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Are regulatory capital adequacy ratios good indicators of bank failure? Evidence from US banks

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ABSTRACT

Motivated by massive bank failures during the financial crisis, this paper examines whether capital adequacy ratios required by regulators are associated with bank failure. It investigates whether the association is affected by the bank's proximity to the minimum required capital ratios. If results show a significant association between regulatory capital and failure of banks falling below the minimum capital ratios, then the ratios are set at an adequate level. Examining a sample of 560 US bank holding companies for the period 2003–2009, results reveal that the association between the core (Tier 1) capital ratio and bank failure becomes significant only if the bank holding company has a Tier 1 capital ratio of less than 6%. This is the level below which US bank regulators do not regard banks as being well capitalized. During the financial crisis period of 2007–2009, there is a significant association only when the criterion is set at or above 8%. Market-based probability of default is more significantly associated with failure relative to Tier 1 capital ratio. The findings of this paper are relevant to regulatory policy discussions and Basel III deliberations on capital adequacy at times of financial turmoil.

1. Introduction

Banking regulation mainly aims at mitigating the systemic risk resulting from bank failures, hence, protecting depositors' interests and maintaining the financial health of the overall economy. The importance of bank regulation stems from banks key function as creators of credit. Accordingly, one of the main reasons the financial crisis of late 2007 became so severe was that banks create credit for financial transactions that are unrelated to the creation of real assets (Werner, 2010). Bank regulators and the insurer body are interested in banks maintaining minimum capital ratios to reduce the probability of failure and systemic risk that jeopardize liquidity, monetary policy and economic stability. Here, the question of whether the risk-based capital ratios give regulators a true indicator of possible bank failure becomes crucial. This paper addresses this question while examining the association between regulatory capital requirements and bank failure. The paper does not seek to develop an early warning signal of failure but rather to provide an understanding and validation of the relevance of minimum capital ratios as a regulatory tool in association with early stages of bank failure, hereafter 'distress'. Reflecting concerns that helped prompt the Basel III deliberations, the paper investigates whether a higher minimum core capital ratio provides an indicator of bank distress during times of turmoil.

In earlier research, minimum capital ratios have been used indirectly, along with market-based measures that proxy for bank distress, to examine their association with default risk (Hall, King, Meyer, & Vaughan, 2002). However, the question of whether the minimum capital ratio itself is a valid proxy for distress has not been tested. In this regard, the paper does so after controlling for market-based default risk measures drawn from extant finance literature. Moreover, the components of the risk-based capital ratio are disentangled to better examine the overall relevance of the ratio to distress.

The US Board of Governors of the Federal Reserve System has expressed full support for the Basel III proposal of the Basel Committee on Banking Supervision (BCBS) that there should be more stringent capital and liquidity requirements. More specifically, federal and international efforts have been focusing on strengthening the quantity and quality of capital through more stringent minimum ratios (Basel Committee on Banking Supervision, 2010). As a key part of its proposal to strengthen the resilience of the banking sector, the BCBS has proposed that banks should maintain a minimum core capital ratio of 6%

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rather than the previously required ratio of 4% in order to be considered adequately capitalized.[1] Under new capital adequacy rules, banks are expected to maintain capital levels well above the minimum required ratios. Furthermore, for a bank to expand its activities under the financial holding company status, it needs to be well capitalized. Hence, the importance of a well-capitalized capital threshold is paramount.

Motivated by the proposals of the BCBS and the FDIC for revised capital requirements under Basel III, this paper examines the association between regulatory capital and bank distress. It finds that this association is more pronounced for banks for which the core capital ratios only narrowly exceed the required minimum. It uses the criterion currently used by US regulators that the ratio is in the range 2% to 6%.[2] Given that a period of financial turmoil might cause an association between regulatory capital and distress to be observed above that range, the paper tests the association between regulatory capital and bank distress during the financial crisis period of 2007–2009. In a follow-on test, higher ranges are used to provide results that are relevant to bank regulators and policy decisions.

The evidence provided in this paper contributes to the literature in a number of ways. First, this paper adds to the meager literature examining the direct association between the regulatory risk-based capital ratio and a leading indicator of bank distress. Unlike Ng and Roychowdhury (2011), who test the association between core regulatory capital or total risk-based capital and bank failure, this paper disentangles components of the regulatory capital ratio to further understand what drives the association. Second, this paper differs from the work of Ronn and Verma (1989) and Cordell and King (1995) by having an institution-specific default-risk focus rather than a market-wide deposit insurance-related emphasis. Rather than estimating a fair capital-to-asset ratio that rests on the pricing of deposit insurance as a put option (Ronn & Verma, 1989) or deriving a leverage ratio based on accounting or market data variations (Bichsel & Blum, 2004), it examines the nature of the association between the core capital ratio and bank distress as well as circumstances in which this association is more pronounced. Finally, unlike Bichsel and Blum (2004), bank distress is used as a dependent variable while using as a control variable a market-based probability of default, the BSM measure of Hillegeist, Keating, Cram, and Lundstead (2004), established in the finance literature. This measure controls for the default risk as assessed by the market through option pricing models.

The remainder of the paper is structured as follows. Section 2 reviews the literature on regulatory capital and default risk. Section 3 lays down the basis for hypotheses development. In section 4 the research design is presented. Section 5 introduces the sample and data sources. Then, the empirical results with a reference to robustness checks are discussed. Furthermore, the implications for further research and regulatory policies are introduced in Section 6. Finally, Section 7 concludes.

2. Background

As a response to bank failures coupled with a decline in bank capital holdings in the early 1980s, US regulators have required banks to hold minimum capital as a percentage of assets. However, these standards have been criticized for failing to take into account the risk in a bank's portfolio of assets. The old minimum capital requirements made no distinction between high-risk asset positions and low-risk asset positions, hence encouraging banks to take excessive risks (Hancock & Wilcox, 1994). In 1990 US bank regulators adopted risk-based capital requirements as part of the international Basel Accord. Accordingly, Tier 1 capital is an equity-like measure of capital. It consists of core capital representing common book equity, less certain disallowed reserves and intangible assets, plus minority interest and other items. Tier 2 capital is a junior debt-like measure of capital. It includes subordinated debt, plus cumulative perpetual preferred stock and certain reserves not included in Tier 1 capital, allowance for loan losses up to a limit, and other items includable in Tier 2 capital. Tier 3 capital consists mainly of short-term subordinated debt. It is usually a very small amount, if not zero. Total risk-based capital is the sum of Tier 1, Tier 2 and Tier 3 capital after some adjustments (Abou-El-Sood, 2012). The ratio of regulatory capital to risk-weighted assets forms the basis to measure the capital adequacy of banks.[3] The regulators' aim has been to match risk-based capital requirements to the real risk of banks. Nonetheless, many recent failures, and the preceding state of distress, occurred during the financial crisis of late 2007 irrelevant to the capital ratios banks disclosed. Therefore, the question is whether the minimum capital ratio required by bank regulators really reflects a true measure of bank vulnerability. In a US setting, the FDIC is the insurer against bank failures. During the financial crisis of 2007, the number of banks entering into the FDIC receivership has increased dramatically.[4]

Earlier research gives mixed results on whether maintaining regulatory capital requirements mitigates excessive risk taking by banks and reduces the probability of failure. The first strand of research rests on the buffer role of regulatory capital. Consistent with the regulatory capital acting as a deposit insurance premium, banks are motivated to incur lower risks the higher the amount of capital and reduce their capital charge at stake in case of default (Aggarwal & Jacques, 2001; Berger, Herring, & Szego, 1995; Furlong & Keeley, 1989; Furlong, 1992; Jacques & Nigro, 1997). Using the option-pricing model, Furlong and Keeley (1989) find that regulatory capital requirements achieve stability for the banking system. They show that banks have lower risk exposure when the regulatory capital ratio increases. Aggarwal and Jacques (2001) report an increase in regulatory capital ratios of banks under regulation without an offsetting increase in credit risk. Berger et al. (1995) point out that costs of failure are borne by debt-holders and partially by shareholders. Therefore, debt-holders might seek higher yields to offset the probability of failure and shift the expected cost of failure to shareholders. In turn, shareholders might reduce such cost by increasing regulatory capital to the point that the reduction in the expected likelihood of failure offsets the reduction in the tax benefits of debt.

