Bank equity risk*

Jens Dick-Nielsen, Zhuolu Gao, David Lando

First version September 18, 2022. This version February 1, 2023

Abstract

Financial regulation has led banks to increase their equity ratios. Yet, several studies find that this has not led to a decrease in bank equity risk. We show theoretically, that keeping less capital in excess of the minimum capital requirement can outweigh the risk-reducing effect on equity of increased total capitalization. Empirically, we find that excess capitalization is a significant determinant of equity risk, and can explain why bank equity risk has not become lower after the Great Financial Crisis. Smaller excess capitalization also leads to decreases in market-to-book ratios. Lower leverage has, however, reduced the cost of bank debt.

*We are grateful for helpful comments from Thomas Eisenbach, Peter van Tassel, our discussant Jens Forssbaeck and seminar participants at Aalto, Copenhagen Business School, New York Fed, Swedish House of Finance.

1 Introduction

Financial regulation in response to the Great Financial Crisis (GFC) has led to an increase in the amount of capital held by banks and to a decrease in their leverage ratios. For US banks, for example, the average Tier 1 capital ratio in the period 1995-2006, was in the range between 9 and 10 percent, whereas the level has been between 13 and 15 percent in the period after 2013, see Figure 1. Standard financial theory suggests that such changes would imply that bank equity should become less volatile. Yet several studies have noted (see for example Basten and Sánchez Serrano (2019), Chousakos and Gorton (2017), Salas-Pérez (2018), Sarin and Summers (2016)), that, if anything, the opposite seems to hold true: Bank equity is at least as volatile now as before the GFC. We argue in this paper, that *excess* capital as opposed to *total* capital is a critical determinant of bank equity risk. A smaller excess capitalization increases equity volatility, and this dominates the effect of having a higher total capitalization. As illustrated in Figure 2, while the capitalization of the banks in our sample has increased, the *excess* capitalization has in fact decreased. The tendency holds also for the very largest banks, i.e., the 8 US GSIBs.

In a standard Merton model, an increase in equity corresponds to a decrease in the amount of debt relative to total asset value, and this will inevitably lead to lower equity volatility. Therefore, we would normally associate an increased capital requirement with lower equity risk. We present a simple model with a regulatory default boundary which is determined from the total debt, the risk density of assets, and the capital ratio set by regulation. The separation of the default boundary from the face value of debt allows us to accommodate several important features: Banks with higher capitalization need not have lower equity volatility since the proximity to the regulatory boundary is an important determinant of equity volatility, and it may dominate the effect of increased capitalization. Our model is a simple extension of Merton (1974) similar in spirit to Black and Cox (1976), but without the continuous default boundary. Furthermore, we link our default boundary explicitly to risk-weighted assets (the risk density) and the capital requirement. This results in a distance from the regulatory boundary which is similar to the distance-to-capital measure used in Chan-Lau and Sy (2007).

A possible explanation for the decline in excess capitalization is that banks deliberately keep equity risk constant engaging in a type of risk compensation. As a colorful analogue, recall the quote by skydiving icon Bill Booth: “The safer skydiving gear becomes, the more chances skydivers will take, in order to keep the fatality rate constant.” Whether the fact that equity risk is still high indicates that the fatality rate of banks will remain constant despite the stricter capital regulation remains to be seen. It is well known that banks voluntarily hold capital in excess of their minimum capital requirements. This is evident from casual inspection of annual reports, and has been documented in, for example Berger et al. (2008) who found that the large BHCs in the US in 2006 had a Tier 1 capital that exceeded the requirement for being ‘well-capitalized’ by 5.27%. Berger et al. (2008) argue, that BHCs actively manage their capital ratios by setting a target capital ratio, which is affected by the size, franchise value, and market-to-book ratio. Whenever banks deviate from their target capital ratio, they gradually adjust their capital ratio, but the speed varies between banks, and depends, among other characteristics, on whether the bank is below or above its target, see for example Gropp and Heider (2010), Greenwood et al. (2015) and Duarte and Eisenbach (2021). Couaillier (2021) investigates how large European banks set the target capital ratio and how they adjust. Using hand-collected data from press announcements of European banks, he finds that capital targets (quite naturally) increase with capital requirements, but not one for one. Importantly, Couaillier (2021) finds that banks do not distinguish the mandatory requirement from the ‘softer’ buffer requirements. To the extent that this perspective is shared by equity owners, it means that excess capitalization is better measured using the effective capital requirements, which include buffers, than using minimum (hard) capital requirements. For that reason, we measure excess capitalization as equity capital in excess of the effective capital requirement.

We test the empirical implications of our model using data on US banks and regress equity risk on bank leverage and proxies for excess capitalization. Our key finding is that excess capitalization is highly significant for all measures of equity risk (realized and implied volatility, beta, and an accounting-based measure), and the finding is robust to the introduction of a variety of different controls. While leverage is also important, the effect from the distance to the regulatory boundary more than compensates for the risk mitigation due to lower leverage.

