirical results presented in the previous section indicate a negative relationship between a bank's capital surplus and the amount of lending, since a greater capital surplus causes a bank to charge a higher loan rate, and the demand for loans will decrease as a result. In this subsection, we consider the post-crisis period (2009Q2-2014Q1), which was not included in the BE analysis. (We omit the crisis period itself due to the relatively small sample size.)

Table 7 shows the post-crisis results for the optimal capital ratio (6) and Table 8 presents the results for the optimal loan rate (7).

Compared to the full sample as well as the pre-crisis period (Tables 3 and 4, respectively), capital ratios have now become positively autocorrelated, and interest expenses now negatively

[20]BE define capital surplus as the difference between the observed value of the capital ratio and its trend resulting from the Hodrick-Prescott filter.

affect capital ratios, consistent with the theory. Other coefficient estimates have changed quantitatively, but not qualitatively. For example, capital ratios have become more sensitive to non-interest expenses since the crisis.

In Section 3, we used target capital ratios based on pre-2007Q2 estimates, to prevent our loan rate regressions from being affected by the financial crisis and the subsequent anticipation of higher capital requirements. Table 8 shows the loan rate regression results, where the target capital ratios are solely based on the post-crisis period from Table 7. Although the explanatory power has declined for the regressions based on the risk-based capital ratios, we see few qualitative differences. If banks hold more capital than targeted, they will charge higher loan rates (with the coefficient estimate on the total risk-based capital surplus having roughly doubled compared to the previous estimates), and interest rate expenses on liabilities still affect loan rates positively, and with similar magnitudes. However, the equity-to-asset ratio does not seem to affect loan rates anymore. This suggests that BHCs have been paying more attention to their regulatory capital requirements, than to their core equity in making loan rate decisions.

B. Vector Autoregression (VAR) Analysis

Finally, we examine whether our proposed channel (capital affects loan rates, which in turn affect the quantity of loans) holds up under a vector autoregression (VAR). Aiyar, Calomiris and Wieladek (2012) set up a VAR to examine whether a change in the capital ratio causes a reduction in loan growth, or whether a shock to loan growth has effects on bank capital ratios. We adopt a similar approach, where we use the total risk-based capital ratio (CR), the quarterly loan rate (r^L) and total loans (L) as endogenous variables, and the one quarter growth rates of real GDP and the GDP deflator as exogenous variables. As such, the reduced-form VAR is

$$\begin{pmatrix} CR_{it} \\ r^L_{it} \\ L_{it} \end{pmatrix} = \sum_{j=1}^{4} \boldsymbol{A} \begin{pmatrix} CR_{it-j} \\ r^L_{it-j} \\ L_{it-j} \end{pmatrix} + \begin{pmatrix} \Delta \ln GDP_t \\ \Delta \ln CPI_t \end{pmatrix} + \begin{pmatrix} \nu^{CR}_{it} \\ \nu^{r^L}_{it} \\ \nu^{L}_{it} \end{pmatrix} \begin{pmatrix} \nu^{CR}_{it} \\ \nu^{r^L}_{it} \\ \nu^{L}_{it} \end{pmatrix}, \tag{9}$$

where the lag length of 4 is based on the Akaike, the Schwartz and the Hannan-Quinn information criteria and each ν is an error term. We impose structure on the errors by means of the Cholesky decomposition method formalized by Sims (1980). We use the order [CR, r^L, L], which is in line with our theory.

The impulse responses following a one standard deviation shock to the total risk-based capital ratio are shown in Figure 2. A one standard deviation shock to the capital ratio is an increase of roughly 2.2 percentage points (which is fairly close to the 2.5 percentage point increase in capital requirements as a result of the capital conservation buffer of Basel III). The effect on the loan rate is immediate and significantly positive, by bumping up loan rates by 8 to 12 basis points within the first two quarters, which is slightly larger than our estimates in Section 3.

The bottom panel shows the response of the natural log of real total loans (the vertical axis is in percent). A typical bank holding company will reduce lending by 10% within the first quarter after a 2.2 percentage point increase in its capital ratio, and by another 5% in the second quarter. The impact dies out through the second year, and after 10 quarters seems to become positive, when banks are likely in a stronger position to lend. In this VAR setup, loan demand appears to be more sensitive to changes in bank capital and loan rates than our estimates in Section 3.

In Figure 3 we shock the log of real total loans by one standard deviation. The first panel shows that total lending remains persistently higher after a shock. The second panel shows that an increase in lending has no immediate impact on loan rates, but loan rates fall sharply during the second quarter following an increase in lending.

The effect on the capital ratio of a shock to total loans is initially positive, but after a couple of quarters not significantly different from zero. It seems that an increase in lending goes hand in hand with a temporary strengthening of bank capital, as a result of which banks can temporarily lower interest rates.

V. Conclusion

In this paper we examine the role of capital in the decision-making of bank holding companies (BHCs) with regard to loan rates and loan quantities. We find that BHCs set their capital ratios based on past realizations of interest and non-interest expenses, as well as the fraction of non-performing loans relative to total loans, among other control variables. Moreover, the current capital ratio appears to be convex in these variables, which supports the hypothesis of Chami and Cosimano (2001) that bank capital, in the presence of regulatory capital requirements, can be viewed as a real call option on the expected value of the loan portfolio. We also find that the target capital ratio of BHCs has a positive effect on the interest rate charged on loans. This finding is a rejection of the Modigliani-Miller (1958) Theorem, which states that in a perfectly competitive, frictionless market, the method of financing should not influence decisions on the asset side.