The second strand of research is based on the notion that raising capital is costly. Therefore, a higher level of regulatory capital should be compensated by taking higher risks to achieve an adequate return to shareholders (Bichsel & Blum, 2004; Koehn & Santomero, 1980; Shrieves & Dahl, 1992). Koehn and Santomero (1980) describe the association between the regulatory capital ratio and the probability of failure as 'ambiguous'. When testing intra-industry effects, they find a higher intra-industry dispersion of the probability of failure. They point out that the regulatory capital requirements drive banks to reallocate their assets inefficiently and consequently increase risk taking. Gennotte and Pyle (1991) and Shrieves and Dahl (1992) find that portfolio risk increases as a result of increased capital requirements. Cordell and King (1995) regress the market-based capital adequacy ratio on risk-weighted asset classes to determine whether the regulatory risk-weights differ from those set by the market. They derive a market-based capital adequacy ratio based on the Ronn and Verma (1986) option pricing model to estimate deposit insurance premiums and extend

[1] It should be noted that, subsequent to the interval examined in this study, Basel III has mandated that 6% should become the minimum capital requirement for banks to be classified as adequately capitalized. The Federal Deposit Insurance Corporation (FDIC) has adopted a new rule requiring a minimum tier 1 capital ratio of 6% to be applied January 1, 2015.

[2] US bank holding companies are classified as critically undercapitalized when they fall at or below the regulatory capital ratio of 2%. Consequently, they are entered into conservatorship/receivership and are considered as failing.

[3] To be well capitalized under the proposed new federal bank regulatory agency definitions, a bank holding company must maintain a tier 1 capital ratio of at least 8%. A bank holding company is adequately capitalized with a tier 1 ratio of 6% or more; undercapitalized below 6%; significantly undercapitalized below 4%; and critically undercapitalized of 2% or less, where banks are put into conservatorship/receivership.

[4] Federal Deposit Insurance Corporation (FDIC) Failed Bank List (http://www.fdic.gov).

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the sample of Ronn and Verma (1989) to include US banks and thrifts. The use of risk weights is criticized for not reflecting differences in credit quality across a particular type of loan, asset risk concentration in a specific class or to a particular entity or region and the covariance among financial instruments. The latter drawback leads to the inaccurate distinction between changes in asset composition that hedge portfolio risk and those that increase portfolio risk. In a sample of Swiss banks, Bichsel and Blum (2004) derive two variations of a non-regulatory capital ratio based on accounting and market data. They use an option-pricing distance-to-default measure as an indicator of failure. Although Bichsel and Blum (2004) find changes in capital ratios are associated with changes in the level of risk, they find no significant association between default probability and the capital ratio.

Overall, prior studies agree that, other things being equal, increasing the capital buffer makes banks more capable of absorbing losses, thus reducing default risk. However, an indirect outcome of capital stringency on default risk might be changing portfolio composition. Hence, the empirical results do not agree on the existence of a significant association between the stringency of capital regulation and bank default risk. Empirical tests have focused on the association between capital stringency and default risk on one hand and between risk and bank failure on the other hand. An overlooked question is whether there is a direct association between the regulatory capital ratio and bank distress.

3. Hypotheses

There has been a recent debate on the level at which the required capital ratios of banks should be set. In particular, the Basel III framework proposes that the minimum Tier 1 capital ratio for banks should be raised from 4% to 6% and the threshold for banks to be regarded as well capitalized should be raised further. This paper is relevant to the debate on required regulatory-capital ratios by examining the association between the regulatory capital ratios of banks and the probability of bank failure. The first hypothesis is as follows:

H_1. There is an association between Tier 1 capital ratio in one period and the probability of bank distress in the subsequent period.

During the sample period, US bank regulators require all banks to have a minimum Tier 1 capital ratio of 4%.[5] They designate banks with Tier 1 capital within the range 4% to 6% as adequately capitalized and banks with Tier 1 capital above 6% as well capitalized. Policy deliberations of the FDIC suggest a final rule prompting the minimum Tier 1 capital ratio to be 6% for adequately capitalized banks and 8% for well-capitalized banks.[6] The objective of the second hypothesis is to examine the new proposed capital adequacy rule during crisis and boom periods. It tests whether a Tier 1 capital ratio of 6% represents a frontier above (below) which there is no association (there is association) between Tier 1 capital and distress. The figure of 6% is of interest in that the Basel III framework required a minimum Tier 1 capital ratio of 6% from January 1, 2015 (Basel Committee on Banking Supervision, 2013). In the light of this, the second hypothesis is as follows:

H_2. The association between Tier 1 capital ratio in one period and the probability of bank distress in the subsequent period is more pronounced for the less capitalized banks than for well-capitalized banks.

Much of the recent debate about regulatory capital ratios has centered on the possibility that the minimum regulatory capital levels required by regulators were set too low. Therefore, the hypotheses are tested (1) for the overall sample, (2) for the interval from 2003 to 2006, prior to the financial crisis, and (3) for the crisis period from 2007 to 2009.

The Tier 1 capital ratio is a combination of three elements, each of which is of potential value in the prediction of distress: (i) the regulatory adjustments to book equity that are made in arriving at Tier 1 capital; (ii) a measure of leverage; (iii) a measure of the risk of the bank's asset portfolio. Hence, all tests are carried out both for the total Tier 1 capital ratio and for each of these three sub-components.

4. Research design

Since bank regulators are held accountable for bank failure, they are interested in bank performance prior to the state of default (Hall et al., 2002). Therefore, a logistic regression model is used with a dummy variable denoting the state of failure as the dependent variable and Tier 1 capital ratio as the explanatory variable. The regulatory measure of Tier 1 capital ratio is based on ex-post measures of risk. Therefore, a bank fails to hit or exceed the minimum capital ratio only after its risk-taking activities have resulted in losses. The regulatory Tier 1 capital ratio does not account for volatility of asset concentrations nor does it consider the risk reduction resulting from a lower covariance of cash flows among diversified assets. The ratio also ignores the potential effect of changes in interest rates on fixed-interest assets such as mortgages. In an event study, Pettawy and Sinkey (1980) have identified that the market signals negative excess equity returns up to two years prior to failure. This signal is found to predate the regulators' examination of problem banks. Moreover, Furlong and Keeley (1989) have objected to the mean-variance utility maximization design used in many studies because it ignores the probability of bank failure and changes in the value of the deposit insurance put option. Hence, there is a need to capture these omitted factors through a market-based variable. The BSM default probability of Hillegeist et al. (2004) provides an ex-ante measure of leverage and volatility to address concerns inherent in the Tier 1 capital ratio. It controls for market-based default factors affecting the probability of failure.

The explanatory variable of interest is the Tier 1 capital to risk-weighted assets ratio. The reason for using the Tier 1 capital ratio is that it magnifies the regulatory emphasis of having a sufficient capital buffer against shocks, given the bank's risk-weighted asset portfolio. Therefore, it constitutes a default-related measure by construction. Likewise, the BSM control variable has two components of leverage and volatility. The former corresponds to the leverage inherent in the regulatory Tier 1 capital ratio. The latter corresponds to the risk-weighted component of the regulatory Tier 1 capital ratio and controls for volatility of bank asset returns. To test the first hypothesis, a logistic regression model is used to examine whether there is a significant association between the regulatory Tier 1 capital ratio and the probability of failure, controlling for other variables that might affect bank default risk. The following model is used to test this association conjectured in H_1:

$$\Pr(Dis_{it+1}) = \beta_1 + \beta_2 TCAP_{it} + \sum_{j=1}^{n} \beta_j Controls_{jit+1} \tag{1}$$

where $\Pr(Dis_{it+1})$ is a latent variable representing the probability of failure. It is expressed as a dummy variable that takes the value 1 if the BHC is in distress and 0 otherwise, for bank holding company i at year $t + 1$. The explanatory variable $TCAP_{it}$ is the ratio of Tier 1 capital to risk-weighted assets for bank holding company i at year t.[7]

The vector of controls includes a proxy for size, a proxy for loan quality, together with the market-based BSM default risk measure. As

[5] The sample US bank holding companies are examined over the period 2003–2009.