Our model can also help explaining the declining market-to-book ratios of equity discussed in Sarin and Summers (2016), who attribute the declining ratios to eroding franchise values of banks. In our model, keeping the asset value and debt level fixed, but increasing the capital requirement, leads to lower excess capitalization, and this decreases the market value of equity without changing the book value. Hence the market-to-book ratio falls in response to a lower excess capitalization. Our empirical analysis confirms this relationship, offering a joint explanation for falling market-to-book ratios and constant equity risk.

Finally, we analyse the cost of bank debt. Two competing effects are at play here. A higher total capitalization should lead to higher recovery rates in default and therefore reduce the cost of debt, but a smaller excess capitalization should lead to a higher probability of default causing the cost of debt to rise. Our regressions indicate that the recovery effect dominates so that the cost of bank debt has in fact decreased, consistent with Kroen (2022) and Pierret and Steri (2020).

Overall, our analysis shows, that the argument made in Admati et al. (2013), that equity 'contains a risk premium that must go down if banks have more equity' is not automatically satisfied, or that we must at least be careful how we look at equity. If a bank keeps a constant distance to its regulatory boundary by maintaining a constant excess capitalization, then an increased capital requirement will lead to equity becoming less risky. But the effect from the increased capital requirement can be offset if the banks have a smaller excess capitalization. Therefore, for the bank to reap the benefit of increased capital in the form of cheaper equity financing, the excess capitalization should not be eroded.

2 Model

In this section, we present our baseline model which incorporates the capital regulation into a standard Merton model. The market value of assets of a bank, V_t, follows a Geometric Brownian motion with drift μ and volatility σ:

$$dV_t = \mu V_t d_t + \sigma V_t dW_t. \tag{1}$$

The bank issues zero-coupon debt with time to maturity T and the face value of debt is D. We consider a simplified model with only one debt class meant to capture everything from insured deposits to subordinated bonds. We assume that the market value of the bank's assets is equal to the book value and therefore define the book value of equity as the difference between the asset value and the face value of debt, $V - D$. Capital regulation requires that this book value of equity is larger than some fraction of assets adjusted for asset riskiness. Specifically, the amount of risk-weighted assets (RWA) of the bank is defined to be a fraction α of total assets, where a higher α means that bank assets are riskier according to regulatory measures of risk. We refer to α as the risk density of the bank.

The bank's capital ratio at time T is the ratio between the book value of equity $V_T - D$ and risk-weighted assets αV_T, and we assume that this ratio must be larger than ρ, the regulatory capital requirement. This means that the bank will default and enter into resolution for the value of V_T solving the equation

$$\frac{V_T - D}{\alpha V_T} = \rho \tag{2}$$

and we can therefore define the default boundary D_B as that value, i.e.,

$$D_B = \frac{D}{1 - \alpha\rho}. \tag{3}$$

Since the risk density α and the required capital ratio ρ, are both between 0 and 1, D_B is larger than D. We further assume that the costs of entering into resolution are large enough so that when insolvency happens, equity is fully wiped out. Assuming, for example, a required capital ratio of $\rho = 0.12$ and a risk density of $\alpha = 0.4$, we have $D_B = 1.05 \cdot D$. This means that a loss in assets of more than 5% when the bank hits the default boundary will leave no assets for the equity holders. Empirical evidence in Bennett and Unal (2015) suggests that bank resolution costs are far bigger than this in practice.

Using the regulatory boundary D_B as the default barrier, we can find the price of equity using standard option pricing[1]. The equity price is given by:

$$
\begin{aligned}
E_0 &= e^{-rT} E^{\mathbb{Q}} \left([V_T - D] \ \mathbf{1}_{\{V_T > D_B\}} \right) \\
&= V_0 \Phi(d_1^{D_B}) - D e^{-rT} \Phi(d_2^{D_B})
\end{aligned}
\tag{4}
$$

$$
\text{where } d_1^{D_B} = \frac{\log \frac{V_0}{D_B} + (r + \frac{\sigma^2}{2})T}{\sigma\sqrt{T}} \text{ , and } d_2^{D_B} = d_1^{D_B} - \sigma\sqrt{T}
$$