Using a 2SLS approach with bank holding company data for the 250 largest BHCs in the United States over the 2001Q1-2014Q1 period we find that an increase in capital ratios will lead to a reduction in bank lending, through higher interest rates on loans. Our findings suggest that an increase in the capital ratio of 2.5 percentage points (which is the size of the capital conservation buffer, proposed under Basel III) will lead to 7 to 8 basis point increases in loan rates, or roughly 5% increases (which is a lower bound, since our loan rates are constructed as the quarterly ratio of interest income to loans). Athough loan demand appeared to be not significantly affected by loan rates before the financial crisis, the loan rate semi-elasticity of loan demand has been significantly negative since 2007Q3. As a result, our estimates indicate a drop in loan demand of roughly 4%.

Panel vector autoregression results point to qualitatively similar, though quantitavely larger, effects; a one-standard deviation shock to the risk-based total capital ratio - roughly equivalent to the increase contemplated in Basel III - will lead to an increase in loan rates of up to 12 basis points in two quarters, and a decline in loans by about 10% in the first quarter.

A Derivation of the Option Value of Capital

The option value of bank capital 'at maturity' (time T) is

$$K_T = \frac{2}{l_1\kappa}\left(L_T - L_\kappa\right)^+ \doteq \max\left\{0, \frac{2}{l_1\kappa}\left(L_T - L_\kappa\right)\right\}$$
$$= \begin{cases} \frac{2}{l_1\kappa}\left(L_T - L_\kappa\right) & \text{if} \quad L_T > L_\kappa \\ 0 & \text{if} \quad L_T > L_\kappa \end{cases}.$$

Unanticipated loans follow a log-normal distribution, so $L_0 = e^{-rT}\mathbf{E}\left[L_T\right]$, where r is the instantaneous risk-free rate. As a result we can write the option value of bank capital at time 0 as

$$K_0 = \frac{2}{l_1\kappa}\mathbf{E}\left[\left(L_T - L_\kappa\right)^+\right] = \frac{2}{l_1\kappa}e^{-rT}\mathbf{E}\left[\left(L_0 e^{\left(r-\frac{1}{2}\sigma^2\right)T+\sigma\sqrt{T}Z} - L_\kappa\right)^+\right],$$

where σ is the standard deviation of loans, and Z is a standard normal random variable. Writing this in integral form,

$$K_0 = \frac{2}{l_1\kappa}e^{-rT}\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty}\left[\left(L_0 e^{\left(r-\frac{1}{2}\sigma^2\right)T+\sigma\sqrt{T}x} - L_\kappa\right)^+\right]e^{-\frac{1}{2}x^2}\mathrm{d}x. \tag{10}$$

The function under the integral is greater than zero when

$$L_0 e^{\left(r-\frac{1}{2}\sigma^2\right)T+\sigma\sqrt{T}x} - L_\kappa > 0,$$

which is equivalent to

$$e^{\left(r-\frac{1}{2}\sigma^2\right)T+\sigma\sqrt{T}x} > \frac{L_\kappa}{L_0}.$$

After taking logarithms this can be written as

$$\left(r - \frac{1}{2}\sigma^2\right)T + \sigma\sqrt{T}x > \ln\left(\frac{L_\kappa}{L_0}\right).$$

Solving for x yields

$$x > \frac{\ln\left(\frac{L_\kappa}{L_0}\right) - \left(r - \frac{1}{2}\sigma^2\right)T}{\sigma\sqrt{T}} \doteq a.$$

We established that the integral in (10) is greater than zero over (a, ∞). As such, we can rewrite (10) as

$$K_0 = \frac{2}{l_1\kappa}e^{-rT}\frac{1}{\sqrt{2\pi}}\int_{a}^{\infty}\left(L_0 e^{\left(r-\frac{1}{2}\sigma^2\right)T+\sigma\sqrt{T}x} - L_\kappa\right)e^{-\frac{1}{2}x^2}\mathrm{d}x. \tag{11}$$

We can simplify the notation,

$$K_0 = e^{-rT}\left(I_1 - I_2\right), \tag{12}$$

where

$$I_1 \doteq \frac{2}{l_1\kappa}\frac{1}{\sqrt{2\pi}}\int_a^\infty L_0 e^{\left(r-\frac{1}{2}\sigma^2\right)T+\sigma\sqrt{T}x}e^{-\frac{1}{2}x^2}\mathrm{d}x$$

and

$$I_2 \doteq \frac{2}{l_1\kappa}\frac{1}{\sqrt{2\pi}}\int_a^\infty L_\kappa e^{-\frac{1}{2}x^2}\mathrm{d}x.$$