[6] On April 8, 2014, the FDIC Board of Directors approved a Final Rule on the Basel III capital standards. The resulting revised Prompt Corrective Action (PCA) ratios are applicable on January 1, 2015 for all banks.

[7] The empirical testing has been conducted using natural logs of values rather than level data and the empirical results have been robust to the alternative specification.

Shrieves and Dahl (1992) point out, size is associated with the bank investment opportunity and its access to equity capital markets. These are relevant to the cost of failure avoidance. Therefore, $SIZE_{it}$ is included to control for the size effect. *Ceteris paribus*, relatively larger banks are expected to have a lower probability of default. Consistent with the evidence in Ng and Roychowdhury (2011) that banks use loan loss allowances to manage regulatory capital, influencing default risk, ALL_{it}, the ratio of allowance for loan losses to total loans is employed as a proxy for management provisioning discretion and loan quality affecting default risk. This proxy controls for the heterogeneity of bank loan screening practices and the inherent adverse selection problem. According to Aggarwal and Jacques (2001), higher allowance for loan losses reflects higher credit risk, hence higher default probability.[8]

To use the BSM default risk measure, $BSMprob_{it}$, the BSM default probability is derived from the option-pricing models of Black and Scholes (1973) and Merton (1974). Hillegeist et al. (2004), who rely on the insight developed in Vassalou and Xing (2004), adapt the Black–Scholes–Merton option pricing model. Accordingly, the equity value of a bank holding company can be viewed as a call option on the value of assets, where the strike price is equal to the face value of liabilities and where the option expires when the debt matures. At maturity, the option is unexercised if the value of assets falls below the face value of liabilities, in which case the bank holding company is assumed in default. Therefore, the default probability is embedded in the BSM measure.[9] The distribution of sample BSM default probabilities exhibits high frequency at both tails. Therefore, the BSM score and the annual percentile rank of the BSM default measure are used in robustness tests rather than raw probabilities. Unlike prior studies on bank distress, the market-based default probability is used as a control rather than a dependent variable to mitigate the possible correlation between the Tier 1 capital ratio and errors in the regression model (Kopcke, 2001).[10]

In another specification, the impact of regulatory pressure on failure probability is examined. According to Calem and Rob (1999), a well-capitalized bank can afford to invest in more risky positions because it is more remote from failure. Therefore, we use a dummy variable D_{it} that takes the value 1 if the BHC falls below the minimum capital ratio of 6% for well capitalized banks and 0 otherwise. The dummy variable is interacted with the Tier 1 capital ratio to control for the proximity to the well-capitalization requirement and the incentive to adjust the composition of risk-weighted assets among sample BHCs.[11] It also reflects the regulatory pressure on bank holding companies and whether the Tier 1 capital ratio is associated with distress given a bank's proximity to the minimum capital ratio. The following model is used to examine the regulatory pressure hypothesis H_2:

$$\Pr(Dis_{it+1}) = \beta_1 + \beta_2 TCAP_{it} + \beta_3 D_{it} + \beta_4 TCAP_{it} \times D_{it} + \sum_{j=1}^{n} \beta_j Controls_{jit+1} \tag{2}$$

In a subsidiary test, the components of $TCAP_{it}$ are disentangled to examine their association with bank distress. To signify the three sub-components of equity adjustments, leverage, and asset risk, Eq_{it} represents Tier 1 capital to total equity capital. Lev_{it} is equity to assets; it represents 1 minus the liabilities to assets leverage ratio. Therefore the coefficient of Lev_{it} should be interpreted as leverage proceeded by a negative sign. $Safe_{it}$ is total assets to risk-weighted assets and it expresses how safe the bank assets are with respect to the Basel risk weighting. This variable can be viewed as a measure of the risk of bank's assets as defined by the regulators.[12] The subsidiary test is applied to the overall sample and sub-sets of 2003–2006 before the financial crisis and of 2007–2009 during the financial crisis. The following model is employed to investigate the effect of the sub-components of regulatory core capital:

$$\Pr(Dis_{it+1}) = \beta_1 + \beta_2 Eq_{it} + \beta_3 Lev_{it} + \beta_4 Safe_{it} + \beta_5 D_{it} + \beta_6 Eq_{it} \times D_{it} + \beta_7 Lev_{it} \times D_{it} + \beta_8 Safe_{it} \times D_{it} + \sum_{j=1}^{n} \beta_j Controls_{jit+1} \tag{3}$$

In the sample period, a 6% minimum capital ratio is required by regulators for banks to be considered well capitalized. Subsequent to the US plan to apply Basel III requirements, the benchmark of 6% for well capitalization is increased. Therefore, in a follow-on test, alternative ratios, higher than the 6% Tier 1 capital ratio, are used to further examine the association between regulatory capital and bank distress during the financial crisis 2007–2009. We apply the models in Eqs. (2) and (3), where we expect an increasingly significant association as the minimum ratio increases.

5. Sample and data

A sample of US bank holding companies for the period 2003–2009 is used. US bank holding companies started filing their detailed regulatory capital data in 2001. However, the number of failing BHCs for the years of 2001 and 2002 is too few to affect the regression results.[13] The period under consideration continues until the end of 2009, during which BHCs have full annual accounting and regulatory data filings. For purposes of the empirical tests, the classification of the National Bureau of Economic Research (NBER) is used. The NBER classifies the fiscal years 2007, 2008 and 2009 as periods of economic downturn.[14] The accounting and regulatory data are obtained from the annual filing of FR Y-9C reports filed at the US Federal Reserve Bank.[15]

To calculate the annualized standard deviation of equity returns for the BSM measure, daily equity returns and price data are obtained from the Center for Research in Security Prices (CRSP). For the calculation of the market value of asset returns, V_A, the market value of equity returns plus the book value of liabilities is used, consistent with Hillegeist et al. (2004). The risk-free rate on US one-year treasury bills is obtained from the Board of Governors of the Federal Reserve System Economic Research database.[16]

The distress definition used in this paper is broader than the actual liquidation or bankruptcy declaration of bank holding companies. Banks are regulated institutions that receive regulatory support, when in a distressed state, in the form of receivership/conservatorship, arranged mergers and capital infusions to mitigate the cost of failure. Therefore, failure of the BHC may not be a clean event, as in a

[8] Three other controls are employed in lieu of ALL_{it} to proxy for loan quality and the inherent credit risk; (1) the ratio of loan loss provisions to total loans, NCO_{it}, (2) net charge-offs to total loans and (3) NPL_{it}, non-performing loans to total loans. Net charge-offs are flow measure reflecting a BHC's current performance while nonperforming loans is a stock measure indicating the accumulation of poor loans to the BHC's loan portfolio.

[9] The calculation of the BSM default measure is included in Appendix A.

[10] For the main tests, firm-fixed effects and year-fixed effects are used.

[11] The dummy variable is interacted with all controls. The results are not tabulated.

[12] We use an alternative distress measure of the standard deviation of equity returns ($StdEQD_{it+1}$) that is widely used in prior literature (e.g. Avery & Berger, 1991). The specification used in this study is a dummy variable denoting a state of failure if the BHC falls below the sample mean, where $StdEQD_{it+1}$ is a dummy that equals 1 if the standard deviation of annualized daily equity returns of the BHC is less than the sample mean and 0 otherwise for bank holding company i at year $t+1$. There has been an insignificant association between $TCAP_{it}$ and the failure indicator. In a subsidiary test, we focus on the leverage (Lev_{it}) and asset risk ($Safe_{it}$) components of the Tier 1 capital ratio to test the association with volatility of equity returns as an indicator of failure. Similar conclusions are reached.

[13] The sample is limited to the period 2003–2009, for more relevant results. Untabulated descriptive statistics show that the years 2001 and 2002 have very few failing BHCs compared to non-failing ones. This limited discrimination render the use of these observations irrelevant. Further tests suggest that the regression results are robust to the inclusion of observations in 2001 and 2002.

[14] Classification of recessionary/crisis years are based on reports of the National Bureau of Economic Research http://www.nber.org

[15] http://www.chicagofed.org/webpages/banking/financial_institution_reports/bhc_data.cfm

[16] http://www.federalreserve.gov

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Table 1
Failing vs. non-failing sample bank holding companies by year.