Note that the regulatory boundary which triggers default is different from the face value of debt paid when the bank is solvent. This also means that the delta, i.e., the partial derivative of the value of the equity call option with respect to asset value, becomes more complicated than in standard Black-Scholes, and therefore equity volatility becomes [2]:

$$
\begin{aligned}
\sigma_E &= \frac{\partial E}{\partial V} \frac{V_t}{E_t} \sigma \\
&= \left[\Phi(d_1^{D_B}) + \frac{D_B - D}{D_B} \varphi(d_1^{D_B}) \frac{1}{\sigma\sqrt{T}} \right] \frac{V_t}{E_t} \sigma \\
&= \left[\Phi(d_1^{D_B}) + (\alpha\rho)\ \varphi(d_1^{D_B}) \frac{1}{\sigma\sqrt{T}} \right] \frac{V_t}{E_t} \sigma
\end{aligned}
\tag{5}
$$

In a standard Merton model, the delta is simply $\frac{\partial E}{\partial V} = \Phi(d_1)$.[3] After taking into account the regulatory boundary, we get a slightly different $\Phi(d_1^{D_B})$ and an additional term $(\alpha\rho)\ \varphi(d_1^{D_B})\frac{1}{\sigma\sqrt{T}}$. The incorporation of a regulatory boundary also modifies the market valuation of equity in Equation 4.

The main implication of the model is that holding asset volatility fixed, equity volatility depends on leverage *and* the distance between total asset and the regulatory boundary. A useful illustration to keep in mind is given in Figure 3 in which we depict a case where Bank B has a lower leverage but also a smaller distance to its regulatory boundary than Bank A. Despite its lower leverage, Bank B may have a higher equity risk due to the smaller distance to regulatory

[1] Chan-Lau and Sy (2007) proposed a new measurement of 'distance-to-capital' based on the distance-to-default measure, the distance-to-capital uses a default boundary of λD where $\lambda = \frac{1}{1-PCAR}$. Our insolvency condition is very similar to the distance-to-capital boundary. Also, Glasserman and Nouri (2012) proposed to impose a similar regulatory constraint in valuing contingent capital.

[2] Proof is in Appendix.

[3] Note the boundary in calculating d_1 here is the face value D.

boundary[4]. Figure 3 will be a useful point of reference in all that follows. Furthermore, we decompose the book equity ratio into two terms which we can think of as excess and minimum capitalization, respectively.

$$\frac{V-D}{V} = \underbrace{\frac{V-D_B}{V}}_{\textit{Excess capitalization}} + \underbrace{\frac{D_B-D}{V}}_{\textit{Minimum capitalization}} \tag{6}$$

$V - D_B$ can be thought of as the voluntary capitalization held by the bank, in excess of the required minimum capital amount $D_B - D$. In our empirical work we normalize capital by the size of bank assets. We will use the two terms 'distance to the regulatory boundary' and 'excess capitalization' interchangeably in the following.

For a graphical illustration of the key mechanism, we plot in Figure 4 how equity risk depends on leverage for different specifications of the regulatory boundary. Since the default boundary D_B is determined by the product of the risk density α and the capital requirement ρ, we first keep α fixed. Importantly, it is possible for a bank with lower leverage to have a higher equity volatility if the low leverage bank operates under a stricter capital requirement. For example, defining the leverage as book assets divided by market equity, a bank with a leverage factor of 20 operating under a 12% capital requirement has an equity volatility of 70% whereas a bank with a leverage factor of 25 operating under a 4% capital requirement has an equity volatility of roughly close to 50%. The case denoted Merton in the graph corresponds to the case where $\rho = 0$, and so the face value of debt and the regulatory boundary are the same. We reach a similar conclusion holding the capital requirement fixed and varying the risk density as shown in the bottom panel, because the distance between the face value of debt and the regulatory boundary depends on α and ρ only through their product. Since we keep the asset volatility fixed, we think of a higher risk density as being caused by regulators demanding higher risk weights assigned to assets with a given volatility.

In Figure 5 we illustrate the same insight from a different angle. Here, we imagine that banks set capital targets that only partially mirror the capital requirement. The graph in the left panel

[4]We can think of Bank A as banks before the GFC, and Bank B as banks after GFC.

shows the capital target of banks as a function of the required capital. If banks kept a constant capital buffer in addition to the regulatory boundary, the target capital ratio (blue line) would be parallel to the 45-degree line (red line). But as suggested in, for example, Greenwood et al. (2015), Duarte and Eisenbach (2021), and Couaillier (2021), banks only partially adjust their capital ratios in response to changes in capitalization. Also, as suggested in Figure 2, the US banks are closer to their effective capital requirements than before the crisis. In Figure 5 we note that an adjustment rate consistent with the empirical evidence (for European banks) in Couaillier (2021), produces an equity volatility that is increasing as a function of the capital requirement above a certain level, but perhaps more interestingly almost constant over the entire range.

As noted in Nagel and Purnanandam (2020), the lognormal dynamics are not a good representation of bank assets for a typical bank, and distance-to-default measures based on lognormal dynamics may be misleading. Our purpose, however, is not to improve default prediction, but rather to build a model which allows us to address how both the amount of capital and the amount of capital in excess of that required by regulation affect the equity risk as well as the market-to-book ratio. Its qualitative predictions would hold under other distributional assumptions, but the comparative statics would not be as simple to derive.