Thus, to compute the value of the real option K_0 we need to calculate the integrals I_1 and I_2. Starting with I_2 we have

$$I_2 = \frac{2L_\kappa}{l_1\kappa}\frac{1}{\sqrt{2\pi}}\int_a^\infty e^{-\frac{1}{2}x^2}\mathrm{d}x = \frac{2L_\kappa}{l_1\kappa}\left(1 - N\left(a\right)\right) = \frac{2L_\kappa}{l_1\kappa}N\left(-a\right), \tag{13}$$

where $N\left(x\right)$ is the cumulative distribution function of the standard normal random variable Z, using the property of $N\left(\cdot\right)$ that

$$\frac{1}{\sqrt{2\pi}}\int_a^\infty e^{-\frac{1}{2}x^2}\mathrm{d}x = 1 - \frac{1}{\sqrt{2\pi}}\int_{-\infty}^a e^{-\frac{1}{2}x^2}\mathrm{d}x = 1 - N\left(a\right) = N\left(-a\right).$$

For I_1 we have

$$I_1 = \frac{2L_0}{l_1\kappa}e^{\left(r-\frac{1}{2}\sigma^2\right)T}\frac{1}{\sqrt{2\pi}}\int_a^\infty e^{\sigma\sqrt{T}x}e^{-\frac{1}{2}x^2}\mathrm{d}x.$$

We can rewrite this as

$$I_1 = \frac{2L_0 e^{\left(r-\frac{1}{2}\sigma^2\right)T}}{l_1\kappa}\frac{1}{\sqrt{2\pi}}\int_a^\infty e^{\frac{1}{2}\sigma^2T-\frac{1}{2}\left(x-\sigma\sqrt{T}\right)^2}\mathrm{d}x,$$

which can be simplified to

$$I_1 = \frac{2L_0}{l_1\kappa}e^{rT}\frac{1}{\sqrt{2\pi}}\int_a^\infty e^{-\frac{1}{2}\left(x-\sigma\sqrt{T}\right)^2}\mathrm{d}x.$$

We can use the change of variable $y = x - \sigma\sqrt{T}$, so that $\mathrm{d}y = \mathrm{d}x$ and the lower limit $x = a$ becomes $y = a - \sigma\sqrt{T}$, and I_1 can be written as

$$I_1 = \frac{2L_0}{l_1\kappa}e^{rT}\frac{1}{\sqrt{2\pi}}\int_{a-\sigma\sqrt{T}}^\infty e^{-\frac{1}{2}y^2}\mathrm{d}y = \frac{2L_0}{l_1\kappa}e^{rT}N\left(-a+\sigma\sqrt{T}\right). \tag{14}$$

Substituting (13) and (14) into (12) gives

$$K_0 = e^{-rT}\left[\left(\frac{2L_0}{l_1\kappa}e^{rT}N\left(-a+\sigma\sqrt{T}\right)\right) - \left(\frac{2L_\kappa}{l_1\kappa}N\left(-a\right)\right)\right]$$

$$K_0 = \frac{2}{l_1 \kappa} \left[L_0 N \left(-a + \sigma \sqrt{T} \right) - e^{-rT} L_\kappa N \left(-a \right) \right],$$

which can be rewritten to look more like the traditional Black-Scholes formula,

$$K_0 = \frac{2}{l_1 \kappa} \left[L_0 N \left(d_1 \right) - e^{-rT} L_\kappa N \left(d_2 \right) \right], \tag{15}$$

where

$$d_1 \doteq -a + \sigma \sqrt{T} = \frac{\ln \left(\frac{L_0}{L_\kappa} \right) + \left(r + \frac{1}{2} \sigma^2 \right) T}{\sigma \sqrt{T}}$$

and

$$d_2 \doteq -a = \frac{\ln \left(\frac{L_0}{L_\kappa} \right) + \left(r - \frac{1}{2} \sigma^2 \right) T}{\sigma \sqrt{T}}.$$

To determine the effect of loans on the the option value of capital we can write the amount of loans at which the bank becomes capital constrained as

$$L_\kappa = L_0 + \frac{1}{2} \varepsilon_\kappa$$

by 12. We see that L_0 has a direct effect on the strike price, L_κ. Hence, we can split up the effect of L_0 on the option value of bank capital, $\frac{\partial K_0}{\partial L_0}$ into the direct effect of loans, $\frac{\partial \left[\frac{2}{l_1 \kappa} L_0 N(d_1) \right]}{\partial L_0}$, and the indirect effect through the strike price, $\frac{\partial \left[-\frac{2}{l_1 \kappa} e^{-rT} L_\kappa N(d_2) \right]}{\partial L_\kappa} \cdot \frac{\partial L_\kappa}{\partial L_0}$. The first term is

$$\frac{\partial \left[\frac{2}{l_1 \kappa} L_0 N \left(d_1 \right) \right]}{\partial L_0} = \frac{2}{l_1 \kappa} N \left(d_1 \right) + \frac{2}{l_1 \kappa} L_0 N \left(\frac{1}{L_0} - \frac{1}{L_0 + \frac{1}{2} \varepsilon_\kappa} \right),$$

where the last term equals zero (see Garven, 2012). This term is positive. The second term (the effect through the strike price) is