Year	Failing	Non-fail	Total
2003	17	448	465
2004	36	416	452
2005	17	399	416
2006	30	368	398
2007	23	346	369
2008	27	316	343
2009	239	79	218
Total	389	2372	2761

Table 2
Descriptive statistics of the decomposed tier 1 capital ratio and BSM default probability — US bank holding companies (2003–2009).

Variables	Mean	Median	Std	Min.	Max.
Dis_{it+1}	0.14	0	0.34	0.00	1.00
$BSMprob_{it}$	0.46	0.42	0.37	0.00	1.00
$BSMLev_{it}$	1.16	1.15	0.69	0.35	20.44
$BSMVol_{it}$	0.24	0.20	0.12	0.07	1.02
$TCAP_{it}$	0.12	0.11	0.06	0.03	0.97
Eq_{it}	0.99	0.98	0.21	0.01	1.00
Lev_{it}	0.09	0.09	0.05	0.04	0.81
$Safe_{it}$	1.39	1.33	0.28	1.01	3.66
$SIZE_{it}$	14.73	14.37	1.66	1.21	22.01
ALL_{it}	0.01	0.01	0.01	0.00	0.43

Dis_{it+1} = a dummy variable that takes the value 1 if the BHC is in distress and 0 otherwise for bank holding company i at year $t+1$, $BSMprob_{it}$ = the default probability from the Hillegeist et al. (2004) BSM model for bank holding company i at year t, $BSMLev_{it}$ = the ratio of market value of assets to book value of liabilities term in the BSM default probability measure where market value of assets is estimated by simultaneously solving the call option equation and the optimal hedge equation as in Hillegeist et al. (2004), $BSMVol_{it}$ = the standard deviation of asset returns estimated by simultaneously solving the call option equation and the optimal hedge equation as in Hillegeist et al. (2004), $TCAP_{it}$ = the ratio of Tier 1 capital to risk-weighted assets, Eq_{it} = the ratio of Tier 1 capital to total equity capital, Lev_{it} = the ratio of equity capital to total book value of assets or 1 – the ratio of liabilities to assets, $Safe_{it}$ = the ratio of assets to risk-weighted assets, $SIZE_{it}$ = natural log of total assets, ALL_{it} = the ratio of allowance for loan losses to total loans.

bankruptcy declaration, to be used in the empirical tests. A distressed bank holding company is defined as a BHC with at least one subsidiary entering into receivership or conservatorship by the FDIC.[17] Although the Federal Deposit Insurance Corporation (FDIC) provides a list of failing banks,[18] this list does not fully cover failures at the bank holding company level. Consequently, each failing bank in the FDIC list is matched with the corresponding bank holding company to denote a state of failure at the parent level. Furthermore, the equity returns of individual bank holding companies are tracked to determine when BHCs cease trading. Additionally, actual failure data of sample BHCs is cross-checked with FRY-9C filings with the Federal Reserve Bank. The failure data from the FDIC failing banks list are validated against trading releases and FRY-9C filings, when applicable. To deal with the possibility that BHCs ceasing to trade or to file regulatory reports is not due to merger and acquisition activities, M&A news are hand collected and tracked for US bank holding companies for the period 2003–2009.[19] Therefore, bank holding companies that cease to provide FRY-9C reports to the Federal Reserve Bank or cease trading, while not having M&A news releases, are classified as failing after validation with the FDIC failed bank list. If the BHC is classified as failing in a specific year due to failure of one or more of its subsidiaries, the entity is dropped from later years of the sample even if it is still trading.

Observations with missing market, accounting, or regulatory data are deleted. Moreover, the BSM data are trimmed at the top and bottom 1% level. Table 1 provides details on the classification of failing and non-failing sample BHCs. The final sample consists of 560 bank holding companies with 2761 bank-year observations for the period 2003–2009.

6. Results

This section presents descriptive statistics of sample bank holding companies and then discusses the results of the logistic regression analyses. It also presents results of robustness tests. Finally, the section concludes with a discussion of wider implications for banking research and regulatory policies.

6.1. Descriptive statistics

Table 2 provides descriptive statistics of the overall sample for the variables of interest. On average, 14% of US BHCs are classified as failing, i.e. either they are placed under the FDIC receivership/conservatorship, or cease trading or stop filing their regulatory reports.[20] The number of distressed BHCs increased noticeably in the later years and dramatically in 2009. The mean Tier 1 capital ratio of sample BHCs is 12% and has shown little variation across the years. To disentangle components of the regulatory Tier 1 capital ratio and how well they measure bank distress, the regulatory ratio is broken down to the multiplicative components of Eq_{it}, Lev_{it} and $Safe_{it}$ to denote equity adjustments, leverage and the asset risk respectively.[21] Likewise, the BSM default probability measure is broken down to its leverage and volatility components; $BSMLev_{it}$ and $BSMVol_{it}$ respectively.[22] Untabulated results provide detailed descriptive statistics of $TCAP_{it}$ based on $SIZE_{it}$ quintile by year and for the overall sample. There is minimal variation in Tier 1 capital ratios between failing and non-failing BHCs across years and within size quintile groups. Relatively small BHCs have better regulatory capitalization as indicated by the larger $TCAP_{it}$, as is consistent with Aggarwal and Jacques (2001). The $BSMprob_{it}$ mean (median) is larger than that of studies using non-financial institution samples. This finding might be attributed to the high leverage of banks compared to non-banking firms.[23] Since leverage is a component used in deriving the measure of the BSM probability of default, the relatively high mean (median) $BSMprob_{it}$ is not surprising.[24] Unreported distribution of $BSMprob_{it}$ shows skewness towards zero probability rather than 1.[25] This result is consistent with the finding of Ronn and Verma (1986)

[17] See Appendix B for more detailed definition of distress/failure and the receivership/conservatorship function of the FDIC.

[18] http://www.fdic.gov

[19] The Online Wall Street Journal is used to get data on M&A news releases. Prior to M&A news validation, there were 437 bank-year failure observations in the sample. The final sample contains 389 bank-year failure observations.

[20] Startling as the proportion of failure may be, US bank failures in this study are based on the failure definition used. Therefore, a failing bank does not necessarily disappear from the sample. For purposes of this study, failing banks are dropped from later years.

[21] $TCAP_{it} = \frac{\text{Tier 1 capital}}{\text{Equity}} \times \frac{\text{Equity}}{\text{Assets}} \times \frac{\text{Assets}}{\text{Risk-weighted assets}} = Eq_{it} \times Lev_{it} \times Safe_{it}$.

[22] It is noted that the leverage component inherent the BSM measure is equal to the market value of assets to book value of liabilities, i.e. the reciprocal of leverage. Therefore, it is expected to find $BSMLev_{it}$ and Lev_{it} positively related.

[23] In alternative tests, the BSM probability control is taken out as it includes a leverage component that might affect the results. Unreported results show slight increase in the Wald statistic of the coefficient on $TCAP_{it}$ however it is still not significant at conventional levels.

[24] As a validation check of the methodology used in this paper to compute the $BSMprob_{it}$ variable, a replication to Hillegeist et al. (2004) was performed for a sample of US non-financial institutions over the period 2003–2009 to examine whether the large magnitude of the variable persists compared to prior literature. Similar results to Hillegeist et al. (2004) were obtained validating the results of the methodology used in this paper to compute $BSMprob_{it}$ for sample US BHCs.

[25] Two other specifications of the market-based default measure are employed to deal with potential skewness of the probability of default data. Rather than the raw probability of default ($BSMprob_{it}$), $BSMscore_{it}$ is used as the log of the proportion of the probability of default to one minus the probability of default. We also employ the annual percentile rank of the probability of default $BSMpct_{it}$. Both alternative control measures produce similar empirical results.

Table 3
Pearson (above diagonal) and Spearman (below diagonal) correlation analysis of the decomposed tier 1 capital ratio and BSM default probability — US bank holding companies (2003–2009).