In summary, our main testable implication is that equity risk depends not only on leverage but also on the distance to the regulatory boundary, and that the effect of the lower distance is strong enough to keep equity risk high in spite of increased capitalization. We will refine the implications when we carry out our empirical analysis.

3 Data and summary statistics

3.1 Bank balance sheet data

We collect the quarterly balance sheet data of US banks from Call reports and FR Y-9C reports. The FR Y-9C report collects basic financial data from a domestic bank holding company (BHC), a savings and loan holding company (SLHC), a US intermediate holding company (IHC), and a securities holding company (SHC) on a consolidated basis (FRB, 2022). These data are used also in, among others, Choi et al. (2020), Duarte and Eisenbach (2021), Fernholz and Koch (2017), and Kovner and Van Tassel (2022). The asset-size threshold for filing the FR Y-9C report has been increasing due to inflation, industry consolidation, and normal asset growth. The current threshold is $3 billion.[5] The bank call report[6] is filed by an individual bank subsidiary of a bank holding company or by a bank that is not a part of BHC. We access all these reports through the WRDS Bank Regulatory database. The unique identifier in both datasets is the RSSD ID, which is a unique identifier assigned to institutions by the Federal Reserve. Each subsidiary of BHC has a unique RSSD ID, and we can map the subsidiary to its corresponding BHC which also has a unique RSSD ID. Given our focus on banks, we restrict our data sample to the BHCs (from Y-9C reports) that own at least one commercial bank (from the call reports).

We retrieve the following data columns: total assets (BHCK2170), total liabilities (BHCK2948), book equity (BHCK3210), Tier 1 capital (BHCK8274), risk-weighted assets (BHCKA223)[7], deposits in domestic offices (BHDM6631 + BHDM6636), cash and balances due from depository institutions (BHCK0081 + BHCK0395 + BHCK0397), net loans (BHCKB529), and total interest expenses (BHCK4073).

Next, we identify the publicly traded banks utilizing the linking table between the RSSD ID and the PERMCO code which is the unique firm identifier used in the CRSP database. The linking table is provided by the Federal Reserve Bank of New York (2021), including 1,471 PERMCO-RSSD links from 1986 to 2021.

[5]The threshold of filing FR Y-9C reports was $150 million before March 2006, and then became $500 million. In March 2015, it increased to $1 billion and in September 2018, it increased to the current level of $3 billion.

[6]Including the FFIEC 031 report filed by banks with domestic and foreign offices and the FFIEC 041 report filed by banks with domestic offices only.

[7]For Tier 1 capital and risk-weighted asset before 2014, the four-letter mnemonic was BHCK. Due to revised regulation framework, the calculation of Tier 1 capital and risk-weighted asset has been changed and the four-letter mnemonic became BHCA since 2014.

3.2 Bank regulation data

We focus in this paper on the period after the Great Financial Crisis during which capital requirements were gradually increased in the US. In 2010, the Basel Committee released 'Basel III' which included new capital standards, and in the US the Dodd-Frank Wall Street Reform and Consumer Protection Act (Dodd-Frank) was passed which required US regulators to tighten capital standards. The incorporation of Basel III and the requirements of Dodd-Frank were announced in 2013 and started coming into effect in January 2015. The minimum Tier 1 risk-based capital ratio was increased to 6% for all banks and BHCs with assets greater than $1 billion.

In addition, banks are required to hold extra buffer capital. The Capital Conservation buffer (CCoB) requires banks to hold a buffer capital of 2.5%, and limitations will be imposed on banks' dividend payout if the buffer requirement is not fulfilled. The CCoB has been in effect since 2016 and had a gradual phase-in from 2016 to 2019, see Walter (2019). Basel III also introduces the Countercyclical buffer which is meant as a flexible buffer requirement that can be increased in good times and loosened in bad times. This buffer has not been brought into play in the US as of this writing.

Beyond the minimum requirements and buffer requirements for all banks, the supervisors also impose individual capital requirements for the largest and most complex banks - the GSIBs. The list of GSIBs is determined by the Basel Committee every year based on a set of financial measures. Based on the score calculated from the financial indicators, banks will be assigned to a certain bucket and the additional capital requirement is determined by the bucket. This methodology is called Method 1 for the GSIBs of the US. In addition to the Basel methodology, the US regulators apply a similar methodology which uses 9 out of 12 indicators in the Basel methodology and includes an additional indicator in calculating the score, which is then called Method 2. The data of indicators is obtained from FR Y-15 reports in Federal Financial Institutions Examination Council. Based on the indicators, the GSIB score for both methods can be calculated. The effective surcharge will then be determined by the higher score between Method 1 and Method 2. The GSIB surcharge is also subject to a transition period from 2016 to

2019[8]. In the regression analysis, we sum up the effective buffer requirement and the minimum capital requirement and define that as the regulatory requirement[9].