$$\frac{\partial \left[-\frac{2}{l_1 \kappa} e^{-rT} L_\kappa N \left(d_2 \right) \right]}{\partial L_\kappa} \cdot \frac{\partial L_\kappa}{\partial L_0} = -\frac{2}{l_1 \kappa} e^{-rT} N \left(d_2 \right) - \frac{2}{l_1 \kappa} e^{-rT} L_\kappa N \left(\frac{1}{L_0} - \frac{1}{L_0 + \frac{1}{2} \varepsilon_\kappa} \right),$$

where the last term again equals zero. This overall term is negative. As a result, L_0 affects bank capital both positively and negatively. For the standard case of $\sigma > 0$ and $T > 0$, $d_1 > d_2$, and thus $N(d_1) > N(d_2)$. Since $0 < e^{-rT} < 1$ for any $r > 0$ and $T > 0$, it will always be the case that $\frac{2}{l_1 \kappa} N(d_1) > \frac{2}{l_1 \kappa} e^{-rT} N(d_2)$. Hence, the direct effect of loans on the option value will always dominate the indirect effect of loans through the strike price. An increase in the current amount of loans will therefore positively affect the option value of capital.

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Table 1: REGULATORY CAPITAL REQUIREMENTS IN THE UNITED STATES

	Total Risk-Based Capital Ratio	Tier 1 Risk-Based Capital Ratio
Well capitalized	$\geq 10\%$	$\geq 6\%$
Adequately capitalized	$\geq 8\%, < 10\%$	$\geq 4\%, < 6\%$
Undercapitalized	$< 8\%$	$< 4\%$

Source: FDIC, "Capital Groups and Supervisory Groups,"
http://www.fdic.gov/deposit/insurance/risk/rrps_ovr.html

Table 2: DESCRIPTIVE STATISTICS OF CAPITAL RATIOS

	2001Q1 -2014Q1	2001Q1 -2007Q2	2007Q3 -2009Q2	2009Q3 -2014Q1
Total RBC Ratio (%)				
Mean	14.3	14.3	12.9	14.8
Median	13.5	12.8	12.2	14.7
St. Dev.	18.5	5.2	3.9	29.4
Tier 1 RBC Ratio (%)				
Mean	9.1	9.0	8.7	9.3
Median	8.8	8.5	8.5	9.4
St. Dev.	5.1	2.9	2.5	7.5
Equity-Asset Ratio (%)				
Mean	9.6	9.3	8.8	10.2
Median	9.1	8.8	8.6	9.9
St. Dev.	4.7	3.2	3.2	6.3
Loan Rate (%)				
Mean	2.08	2.39	2.02	1.70
Median	1.93	2.18	1.94	1.57
St. Dev.	1.27	1.54	0.52	0.89

NOTES: The sample includes the 250 largest bank holding companies as of 2013Q1. 'RBC' stands for 'risk-based capital'.

Table 3: RESULTS FOR THE OPTIMAL CAPITAL RATIO, 2001Q1-2014Q1 (6)

	Capital Ratio (CR_{it})		
	Total RBC	Tier 1 RBC	Equity-Asset Ratio
$\Delta(CR_{it-1})$	-0.132**	-0.137**	-0.121*
	(0.061)	(0.059)	(0.064)
$\Delta(CR_{it-1}) \times CR_{it-1}$	0.005	0.005*	0.006
	(0.003)	(0.003)	(0.003)
$\frac{IntExp_{it-1}}{Liabilities_{it-1}}$	0.682***	0.607***	0.374
	(0.215)	(0.183)	(0.230)
$\frac{IntExp_{it-1}}{Liabilities_{it-1}} \times CR_{it-1}$	-0.057***	-0.057***	-0.041
	(0.019)	(0.018)	(0.025)
$\frac{NonIntExp_{it-1}}{Assets_{it-1}}$	-0.730***	-0.647***	-0.432*
	(0.220)	(0.200)	(0.243)
$\frac{NonIntExp_{it-1}}{Assets_{it-1}} \times CR_{it-1}$	0.053***	0.054***	0.045*
	(0.017)	(0.016)	(0.026)
$\frac{NonPerfLoans_{it-1}}{Loans_{it-1}}$	-0.410***	-0.323***	-0.268***
	(0.090)	(0.075)	(0.063)
$\frac{NonPerfLoans_{it-1}}{Loans_{it-1}} \times CR_{it-1}$	0.033***	0.031***	0.033***
	(0.006)	(0.006)	(0.008)
$\Delta \ln(GDP_{t-1})$	-242.87***	-209.10***	-107.23*
	(51.167)	(38.095)	(55.395)
$\Delta \ln(GDP_{t-1}) \times CR_{it-1}$	16.871***	15.877***	10.162*
	(3.668)	(3.160)	(5.799)
$\Delta \ln(Deflator_{t-1})$	-831.84***	-731.01***	-592.14***
	(84.425)	(66.576)	(88.252)
$\Delta \ln(Deflator_{t-1}) \times CR_{it-1}$	53.883***	52.556***	57.517***
	(6.136)	(5.565)	(9.962)
$Lending\,Std_{t-1}$	-0.017***	-0.018***	-0.008***
	(0.003)	(0.003)	(0.002)
VIX_{t-1}	-0.006	-0.006	-0.008
	(0.005)	(0.005)	(0.005)
Adj. R^2	0.724	0.748	0.610

NOTES: Each regression includes bank holding company fixed effects. These regressions are the first stage for the subsequent second stage loan rate and loan regressions. Serial correlation robust standard errors are in parentheses. Coefficients estimated but not reported include an intercept term, loan loss provision relative to total loans (and its interaction with the relevant capital ratio), the log of total assets, the one-quarter change in the log of total loans, and the liability-asset ratio of nonfinancial businesses. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.