Variable	Dis_{it+1}	$BSMprob_{it}$	$BSMLev_{it}$	$BSMVol_{it}$	$TCAP_{it}$	Eq_{it}	Lev_{it}	$Safe_{it}$	$SIZE_{it}$	ALL_{it}
Dis_{it+1}		0.1370	−0.0231	0.1975	−0.0062	−0.0309	−0.0068	−0.0122	−0.0370	0.2390
		(<0.0001)	(0.2021)	(<0.0001)	(0.7356)	(0.0873)	(0.7066)	(0.4998)	(0.0438)	(<0.0001)
$BSMprob_{it}$	0.1367		0.0997	0.4409	−0.1579	−0.0201	−0.1454	−0.0494	−0.0299	−0.0338
	(<0.0001)		(<0.0001)	(<0.0001)	(<0.0001)	(0.2675)	(<0.0001)	(0.0064)	(0.0989)	(0.0617)
$BSMLev_{it}$	−0.1308	0.1283		−0.1463	0.6695	−0.0892	0.6938	0.0549	0.0476	0.0373
	(<0.0001)	(<0.0001)		(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)	(0.0021)	(0.0086)	(0.0365)
$BSMVol_{it}$	0.2012	0.4058	−0.3904		−0.1962	0.1714	−0.2038	−0.1040	−0.1979	−0.1867
	(<0.0001)	(<0.0001)	(<0.0001)		(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)
$TCAP_{it}$	−0.0050	−0.2155	0.0488	−0.0714		0.0356	0.8125	0.3038	−0.0957	−0.1050
	(0.7855)	(<0.0001)	(0.0071)	(<0.0001)		(0.0493)	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)
Eq_{it}	−0.0329	−0.0571	−0.2727	0.1812	0.0382		−0.3564	−0.0510	−0.3835	0.0398
	(0.0773)	(0.0016)	(<0.0001)	(<0.0001)	(0.0352)		(<0.0001)	(0.0043)	(<0.0001)	(0.0258)
Lev_{it}	−0.0177	−0.1709	0.3048	−0.1540	0.2845	−0.6170		0.0228	0.0397	−0.0489
	(0.3284)	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)		(0.2017)	(0.0282)	(0.0061)
$Safe_{it}$	−0.0008	−0.3583	0.0700	−0.1405	0.3583	−0.1191	0.0824		0.0155	0.1424
	(0.9629)	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)		(0.3938)	(<0.0001)
$SIZE_{it}$	−0.0404	−0.0120	0.2900	−0.1914	−0.2000	−0.3593	0.0574	0.0545		0.0720
	(0.0277)	(0.5077)	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)	(0.0015)	(0.0026)		(<0.0001)
ALL_{it}	0.1621	−0.0225	0.1049	−0.1336	−0.0946	0.2667	−0.0503	0.1136	0.0825	
	(<0.0001)	(0.2152)	(<0.0001)	(<0.0001)	(<0.0001)	(0.1353)	(0.0048)	(<0.0001)	(<0.0001)	

(P-values in parentheses).

Dis_{it+1} = a dummy variable that takes the value 1 if the BHC is in distress and 0 otherwise for bank holding company i at year $t+1$, $BSMprob_{it}$ = the default probability from the Hillegeist et al. (2004) BSM model for bank holding company i at year t, $BSMLev_{it}$ = the ratio of market value of assets to book value of liabilities term in the BSM default probability measure where market value of assets is estimated by simultaneously solving the call option equation and the optimal hedge equation as in Hillegeist et al. (2004), $BSMVol_{it}$ = the standard deviation of asset returns estimated by simultaneously solving the call option equation and the optimal hedge equation as in Hillegeist et al. (2004), $TCAP_{it}$ = the ratio of Tier 1 capital to risk-weighted assets, Eq_{it} = the ratio of Tier 1 capital to total equity capital, Lev_{it} = the ratio of equity capital to total book value of assets or 1 − the ratio of liabilities to assets, $Safe_{it}$ = the ratio of assets to risk-weighted assets, $SIZE_{it}$ = natural log of total assets, ALL_{it} = the ratio of allowance for loan losses to total loans.

that a majority of safe banks with a flat deposit premium subsidize risky banks.[26]

The Pearson and Spearman correlation coefficients of the variables are presented in Table 3. Results are similar to those of earliers literature. The Tier 1 capital ratio is insignificantly negatively correlated with the distress indicator. From the correlations between Tier 1 capital components and the probability of distress, we can see that these components are insignificantly associated with failure. This finding provides a preliminary analysis of the relation between the regulatory ratio and bank failure. The association is sustained when accounting for individual sub-components of the regulatory ratio.

An interesting finding in Table 3 is that, although $TCAP_{it}$ is insignificantly associated with failure in contrast to the market-based $BSMprob_{it}$ measure, the leverage components of $BSMLev_{it}$ and Lev_{it} are correlated with a Pearson (Spearman) coefficient of 0.69 (0.30) significant at the 1% level. Likewise, the volatility/risk components $BSMVol_{it}$ and $Safe_{it}$ are significantly correlated at the 1% level with a relatively low Pearson (Spearman) coefficient of −0.10 (−0.14).[27] These findings suggest that a potential cause of the regulatory measure having an insignificant association with failure relative to the market-based measure is that the former does not account for the expected growth in asset values relative to asset volatility.

The volatility component of the BSM measure, $BSMVol_{it}$, is a significant variable in bankruptcy prediction. Thus, it reflects the probability that the value of BHC's assets decline to the extent that the BHC is unable to repay its depositors and other creditors. The univariate results reported in Table 3 confirm that conjecture. One unit increase in the standard deviation of asset returns increases the probability of BHC failure by approximately 20%. We control for such significant component included in the $BSMprob_{it}$ measure that captures an element of default risk.

As Table 3 shows, the three sub-components of the Tier 1 capital ratio are negatively correlated with the probability of distress. Other controls are significantly correlated with failure.

6.2. Univariate results

Table 4 presents the frequency distribution of failing and non-failing BHCs based on their regulatory capitalization. The purpose of this preliminary test is to explore whether there is a significant association between Tier 1 capital ratio in one period and failure of BHCs in the subsequent period.[28] The first panel of Table 4 shows that 55% of all BHCs are above the 6% regulatory threshold of well-capitalized banks. The frequency distribution suggests that the relation between the level of regulatory capital ratio and distress is more pronounced for the failing BHCs sub-sample. Therefore, the univariate tests provide preliminary support for the preposition of hypothesis H_1 and motivate a more refined test. Moreover, the more pronounced relation between Tier 1 capital ratio and distress, taking into account whether the bank falls above (below) the 6% threshold, suggests the need for further tests. A chi-square test reveals a significant association at the 1% level between failure and regulatory capital ratio for regulatory capital-constrained BHCs. In panels B, C and D alternative regulatory capitalization thresholds of 8%, 10% and 12% Tier 1 capital ratio are used. The results are accentuated as the regulatory threshold is increased as evidenced by chi-square tests.

[26] The $BSMprob_{it}$ statistics are distinguished from the indicator of distress used in this study. As the coefficient of the $BSMprob_{it}$ is as three times as that of F_{it+1}, the BSM measure is scaled to force its mean to equal that of the actual probability of failure variable. Therefore, in the logistic regression tests, $BSMprob_{it}$ is multiplied by 0.14/0.46. The direction of the association in the regression models and the significance of coefficients are sustained after scaling the BSM probability of default measure.

[27] The negative coefficient is due to the $Safe_{it}$ measure reflecting the ratio of assets to risk-weighted assets. Therefore, the higher the ratio is, the lower the degree of risk in the asset portfolio.

[28] A frequency distribution by year for the benchmark base case of 6% is introduced in Appendix C. The results suggest a negative association between tier 1 capital ratio and bank failure.

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Table 4
Tier 1 capital ratio benchmarks and failure frequency distribution of sample US bank holding companies (2003–2009).*, **

$TCAP_{it}$	Fail	Non-fail	Total
Panel A: phased-out 6% benchmark			
Above 6%§	175 (6%)	1341 (49%)	1516 (55%)
Below 6%	214 (8%)	1031 (37%)	1245 (45%)
Total bank-year obs	389 (14%)	2372 (86%)	2761 (100%)
X^2 statistic (df = 1)	18.00***		
Panel B: 8% benchmark			
Above 8%§	145 (5%)	1345 (49%)	1490 (54%)
Below 8%	244 (9%)	1027 (37%)	1271 (46%)
Total bank-year obs	389 (14%)	2372 (86%)	2761 (100%)
X^2 statistic (df = 1)	45.50***		
Panel C: 10% benchmark			
Above 10%§	60 (2%)	1375 (50%)	1435 (52%)
Below 10%	329 (12%)	997 (36%)	1326 (48%)
Total bank-year obs	389 (14%)	2372 (86%)	2761 (100%)
X^2 statistic (df = 1)	242.33***		
Panel D: 12% benchmark			
Above 12%§	9 (0.02%)	1385 (50%)	1394 (50%)
Below 12%	380 (13.8%)	987 (36%)	1367 (50%)
Total bank-year obs	389 (14%)	2372 (86%)	2761 (100%)
X^2 statistic (df = 1)	420.39***		

$TCAP_{it}$ = the ratio of Tier 1 capital to risk-weighted assets for bank holding company *i* at year *t*.
* Represent two-tailed significance at the 10% level.
** Represent two-tailed significance at the 5% level.
*** Represent two-tailed significance at the 1% level.
§ Well-capitalization benchmark is the regulatory minimum Tier 1 capital to risk-weighted assets ratio for BHCs.