In March 2020, the Federal Reserve approved the rule to finalize the 'Stress Capital Buffer' regime, which integrates the stress test results with the non-stress capital requirements for large banks. For the banks involved, the stress-based buffer requirement will replace the fixed CCoB requirement of 2.5%. The banks will be informed of the test results and the corresponding buffer requirement in June every year. In our main analysis, we do not include this development, since we have excluded the period after 2019 to avoid the effect of the COVID-19 crisis.

3.3 Equity risk measures

We construct four different measures of equity risk: equity beta from a market CAPM model, historical volatility of stock returns, implied volatility from options on bank stocks, and implied cost of capital (ICC). ICC is a measure of equity cost of capital based on analyst forecasts which we construct following Dick-Nielsen et al. (2022) and Lee et al. (2021).

We obtain daily stock returns of banks from the CRSP database and daily market returns from the Kenneth R. French Data Library. We calculate a forward-looking market beta using 252 returns following the current date. Also, we calculate forward-looking volatility by taking the annualized standard deviation of the 252 stock returns.

We collect the implied volatility from the Option Metrics and CRSP databases. The WRDS Option suite provides an analytical tool based on the two databases, from which we can obtain the implied volatility of the underlying stocks. We retrieve the implied volatility of at-the-money options[10], with time to maturity of 28 to 32 days (WRDS Research, 2017).

Finally, we collect monthly analysts' forecasting data from the IBES database. We retrieve the five data columns: median of one-year-ahead forecast of EPS (EPS_1), median of two-

[8]For both CCoB and GSIB surcharge, the phase-in transition is scheduled as: the requirement for 2016 is 25% of the sum of surcharge, the requirement for 2017 is 50%, the requirement for 2018 is 75% and the requirement for 2019 and onwards is 100%.

[9]The empirical evidence in Couaillier (2021) shows that banks treat the soft buffer requirement as hard requirement and they are reluctant to touch the buffers.

[10]We filter the at-the-money options based on the moneyness, which is the strike price of the option divided by the closing price of the underlying security, to be between 0.95 and 1.05.

year-ahead forecast of EPS (EPS_2), median of long-term growth (LTG), current price (P_0), median of one-year-ahead forecast of DPS (DPS_1). Following Dick-Nielsen et al. (2022), we supplement this dataset with the accounting data from the Compustat database and calculate ICC by taking the average of the following two equations 7 and 8:

$$ICC^{OJ} = A + \sqrt{A^2 + \frac{EPS_1}{P_0}(STG - (\gamma - 1))}, \tag{7}$$

$$with\ A = \frac{1}{2}\left((\gamma - 1) + \frac{DPS_1}{P_0}\right),\ and\ STG = \sqrt{\frac{EPS_2}{EPS_1} * LTG}$$

$$ICC^{PEG} = \sqrt{\frac{EPS_1}{P_0} * STG} \tag{8}$$

The variables are available from IBES dataset or the supplementary Compustat dataset, except for the long term momentum of EPS growth ($\gamma - 1$), which we proxy by the ten-year Treasury rate.

We lead the ICC measure and the implied volatility by one month since the quarterly report is usually released one month after each quarter-end.

3.4 Cost of debt

We proxy the riskiness of bank debt by the cost of interest expenses of banks following the method applied in Dick-Nielsen et al. (2022). It is defined by the interest expenses divided by the total liability of a bank i at time t,

$$\text{Cost of debt}_{i,t} = \frac{\sum_{k=0}^{3} \text{Interest expenses}_{i,t-k}}{\frac{1}{4}\sum_{j=1}^{4} \text{Total liabilities}_{i,t-j}} \tag{9}$$

where the data of interest expenses and total liability are obtained from the balance sheet dataset.

3.5 Bank industry data

We collect a series of variables that can measure the development of the banking industry in the US, which are the net interest margin (USNIM), the tightening index for C&I loans (DRTSCILM), the ratio of non-performing loans to total loans (NPTLTL). These datasets are updated quarterly and published on the FRED Economic Data website.

3.6 Summary statistics

Following Sarin and Summers (2016), our data sample starts from 2002 to avoid the effect of the dot-com bubble. In addition, we exclude the data between 2008 and 2009 to avoid the effect of the GFC. Table 1 and 2 summarize the riskiness data and balance sheet data in different time periods. Comparing the capital ratios between pre-GFC and post-GFC period, both the Tier 1 risk capital ratio and the book equity to total asset ratio have increased significantly. The slight drop of Tier 1 ratio after 2015 is possibly due to the stricter definition of capital in Basel III. Although Tier 1 ratio has dropped after the Basel III, the book equity to total asset ratio has increased significantly.