Table 4: RESULTS FOR THE OPTIMAL CAPITAL RATIO, 2001Q1-2007Q2 (6)

	Capital Ratio (CR_{it})		
	Total RBC	Tier 1 RBC	Equity-Asset Ratio
$\Delta(CR_{it-1})$	-0.162	-0.146	-0.012
	(0.102)	(0.096)	(0.078)
$\Delta(CR_{it-1}) \times CR_{it-1}$	0.005	0.005	-0.007
	(0.006)	(0.006)	(0.007)
$\frac{IntExp_{it-1}}{Liabilities_{it-1}}$	0.264**	0.161	-0.023
	(0.114)	(0.101)	(0.023)
$\frac{IntExp_{it-1}}{Liabilities_{it-1}} \times CR_{it-1}$	-0.024**	-0.017	0.002
	(0.011)	(0.011)	(0.003)
$\frac{NonIntExp_{it-1}}{Assets_{it-1}}$	-0.294**	-0.170	0.023
	(0.126)	(0.107)	(0.028)
$\frac{NonIntExp_{it-1}}{Assets_{it-1}} \times CR_{it-1}$	0.022**	0.015	-0.003
	(0.010)	(0.009)	(0.003)
$\frac{NonPerfLoans_{it-1}}{Loans_{it-1}}$	-0.855***	-0.685***	-0.182**
	(0.239)	(0.208)	(0.071)
$\frac{NonPerfLoans_{it-1}}{Loans_{it-1}} \times CR_{it-1}$	0.063***	0.056***	0.010*
	(0.017)	(0.017)	(0.006)
$\Delta \ln(GDP_{t-1})$	-80.710*	-59.791*	-51.121*
	(42.389)	(33.408)	(27.375)
$\Delta \ln(GDP_{t-1}) \times CR_{it-1}$	5.435*	4.497*	4.832*
	(3.002)	(2.697)	(3.017)
$\Delta \ln(Deflator_{t-1})$	-416.27***	-325.39***	-356.26***
	(95.179)	(80.170)	(50.489)
$\Delta \ln(Deflator_{t-1}) \times CR_{it-1}$	27.750***	24.173***	39.028***
	(6.715)	(6.444)	(5.219)
$Lending\,Std_{t-1}$	-0.001	-0.002	0.004*
	(0.004)	(0.004)	(0.002)
VIX_{t-1}	-0.005	-0.004	-0.006
	(0.008)	(0.008)	(0.005)
Adj. R^2	0.756	0.785	0.754

NOTES: Each regression includes bank holding company fixed effects. These regressions are the first stage for the subsequent second stage loan rate and loan regressions. Serial correlation robust standard errors are in parentheses. Coefficients estimated but not reported include an intercept term, loan loss provision relative to total loans (and its interaction with the relevant capital ratio), the log of total assets, the one-quarter change in the log of total loans, and the liability-asset ratio of nonfinancial businesses. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.

Table 5: RESULTS FOR THE OPTIMAL LOAN RATE, 2001Q1-2014Q1 (7)

	Loan Rate ($\frac{IntInc_{it}}{Loans_{it}+Securities_{it}}$)		
	Total RBC	Tier 1 RBC	Equity-Asset Ratio
$\frac{CR_{it}-\widehat{CR}_{it}}{\widehat{CR}_{it}}$	0.228***	0.270***	0.114*
	(0.046)	(0.049)	(0.061)
$\frac{IntExp_{it}}{Liabilities_{it}}$	1.291***	1.356***	1.270***
	(0.044)	(0.050)	(0.096)
$\frac{NonIntExp_{it}}{Assets_{it}}$	0.035	0.026	0.219
	(0.081)	(0.077)	(0.232)
$\frac{NonPerfLoans_{it}}{Loans_{it}}$	-0.026***	-0.029***	0.001
	(0.005)	(0.005)	(0.025)
$\Delta\ln(GDP_t)$	4.404***	4.652***	4.317***
	(1.153)	(1.160)	(1.464)
$\Delta\ln(Deflator_t)$	8.668***	10.835***	2.586
	(3.334)	(3.329)	(4.843)
$Lending\,Std_t$	-0.001***	-0.001***	-0.002***
	(0.000)	(0.000)	(0.001)
VIX_t	0.003***	0.003**	0.007**
	(0.001)	(0.001)	(0.003)
Adj. R^2	0.673	0.685	0.469

NOTES: The first stage estimates for the capital ratio ($\widehat{CR}$) are based on the sample period 2001Q1-2007Q2 from Table 4. The shorter time period is used to minimize a bias resulting from an anticipation of an increase in capital requirements after the financial crisis and passage of Basel III. Each regression includes bank holding company fixed effects. There is no evidence of a unit root, when using the LLC, IPS-W, adjusted DF, or PP tests. Serial correlation robust standard errors are in parentheses. Coefficients estimated but not reported include an intercept term, loan loss provision relative to total loans, the log of total assets, the one-quarter change in the log of total loans, and the liability-asset ratio of nonfinancial businesses. *, ** and *** indicate statistical significance at the 10%, 5% and 1% level,respectively.