Table 5
Logistic regression of regulatory capital and distress for sample US bank holding companies.

$$\text{Model (1)}: Pr(Dis_{it+1}) = \beta_1 + \beta_2 TCAP_{it} + \sum_{j=1}^{n} \beta_j Controls_{jit+1}$$

Model	Prediction	2003–2009	2003–2006	2007–2009
Intercept	+/−	−0.96 (2.7***)	−0.89 (2.1**)	−0.72 (1.1)
$TCAP_{it}$	-	−0.26 (0.1)	−0.28 (0.3)	−0.21 (0.1)
$BSMprob_{it}$	+	1.11 (16.7***)	1.17 (18.1***)	1.19 (18.9***)
$SIZE_{it}$	-	−0.12 (8.9***)	−0.12 (7.1***)	−0.12 (9.1***)
ALL_{it}	+	22.56 (19.6***)	20.16 (12.8***)	23.06 (12.8***)
Log likelihood		199.2***	198.7***	190.1***
No. of obs Fail = 1		389	100	289
No. of obs Fail = 0		2372	1631	741

(Wald χ^2 are in parentheses).
*, **, and *** represent significance at the 10%, 5% and 1% level respectively. Significance is one-tailed unless the sign of the coefficient is indeterminate.
The dependent variable coefficients are log-odds of failure.
Unreported coefficients of interacting dummies with the control variables are significant at conventional levels.
$Pr(Dis_{it+1})$ = is a latent variable representing the probability of failure. It is expressed as a dummy variable that takes the value 1 if the BHC is in distress and 0 otherwise for bank holding company *i* at year *t* + 1, $TCAP_{it}$ = the ratio of Tier 1 capital to risk-weighted assets for bank holding company *i* at year *t*, $BSMprob_{it}$ = the default probability from the Hillegeist et al. (2004) BSM model, $SIZE_{it}$ = natural log of total assets, ALL_{it} = the ratio of allowance for loan losses to total loans.

6.3. Regression results

Table 5 reports the logistic regression models that test hypotheses H_1, while Table 6 provide results examining H_2 for the total sample interval from 2003 to 2009. In Table 6, the columns, from left to right, present coefficient estimates of the explanatory variable for Models (1) and (2) for (i) the total Tier 1 capital ratio, (ii) the equity-adjustment element of the Tier 1 capital ratio, (iii) the leverage element of the Tier 1 capital ratio, and (iv) the asset-risk element of the Tier 1 capital ratio.

As apparent in Table 5, the Tier 1 capital ratio is negatively associated with distress. However, the association is not statistically significant. The BSM probability of default measure is significantly associated with distress in the overall sample, pre-crisis, and financial crisis periods.

The results for Model (1) in Table 6 show that the association between the total Tier 1 capital ratio and the probability of distress is negative but not significant. This result is expected given the descriptive statistics of Table 2 that show a relatively low standard deviation of 0.06 for $TCAP_{it}$ and prior literature suggesting that banks smooth Tier 1 capital to keep it at stable levels (Berger, DeYoung, Flannery, Lee, & Öztekin, 2008). As expected, the market-based probability of default, $BSMprob_{it}$, is significantly associated with failure. Furthermore, bank holding companies that have larger probability of failure tend to be of smaller size and allow more for loan losses. Overall, the regression results support the preliminary univariate analysis provided in Table 4.

Model (2) includes an interaction term ($TCAP_{it} \times D_{it}$) for which the coefficient measures the excess of (i) the coefficient on the Tier 1 capital ratio in the range 4% to 6% over (ii) the coefficient on the Tier 1 capital ratio above 6%. The coefficient on $TCAP_{it}$ (−0.46) is negative and not statistically different from zero, and the coefficient on $TCAP_{it} \times D_{it}$ (−24.46) is negative and significant. This indicates that, above (below) the well-capitalized threshold of 6%, there is no significant association (there is significant association) between the Tier 1 capital ratio and the probability of distress.[29]

As further examination of hypothesis H_2, the results of model (2) across Table 6 show that the Tier 1 capital ratio is insignificantly associated with failure. However, the association is significant only for BHCs hitting the regulatory minimum Tier 1 capital ratio. Unreported coefficients of interacting D_{it} with all controls are statistically significant at conventional levels. The results do not change when the dummy variable is interacted with all the controls. The Tier 1 capital ratio is decomposed to signify equity adjustments (Eq_{it}), leverage (Lev_{it}), and risk ($Safe_{it}$), respectively. The interaction of Eq_{it} and the capital-constraint dummy proves insignificant in association with failure. Contrarily, Lev_{it} and $Safe_{it}$ are significant in association with failure after interaction with the capital-constraint dummy. This result sheds light on two strategies capital-constrained banks might use to mitigate failure; namely managing leverage and asset portfolio risk. All in all, the results in Table 6 provide evidence that support hypothesis H_2. The results also provide evidence on the importance of Tier 1 capital ratio as an indicator of failure only for those BHCs having a Tier 1 capital ratio in the range below 6%.

In a follow-on test, regulatory minimum capital ratios are set at successively increasing thresholds, in an attempt to determine the ratio at which the association is significant during the financial crisis period. The sample is divided into subsamples of BHCs having regulatory capital ratios falling below the minimum ratio and those having regulatory capital ratios above the minimum ratio. Table 7 summarizes the results. Using the benchmark of 6% produces insignificant results for the interaction term $TCAP_{it} \times D_{it}$. However, when the regulatory capital threshold

[29] The sample is divided according to whether bank holding companies fall above (below) the regulatory capital threshold and perform alternative regression tests without incorporating the dummy variable and the results are sustained.

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Table 6
Logistic regression of regulatory capital ratio (components) and distress for sample US bank holding companies.

$$\text{Model (2)}: \Pr(Dis_{it+1}) = \beta_1 + \beta_2 TCAP_{it} + \beta_3 D_{it} + \beta_4 TCAP_{it} \times D_{it} + \sum_{j=1}^{n} \beta_j Controls_{jit+1}$$

$$\text{Model (3)}: \Pr(Dis_{it+1}) = \beta_1 + \beta_2 Eq_{it} + \beta_3 Lev_{it} + \beta_4 Safe_{it} + \beta_5 D_{it} + \beta_6 Eq_{it} \times D_{it} + \beta_7 Lev_{it} \times D_{it} + \beta_8 Safe_{it} \times D_{it} + \sum_{j=1}^{n} \beta_j Controls_{jit+1}$$