For the equity riskiness variables, we find similar results as reported in Sarin and Summers (2016). The forward-looking market beta has been increasing and the forward-looking historical volatility is relatively unchanged. The equity risk implied from analysts' forecasts is also stable. We do not have observations of options on bank stocks before 2007, but the implied volatility is also stable comparing the statistics before and after Basel III implementation. The average cost of debt has been decreasing, but this is also related to the decreased interest rate. In our regression analysis, we mainly focus on the time period from January 2012 to December 2019 which is an ideal period because of the gradual increase in capital requirements. This is because there is little variation in capital requirement before the Great Financial Crisis, and the extreme volatility during the crisis as well as during the Covid crisis adds considerable noise to the empirical analysis.

4 Results

We now turn to empirical tests to see how different measures of equity risk respond to minimum and excess capitalization, and how capitalization affects market-to-book ratios and cost of debt.

4.1 Equity risk

As seen from Equation 5, equity volatility is given by the product of three terms: the sensitivity of the equity value with respect to asset value ($\frac{\partial E}{\partial V}$), the leverage ($\frac{V}{E}$), and the asset volatility (σ). After taking logarithm of the equation, we obtain a linear equation:

$$\log \sigma_E = \log \frac{\partial E}{\partial V} + \log \frac{V}{E} + \log(\sigma) \tag{10}$$

where the partial derivative of equity with respect to asset value is given by:

$$\frac{\partial E}{\partial V} = \Phi(d_1^{D_B}) + (\alpha\rho)\ \varphi(d_1^{D_B})\frac{1}{\sigma\sqrt{T}} \tag{11}$$

Comparing (11) with the standard Merton model in which $\frac{\partial E}{\partial V} = \Phi(d_1)$, we note the additional term $(\alpha\rho)\varphi(d_1^{D_B})\frac{1}{\sigma\sqrt{T}}$ is always positive. More importantly, the extra term increases in the product of $\alpha\rho$ as long as the bank's initial asset value is above the regulatory default boundary ($V_0 \geq D_B$). On the other hand, an increase in $\alpha\rho$ will lead to a decline in $\Phi(d_1^{D_B})$, because equity is closer to being wiped out but the payoff given survival has not changed. On the whole, we find the increment due to the additional term will dominate the decrease in $\Phi(d_1^{D_B})$ when $\alpha\rho$ increases (and under the condition of $V_0 \geq D_B$). So the partial derivative of equity with respect to asset will increase in $\alpha\rho$, which is a direct measurement of the difference between the regulatory default boundary and the face value of debt (recall that $\alpha\rho = \frac{D_B - D}{D_B}$).

To further elaborate on the role of $\alpha\rho$, note that the numerator of $d_1^{D_B}$ is $\log \frac{V}{D_B} + (r + \frac{1}{2}\sigma^2)T$, and the important term here is $\log \frac{V}{D_B}$ which we rewrite as

$$\underbrace{\log \frac{V}{D_B}}_{\text{distance to regulatory boundary}} = \log \frac{V(1-\alpha\rho)}{D} = \underbrace{\log \frac{V}{D}}_{\text{distance to debt face value}} + \underbrace{\log(1-\alpha\rho)}_{\text{regulatory adjustment}} \tag{12}$$

In a model without a regulatory requirement, the term $\log \frac{V}{D}$ is a measure of distance to default, but when regulation enters, this measure needs to be adjusted by the term $\log(1-\alpha\rho)$. The adjustment is decreasing in the capital requirement and the risk density, and since the product $\alpha\rho$ is small, $\log(1-\alpha\rho) \approx -\alpha\rho$, so the adjustment is approximately linear in $\alpha\rho$.

4.1.1 Univariate regression

Our main focus is whether equity risk depends on excess capitalization and ultimately whether a fall in excess capitalization can explain why equity risk has not been lowered despite higher capital requirements. As a first sanity check, we run the univariate regression

$$\log \text{Equity risk}_{i,t} = \beta \log \text{Capitalization}_{i,t} + \text{Bank FE}_i + \epsilon_{i,t}. \tag{13}$$

We use our four different measures of equity risk on the left hand side. To proxy for capitalization, we first use $\frac{V-D_B}{V}$ which measures excess capitalization, and then $\frac{V-D}{V}$, which measures total capitalization. Recall, $D_B - D$ is the minimum amount of book equity required to satisfy the capital requirement, and therefore $V_D - B$ is excess book capital. We include a bank fixed effect to control for differences in asset volatility.

In Table 3 Panel A we present the result of the regression using monthly observations from January 2012 to December 2019. We find a significant and negative effect of excess capitalization for all four measures of equity risk consistent with the idea that a higher excess capitalization results in lower equity risk.