Table 6: RESULTS FOR THE OPTIMAL QUANTITY OF LOANS (8)

	$\ln(Loans_{it}/Deflator_t)$		
	2001Q1-2014Q1	2001Q1-2007Q2	2007Q3-2014Q1
$\frac{\widehat{IntInc_{it-1}}}{Loans_{it-1}+Securities_{it-1}}$	0.000**	0.000**	-0.538***
	(0.000)	(0.000)	(0.000)
$\Delta\ln(GDP_{t-1})$	-12.998***	-5.407*	-4.365
	(2.111)	(2.988)	(3.695)
$\Delta\ln(Deflator_{t-1})$	-58.018***	-9.090	-49.682***
	(7.000)	(6.041)	(12.394)
VIX_{t-1}	-0.010***	0.001	-0.007*
	(0.001)	(0.002)	(0.004)
Adj. R^2	0.859	0.885	0.816

NOTES: The predicted interest rate follows from the first column of Table 5. Each regression includes bank holding company fixed effects. Serial correlation robust standard errors are in parentheses. Coefficients estimated but not reported include an intercept term and the liability-asset ratio of nonfinancial businesses. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.

Table 7: RESULTS FOR THE OPTIMAL CAPITAL RATIO, 2009Q2-2014Q1 (6)

	Capital Ratio (CR_{it})		
	Total RBC	Tier 1 RBC	Equity-Asset Ratio
$\Delta(CR_{it-1})$	0.271***	0.239***	0.209
	(0.071)	(0.070)	(0.194)
$\Delta(CR_{it-1}) \times CR_{it-1}$	-0.005**	-0.005**	-0.003
	(0.002)	(0.002)	(0.004)
$\frac{IntExp_{it-1}}{Liabilities_{it-1}}$	-11.021***	-8.634***	-3.298
	(2.797)	(2.851)	(2.248)
$\frac{IntExp_{it-1}}{Liabilities_{it-1}} \times CR_{it-1}$	0.658***	0.571***	0.326**
	(0.154)	(0.180)	(0.134)
$\frac{NonIntExp_{it-1}}{Assets_{it-1}}$	-1.204***	-1.143***	-2.071***
	(0.405)	(0.417)	(0.796)
$\frac{NonIntExp_{it-1}}{Assets_{it-1}} \times CR_{it-1}$	0.061***	0.061***	0.095***
	(0.008)	(0.009)	(0.014)
$\frac{NonPerfLoans_{it-1}}{Loans_{it-1}}$	0.043	0.009	-0.007
	(0.115)	(0.101)	(0.100)
$\frac{NonPerfLoans_{it-1}}{Loans_{it-1}} \times CR_{it-1}$	0.004	0.005	0.014
	(0.007)	(0.007)	(0.010)
$\Delta\ln(GDP_{t-1})$	-387.640***	-311.331***	-166.809
	(131.941)	(110.441)	(113.790)
$\Delta\ln(GDP_{t-1}) \times CR_{it-1}$	26.537***	25.061***	16.937**
	(9.051)	(8.668)	(8.461)
$\Delta\ln(Deflator_{t-1})$	-508.937**	-484.355***	-370.208
	(205.556)	(173.293)	(234.096)
$\Delta\ln(Deflator_{t-1}) \times CR_{it-1}$	39.986***	42.814***	20.557
	(13.081)	(12.302)	(17.159)
$Lending\,Std_{t-1}$	-0.003	-0.005	-0.023**
	(0.007)	(0.008)	(0.010)
VIX_{t-1}	-0.007	-0.007	-0.013*
	(0.008)	(0.008)	(0.008)
Adj. R^2	0.793	0.799	0.575

NOTES: Each regression includes bank holding company fixed effects. Serial correlation robust standard errors are in parentheses. Coefficients estimated but not reported include an intercept term, loan loss provision relative to total loans (and its interaction with the relevant capital ratio), the log of total assets, the one-quarter change in the log of total loans, and the liability-asset ratio of nonfinancial businesses. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.

Table 8: RESULTS FOR THE OPTIMAL LOAN RATE (7), 2009Q2-2014Q1

	Loan Rate ($\frac{IntInc_{it}}{Loans_{it}+Securities_{it}}$)		
	Total RBC	Tier 1 RBC	Equity-Asset Ratio
$\frac{CR_{it}-\widehat{CR}_{it}}{\widehat{CR}_{it}}$	0.462***	0.216***	0.068
	(0.125)	(0.061)	(0.059)
$\frac{IntExp_{it}}{Liabilities_{it}}$	1.473***	1.447***	1.039***
	(0.172)	(0.177)	(0.242)
$\frac{NonIntExp_{it}}{Assets_{it}}$	0.051	0.056	0.066
	(0.095)	(0.098)	(0.103)
$\frac{NonPerfLoans_{it}}{Loans_{it}}$	-0.013	-0.017**	-0.017**
	(0.009)	(0.009)	(0.008)
$\Delta \ln(GDP_t)$	-1.309	-1.523	-1.445
	(2.015)	(2.074)	(2.804)
$\Delta \ln(Deflator_t)$	13.757	15.250*	10.109
	(8.593)	(8.872)	(10.810)
$Lending\, Std_t$	0.000	0.001	0.000
	(0.001)	(0.001)	(0.002)
VIX_t	0.002	0.002	0.001
	(0.001)	(0.001)	(0.001)
Adj. R^2	0.476	0.467	0.667