Model	Prediction	2003–2009		2003–2006		**2007–2009**	
		Model (1)	Model (2)	Model (1)	Model (2)	Model (1)	Model (2)
Intercept	+/−	−0.87 (2.2**)	−0.97 (2.3**)	−0.73 (1.1)	−0.74 (2.1**)	−0.16 (0.1)	−0.09 (1.7*)
$TCAP_{it}$	−	−0.46 (0.2)		−0.41 (0.3)		−1.55 (1.2)	
Eq_{it}	+/−		−0.2 (0.1)		−0.2 (0.1)		−0.1 (0.1)
Lev_{it}	−		−0.23 (0.1)		−0.12 (0.1)		−1.10 (0.3)
$Safe_{it}$	−		−0.11 (0.3)		−0.09 (0.2)		−0.12 (0.4)
D_{it}	+	0.29 (0.5)	1.83 (3.1***)	0.23 (0.3)	1.61 (2.8***)	0.36 (1.7*)	1.92 (3.4***)
$TCAP_{it} \times D_{it}$	−	−24.46 (3.8***)		−17.3 (2.9***)		−14.56 (1.1)	
$Eq_{it} \times D_{it}$	+/−		−0.82 (0.6)		−0.51 (0.5)		−0.22 (0.4)
$Lev_{it} \times D_{it}$	−		−11.21 (3.4***)		−10.12 (3.1***)		−13.3 (1.3)
$Safe_{it} \times D_{it}$	−		−3.19 (2.6***)		−3.41 (2.7***)		−2.23 (1.2)
$BSMprob_{it}$	+	1.13 (17.4***)	1.10 (14.1***)	1.08 (13.5***)	1.01 (10.4***)	1.40 (15.3***)	1.17 (9.4***)
$SIZE_{it}$	−	−0.12 (9.4***)	−0.12 (7.1***)	−0.10 (8.2***)	−0.11 (6.2***)	−0.19 (11.7***)	−0.11 (7.3***)
ALL_{it}	+	24.00 (13.6***)	13.82 (10.2***)	21.07 (12.3***)	8.83 (7.4***)	31.18 (18.5***)	9.10 (11.2***)
Log likelihood		205.6***	211.10***	205.1***	214.67***	119.85***	204.07***
No. of obs Fail = 1		389		100		289	
No. of obs Fail = 0		2372		1631		741	

(Wald χ^2 are in parentheses).
*, **, and *** represent significance at the 10%, 5% and 1% level respectively. Significance is one-tailed unless the sign of the coefficient is indeterminate.
The dependent variable coefficients are log-odds of failure.
Unreported coefficients of interacting dummies with the control variables are significant at conventional levels.
$\Pr(Dis_{it+1})$ = is a latent variable representing the probability of failure. It is expressed as a dummy variable that takes the value 1 if the BHC is in distress and 0 otherwise for bank holding company i at year $t+1$, $TCAP_{it}$ = the ratio of Tier 1 capital to risk-weighted assets for bank holding company i at year t, D_{it} = a dummy variable that equals 1 if the Tier 1 capital to risk-weighted assets ratio of the BHC is below 6% and zero otherwise, Eq_{it} = the ratio of Tier 1 capital to total equity capital for bank holding company i at year t, Lev_{it} = the ratio of equity capital to total book value of assets or 1 – the ratio of liabilities to assets, $Safe_{it}$ = the ratio of assets to risk-weighted assets, $BSMprob_{it}$ = the default probability from the Hillegeist et al. (2004) BSM model, $SIZE_{it}$ = natural log of total assets, ALL_{it} = the ratio of allowance for loan losses to total loans.

is increased to 8% or above, the association between regulatory capitalization and failure is marginally significant.[30]

6.4. Implications

Prior research provides evidence on the association between bank risk taking and regulation. However, it describes the association between regulation and bank failure as ambiguous. Consequently, the regulatory capital constraint that banks face, upon being close to minimum capital requirements, provides a significant factor that enhances the association with bank distress.

The findings of the paper are relevant to bank regulators setting stringent capital adequacy requirements and to future research efforts in the area of bank performance and default risk. The capital adequacy ratio may not form a good indicator of failure in such studies. A high Tier 1 capital ratio should not be taken as a significant indicator of financial health simply because it surpasses a capitalization benchmark.

As US bank regulators are phasing in Basel III, the final rule sets new minimum thresholds of Tier 1 capital ratios. A follow-on empirical validation test examines associations when using the regulatory capital ratios of 6% or above in the period of financial turmoil of 2007–2009. Results suggest that increasing the Tier 1 capital ratio provides significant association with failure, which increases the relevance of capital adequacy ratios during economic bust. Contrarily, during the period 2007–2008, where non-failing BHCs constitute a large percentage of the sample, the findings are not sustained. Hence, bank regulators should consider validating the regulatory benchmark for banks to be considered well capitalized, especially in periods of economic turmoil when the financial health of banks is at stake.

Furthermore, the current findings urge for the consideration of other more relevant controls by banks regulators. This is in line with the evidence provided in Werner (2014) confirming that banks create money supply. Hence, merely imposing higher regulatory capital requirements during bust periods will not be as effective in isolation from other measures. Banks will always be able to raise their capital ratios by providing credit, which will fuel asset prices and exacerbate the procyclicality involved.

7. Conclusion

One of the aims of banking regulation is to preclude bank failure. This is due to the importance of the banking system resilience in sustaining economic growth. This paper examines whether the minimum capital ratios required by bank regulators are associated with bank distress. More specifically, we investigate the association between the regulatory Tier 1 capital ratio and US bank holding company distress during 2003–2009. The results show that Tier 1 capital ratio is insignificantly negatively associated with bank distress. However, the association is significant when bank holding companies fall below the well-capitalization ratio of 6%. In a subsidiary test, findings show that although the components of the Tier 1 capital ratio signifying equity adjustments, leverage and risk are insignificantly associated with bank distress, the association is significant when banks hit the 6% ratio.

Further tests show that the Tier 1 capital ratio is insignificant in association with distress if the bank holding company is well capitalized. The regulatory capital is associated with bank distress only when banks have below 6% Tier 1 capital ratio i.e. without hitting the critical threshold, below which they are placed into receivership/conservatorship. This result is expected as regulatory-capital-constrained banks are faced with significant direct and indirect sanctions if they do not meet

[30] In unreported test, the sample is further broken down to year 2009 and the period 2007–2008. It is expected that the results are driven by observations of 2009 where the number of failing BHCs exceeds that of non-failing BHCs. The results of Table 7 are sustained. For the period 2007–2008, unlike year 2009, all regulatory benchmarks, including the 6% benchmark, are statistically significant in association with failure.

Table 7
Summary of statistical significance results of regulatory capital and distress for sample US bank holding companies during financial crisis period 2007–2009.

Panel A: tier 1 capital ratio

Model (2): $Pr(Dis_{it+1}) = \beta_1 + \beta_2 TCAP_{it} + \beta_3 D_{it} + \beta_4 TCAP_{it} \times D_{it} + \sum_{j=1}^{n} \beta_j Controls_{jit+1}$

Regulatory tier 1 capital ratio	Sample < the minimum ratio $TCAP_{it} \times D_{it}$ significant?	Sample ≥ the minimum ratio $TCAP_{it} \times D_{it}$ significant?
6%		
6.5%		
7%		
7.5%		
8%	✓	
8.5%	✓	
9%	✓	
9.5%	✓	
10%	✓	
10.5%	✓	
11%	✓	
11.5%	✓	
12%	✓	

Panel B: components of tier 1 capital ratio

Model (3): , $Pr(Dis_{it+1}) = \beta_1 + \beta_2 Eq_{it} + \beta_3 Lev_{it} + \beta_4 Safe_{it} + \beta_5 D_{it} + \beta_6 Eq_{it} \times D_{it} + \beta_7 Lev_{it} \times D_{it} + \beta_8 Safe_{it} \times D_{it} + \sum_{j=1}^{n} \beta_j Controls_{jit+1}$

Components of regulatory tier 1 capital ratio	Equity Adjustments		Leverage		Asset Risk	
	Sample < the minimum ratio $Eq_{it} \times D_{it}$ significant?	Sample ≥ the minimum ratio $Eq_{it} \times D_{it}$ significant?	Sample < the minimum ratio $Lev_{it} \times D_{it}$ significant?	Sample ≥ the minimum ratio $Lev_{it} \times D_{it}$ significant?	Sample < the minimum ratio $Safe_{it} \times D_{it}$ significant?	Sample ≥ the minimum ratio $Safe_{it} \times D_{it}$ significant?
6%						
6.5%						
7%						
7.5%						
8%			✓		✓	
8.5%			✓		✓	
9%			✓		✓	
9.5%			✓		✓	
10%			✓		✓	
10.5%			✓		✓	
11%			✓		✓	
11.5%			✓		✓	
12%			✓		✓	

For all thresholds, the coefficients on all terms referred to above are negative. A tick (✓) indicates that the coefficient is significant at conventional levels.
$Pr(Dis_{it+1})$ = is a latent variable representing the probability of failure. It is expressed as a dummy variable that takes the value 1 if the BHC is in distress and 0 otherwise for bank holding company *i* at year *t* + 1, $TCAP_{it}$ = the ratio of Tier 1 capital to risk-weighted assets for bank holding company *i* at year *t*, D_{it} = a dummy variable that equals 1 if the Tier 1 capital to risk-weighted assets ratio of the BHC is below 6% and zero otherwise, Eq_{it} = the ratio of Tier 1 capital to total equity capital for bank holding company *i* at year *t*, Lev_{it} = the ratio of equity capital to total book value of assets or 1 – the ratio of liabilities to assets, $Safe_{it}$ = the ratio of assets to risk-weighted assets, $BSMprob_{it}$ = the default probability from the Hillegeist et al. (2004) BSM model, $SIZE_{it}$ = natural log of total assets, ALL_{it} = the ratio of allowance for loan losses to total loans.

regulatory minimum requirements. On the other hand, well-capitalized banks may face lower pressure to mitigate distress even upon a significant reduction in their Tier 1 capital ratios. Additionally, the association between regulatory capital ratios and bank distress differs in the period of the financial crisis of 2007–2009.