Note, however, that we could find similar results when we replace the excess capitalization with the total capitalization as shown in Panel B. A better total capitalization will also lead to a lower equity risk - at least for three of the measures. The univariate regression does not allow us to clearly distinguish the effect on equity risk of the excess capitalization from the effect of total capitalization.

4.1.2 Separating excess and total capitalization

To single out the effect stemming from the excess capitalization, we run two different sets of regressions. First, we regress equity risk on leverage and minimum capitalization ($\frac{D_B-D}{V}$) while still controlling for a bank fixed effect to account for, among other things, bank specific asset volatility:

$$\log \text{Equity risk}_{i,t} = \beta_1 \log \text{Leverage}_{i,t} + \beta_2 \log \text{Minimum capitalization}_{i,t} + \text{Bank FE}_i + \epsilon_{i,t} \tag{14}$$

For leverage, we employ two different measures: book leverage and risk leverage. Book leverage is total book assets divided by book equity, while risk leverage is total RWA over Tier 1 capital. Note that since we include total leverage in the regression, we would expect a positive correlation between equity risk and the minimum capitalization. This is because when leverage is kept fixed, a higher minimum capitalization implies a shorter distance to the regulatory boundary and hence higher equity risk.

The test results are summarized in Table 4. In the first four columns, we present the regressions with four different risk measures on the book leverage and the minimum capitalization. In the following four columns, the book leverage is replaced by the risk leverage. The results consistently show that higher leverage is associated with higher equity risk. More importantly, the minimum capitalization term has a significantly positive coefficient. This shows precisely that a smaller excess capitalization contributes to equity risk in that keeping the leverage constant while increasing *minimum* capitalization results in a smaller *excess* capitalization.

We now ask whether the effect from the increased minimum capitalization, and hence shorter distance to default, is not only significant but also large enough to explain the unchanged or even increased level of equity risk. To answer this, we calculate the cross-sectional average of the independent variables: $\log$ Book leverage and $\log$ Minimum capitalization. Then we multiply the average level of log Book leverage and log Minimum capitalization by the coefficients that we find in Table 4 and sum them up. We use the coefficients estimated from our sample but extend the period back to before the financial crisis. The result is shown in Figure 9. The left panel corresponds to the first two columns in Table 4 with dependent variables of log Equity beta and log Historical volatility; the right-hand-side panel corresponds to the third and forth columns with dependent variables of log ICC and log Implied volatility. The plots illustrate, that after taking into account the excess capitalization, the effect of lower leverage has been outweighed by the effect of less excess capitalization.

4.1.3 Two-step orthogonalized regression

Our second approach to isolating the effect of excess capitalization is applying a two-step orthogonalized regression. In the first step, we run the linear regression of excess capitalization ($\frac{V-D_B}{V}$) on the total capitalization ($\frac{V-D}{V}$):

$$\text{Excess capitalization}_{i,t} = \alpha + \beta \text{ Total capitalization}_{i,t} + \epsilon_{i,t} \tag{15}$$

We then use the residuals from this regression to obtain the change in excess capitalization that cannot be explained by a change in total capitalization. We denote the residual variable the 'orthogonalized excess capitalization'. In the second step, we conduct the following regression:

$$\begin{aligned} \log \text{Equity risk}_{i,t} = \beta_1 \log \text{Leverage}_{i,t} + \beta_2 \text{ Orthogonalized excess capitalization}_{i,t} \\ + \text{Bank FE}_i + \epsilon_{i,t} \end{aligned} \tag{16}$$

This of course resembles our first approach above, but note that unlike the first method, in this regression, an increase in our key variable of interest, the orthogonalized excess capitalization, signals a *larger* excess capitalization. As a result, we would expect a negative sign of β_2 since a larger excess capitalization will reduce equity risk. The test results summarized in Table 5, Panel A show that the coefficient β_2 is indeed consistently and significantly negative.

4.1.4 Equivalence of orthogonalized regression

It has been noticed that the product of $\alpha\rho$ plays an important role in determining the excess capitalization. We also find the intuitive explanation of this product in Equation 12, that $\log(1-\alpha\rho)$ is a regulatory adjustment on the distance to default. So the regulatory adjustment can also help isolate the effect that solely comes from the excess capitalization. We run the regression of the equity risk on the leverage and the regulatory adjustment. The regression formula is specified as:

$$\begin{aligned}\log \text{Equity risk}_{i,t} = \beta_1 \log \text{Leverage}_{i,t} + \beta_2 \text{ Regulatory adjustment}_{i,t} \\ + \text{Bank FE}_i + \epsilon_{i,t}\end{aligned} \tag{17}$$

The test results are summarized in Table 5, Panel B. Again, we find the results consistent with the main results we have shown above. More importantly, we find that the results of the regression with the regulatory adjustment as a regressor are extremely close to the results using the orthogonalized excess capitalization. That is to say, the regulatory adjustment is a good proxy to capture the part in the excess capitalization that is unexplained by the total capitalization. The correlation between the two series is in fact 0.97.