NOTES: The first stage estimates for the capital ratio ($\widehat{CR}$) are based on the sample period 2009Q2-2014Q1 from Table 7. Each regression includes bank holding company fixed effects. Serial correlation robust standard errors are in parentheses. Coefficients estimated but not reported include an intercept term, loan loss provision relative to total loans, the log of total assets, the one-quarter change in the log of total loans, and the liability-asset ratio of nonfinancial businesses. *, ** and *** indicate statistical significance at the 10%, 5% and 1% level,respectively.

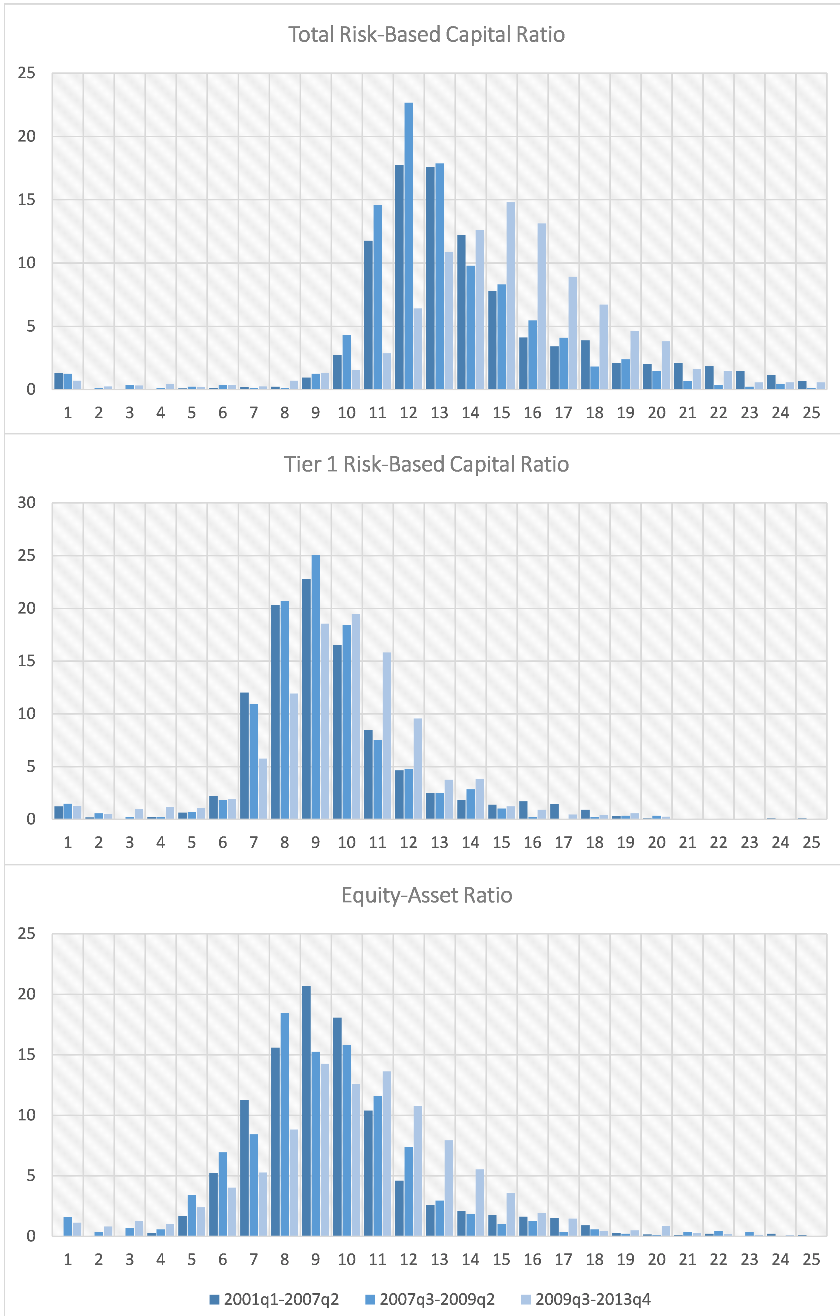

Figure 1: Distributions of Capital Ratios: Before, During and After the Crisis

NOTES: The sample includes the 250 largest bank holding companies as of 2013Q1. For the capital requirements for each of the capital definitions, see Table 1.