To conclude, this paper shows that the regulatory capital is not the only reason banks are put into distress. There are other significant reasons that need to be accounted for. Market-based default probability measures and bank-specific characteristics like size and the loan provisioning all prove relatively more significant in association with bank distress. This finding is sensitive to the degree of bank regulatory capitalization. Resilience of the banking sector can be enhanced by enhancing regulatory capital in terms of quantity and quality. With regards to the former, higher minimum capital ratios and more stringent definitions of capital are essential. However, these measures need to be coupled with the latter, namely, enhancing the quality of capital requirements. Tighter regulations on transactions that do not create real assets or add to GDP may prove essential. The results of this paper should be taken in perspective of the credit creation function of banks (Werner, 2014). Accordingly, banks can create money out of 'thin air'. Hence, the mere increase of regulatory capital requirements is not adequate.

Basel III regulations have increased capital and liquidity which resulted in a substantial lower probability of a crisis event. However, the desired level of bank equity capital is larger than what banks have used in recent years and the targets set by the Basel III framework (Miles, Yang, & Marcheggiano, 2011). Furthermore, the highly stringent regulations may reduce the competition for existing banks while place high entry barriers for new banks. This may cause disruption to the supply of credit to the economy and the growth rate of the economy over the long run (Allen, Chan, Milne, & Thomas, 2012). This is beyond the scope of this paper, but suggests interesting venues for future research.

Future research is needed to explore other circumstances when the regulatory capital proves significant in association with default risk. Research on the association between regulatory capital and risk-taking behavior has been progressing. However, the association between regulatory capital and failure has been described in prior research as being ambiguous. More efforts are needed to clear out such ambiguity with respect to small banks as opposed to those that are too-big-to-fail. It is crucial to provide empirical results with a regulatory policy focus.

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Appendix A. Calculating the BSM Market-based Default Measure

Hillegeist et al. (2004) adapt the Black–Scholes–Merton option pricing model that values equity, V_E, as a European call option on the value of assets

$$V_E = V_A e^{-\delta T} N(d_1) - L e^{-rT} N(d_2) + \left(1 - e^{-\delta T}\right) V_A \tag{1.a}$$

where V_E and V_A denote the current market value of equity and the market value of assets respectively, L is the value of liabilities maturing at time T, r is the continuously compounded risk-free rate of return, δ is the continuous dividend rate expressed in terms of V_A [31]and $N(.)$ is the cumulative density function of the standard normal distribution d_1 and d_2 respectively, and

$$d_1 = \frac{\ln[V_A/L] + \left(r - \delta + \left(\sigma_A^2/2\right)\right)T}{\sigma_A \sqrt{T}} \tag{1.b}$$

and

$$d_2 = d_1 - \sigma_A \sqrt{T} = \frac{\ln[V_A/L] + \left(r - \delta - \left(\sigma_A^2/2\right)\right)T}{\sigma_A \sqrt{T}} \tag{1.c}$$

where σ_A is the standard deviation of asset returns.

The default probability derived in Hillegeist et al. (2004) is

$$BSMprob = N\left(-\frac{\ln(V_A/L) + \left(\mu - \delta - \left(\sigma_A^2/2\right)T\right)}{\sigma_A \sqrt{T}}\right) \tag{1.d}$$

where μ is the continuously compounded expected rate of return on assets, which is used in lieu of the risk-free rate r as the default probability is based upon the actual distribution of future asset values rather than the risk free-rate.

Hillegeist et al. (2004) find the BSM default probability measure more superior than other standard accounting-based measures in predicting bankruptcy. This finding might be due to using market-based rather than the lagging accounting data and the fact that the BSM measure accounts for both the leverage and volatility components; where $\ln(V_A/L)$ represents leverage of assets over liabilities plus $(\mu - \delta - (\sigma_A^2/2))$ an expected asset growth term and $\sigma_A \sqrt{T}$ represents volatility of asset returns.

Appendix B. Distress definition and the receivership/conservatorship Function of the FDIC

B.1. Distress definition

The distress notion used in this study is more fundamental than the failure definition used by the Federal Deposit Insurance Corporation (FDIC). The FDIC defines a failing bank as one that is unable to meet its obligations to depositors and other parties.[32] The nature of banks does not allow for following the normal bankruptcy filing procedures of failing non-banks. For banks insured by the FDIC, including banks chartered by the federal government as well as most banks chartered by the state governments, the FDIC acts as a receiver or conservator in the event of failure to protect depositors' funds. In this study, a failing bank holding company is defined as one that fails at the parent level or has one or more failing subsidiaries. Therefore, the wider notion of distress is used to describe the unclean event of failure.

[31] δ is the continuous common and preferred dividend rate expressed in terms of V_A.

[32] http://www.fdic.gov

B.2. The FDIC Receivership/Conservatorship Function

Upon bank failure, the FDIC is typically appointed as a receiver or conservator for the purpose of administering that bank's assets and liabilities. The appointment is determined by the state or federal regulatory agency according to the charter of the failing bank. If the FDIC is appointed as a receiver, it has powers to allow or disallow claims, repudiate any burdensome contract, expedite the liquidation process for failing banks and merge the failing bank with another insured financial institution. In exercising these powers, the aim of the FDIC is to maximize the return on assets of failing banks. On the other hand, if the FDIC acts as a conservator, it operates the bank for a specific period with the objective of returning it to a sound and solvent institution. The aim is to preserve operations of the bank as a "going concern" through remaining under the supervision of the respective state or federal regulatory agency. As in the receivership function, the FDIC also has powers to repudiate or disaffirm contracts such as leases and securitizations. However, it may choose not to do so if this is for the benefit of the bank operations (Federal Deposit Insurance Corporation, 2003).

Appendix C. By-year classification of the base case of 6% benchmark tier 1 capital ratio and failure frequency distribution of sample US bank holding companies (2003–2009)

Year	$TCAP_{it}$	Fail	Non-Fail	Total
2003	Above 6%	6 (35%)	229 (51%)	235 (51%)
	Below 6%	11 (65%)	219 (49%)	230 (49%)
2004	Above 6%	13 (36%)	216 (52%)	229 (51%)
	Below 6%	23 (64%)	200 (48%)	223 (49%)
2005	Above 6%	6 (35%)	236 (59%)	242 (58%)
	Below 6%	11 (65%)	163 (41%)	174 (42%)
2006	Above 6%	9 (30%)	201 (55%)	210 (53%)
	Below 6%	21 (70%)	167 (45%)	188 (47%)
2007	Above 6%	10 (43%)	224 (65%)	234 (63%)
	Below 6%	13 (57%)	122 (35%)	135 (37%)
2008	Above 6%	8 (30%)	209 (66%)	217 (49%)
	Below 6%	19 (70%)	107 (34%)	226 (51%)
2009	Above 6%	70 (29%)	50 (63%)	120 (38%)
	Below 6%	169 (71%)	29 (37%)	198 (62%)
Total Bank-Year Obs		389 (14%)	2372 (86%)	2761 (100%)

[§]Well-capitalization benchmark is the regulatory minimum Tier 1 capital to risk-weighted assets ratio for BHCs.
$TCAP_{it}$ = the ratio of Tier 1 capital to risk-weighted assets for bank holding company i at year t.

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