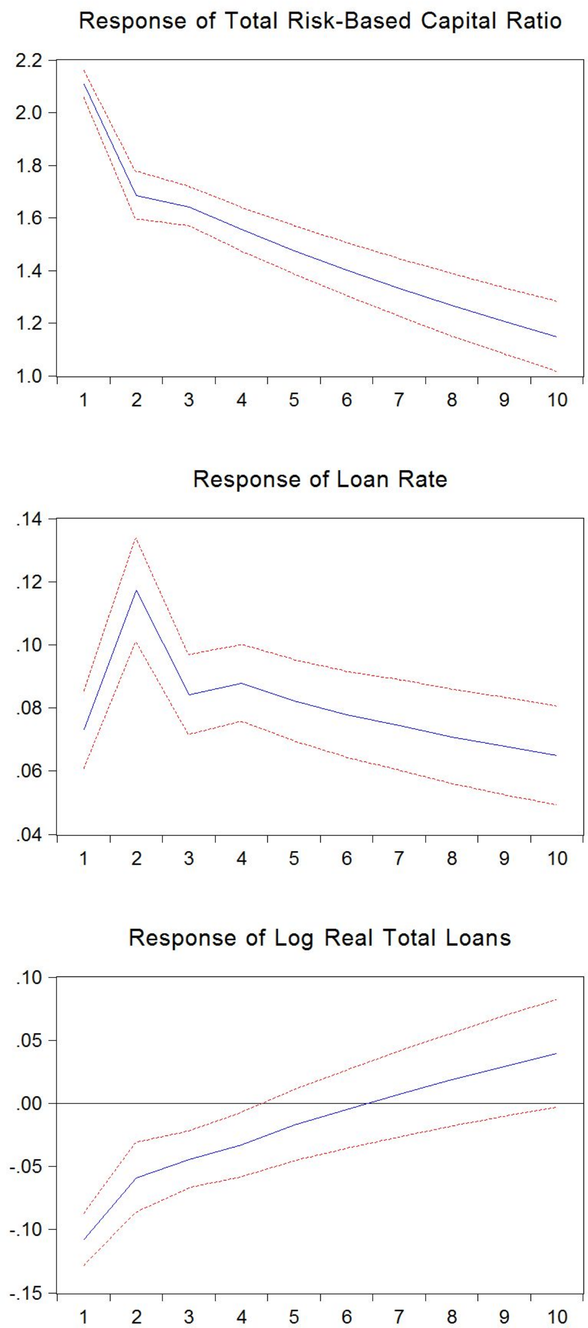

Figure 2: Impulse Responses for a Shock to the Total Risk-Based Capital Ratio (2001Q1-2014Q1)
Response to Cholesky One SD Innovations $\pm$ 2 S.E.

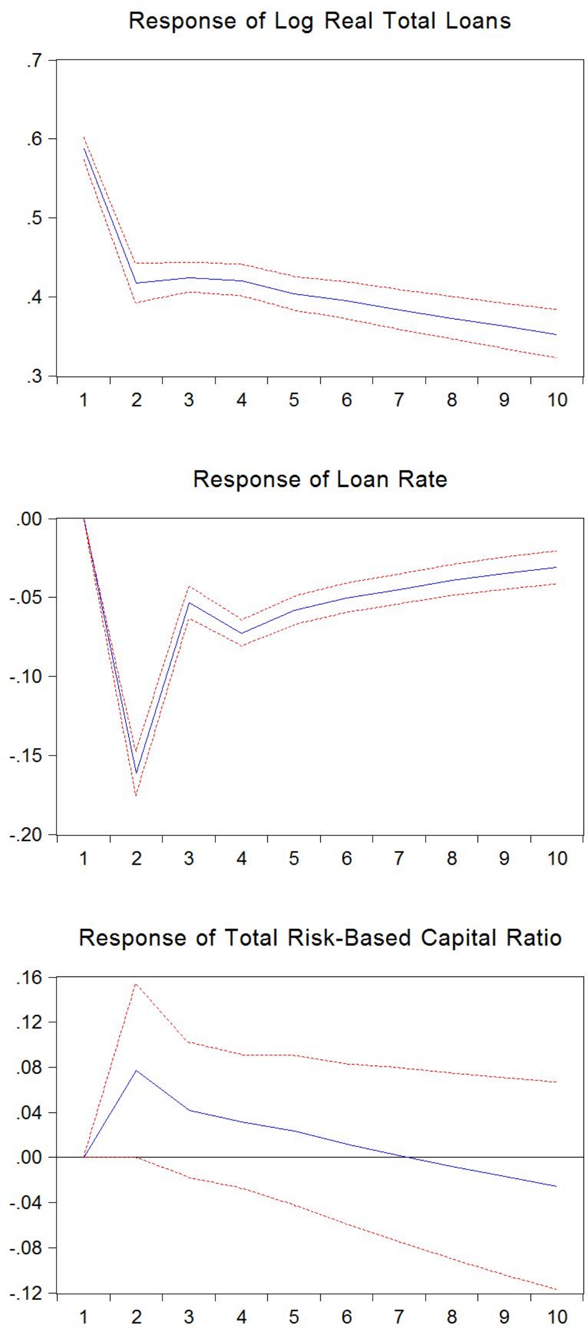

Figure 3: Impulse Responses for a Shock to Log Real Total Loans (2001Q1-2014Q1)
Response to Cholesky One SD Innovations $\pm$ 2 S.E.