In terms of the order of magnitude of the coefficients, we take the first column in Table 5, Panel B as an example. The coefficient of the logarithm of regulatory adjustment is -5.18, meaning *ceteris paribus*, a 1% increase in $(1-\alpha\rho)$ will lead to a 5.18% drop in equity beta. For numerical illustration, suppose that the bank has the risk density equal to 50%, when the Tier 1 capital requirement drops from 12% to 10%, the term $(1-\alpha\rho)$ will increase by roughly 1%, and it will lead to a 5.18% drop in equity beta. On the other hand, the coefficient of the logarithm of leverage factor is 0.056, which implies that, *ceteris paribus*, a 10% decrease in leverage will lead to a 0.56% drop in equity beta. Suppose a bank's book capital ratio increases from 9% to 10%, the leverage factor will decrease by 10%, that will lead to 0.56% drop in equity beta. Again, this supports our claim that the effect of the regulatory adjustment is economically large and dominates the leverage effect in our sample, consistent with our model implication.

4.2 Robustness tests

In the above baseline results, we take the bank fixed effect as a control for asset volatility. In this section, we re-run the regressions in Equation 14, 16 and 17 but replace the bank fixed effect with a proxy of asset volatility, the standard deviation of five-year observations of quarterly book asset return. The regressions are specified by the following equation in which we use different measures to isolate the effect of excess capitalization as described above.

$$\begin{aligned}\log \text{Equity risk}_{i,t} &= \alpha_{i,t} + \beta_1 \log \text{Leverage}_{i,t} + \beta_2 \text{Measure of excess capitalization}_{i,t} \\ &\quad + \theta \text{Asset vol}_{i,t} + \gamma_1 \text{Bank controls}_{i,t} + \gamma_2 \text{Bank industry controls}_t + \epsilon_{i,t} \qquad (18)\end{aligned}$$

Table 6 summarizes the results of regressions in which the orthogonalized excess capitalization is used[11]. We also include three bank specific characteristics as additional controls for the riskiness of assets. These are the loan to asset ratio, the deposit to liability ratio, and the cash holding to asset ratio. In addition, we add two variables that reflect the performance of the entire banking industry, which are the net interest margin, and average tightening index for C&I loans.

The coefficients of orthogonalized excess capitalization remain significant and negative in all regressions using different risk measures. However, the coefficients for the leverage become undetermined: in some regressions, it loses significance; and in some regressions, the equity risk becomes negatively correlated with leverage. This could indicate that the bank fixed effects capture effects that our choice of covariates are not able to capture. We further extend the regressions by including more macro variables following Welch and Goyal (2008), to address the concern of unobservable time-varying factors that can affect the bank risk in general. The extended regressions are presented in Appendix Table A.I. We only find the regressions with implied volatility from options that deviate from the baseline results, suggesting a robust result in general.

Equity volatility and the risk of debt both depend on the volatility of bank assets, and we

[11] We also conduct the robustness tests using the minimum capitalization and regulatory adjustment and get similar results.

have controlled for bank asset volatility in our regressions both using fixed effects and using a measure of volatility. This, however, does not rule out that an increase in asset volatility could also help explaining why equity risk has not decreased. We therefore measure asset volatility in our sample using three different proxies: 1) the quarterly percentage change of book asset (or quarterly asset return), 2) the standard deviation of the asset return using 5 years' observations, and 3) the implied asset volatility from our modified model using Equation 5, where both the asset value and the equity are measured at market values. Figure 6, 7 and 8 plot the time evolution of the three measures. The level of asset volatility after the crisis is close to the level before the crisis, and there are no clear change during our sample period.

4.3 Market equity to book equity ratio

Sarin and Summers (2016) argue that large financial institutions have experienced a significant decline in the franchise value of their banking business after the GFC, and this decline has led to the unreduced bank risk through a leverage channel. In this section, we investigate whether smaller excess capitalization can have a negative impact on the market-to-book equity ratio. The intuition is that increasing D_B while keeping the asset value and debt level fixed leads to a decline in the market value of equity whereas book equity by assumption remains fixed.

In order to alleviate concerns of non-stationarity of the market-to-book ratio, we use a first-difference regression specified as

$$\begin{aligned}\Delta(\text{ME/BE ratio})_{i,t} &= \beta_1 \Delta\text{Leverage}_{i,t} + \beta_2 \Delta\text{Measure of excess capitalization}_{i,t} \\ &\quad + \gamma_1 \Delta\text{Bank controls}_{i,t} + \gamma_2 \Delta\text{Bank industry controls}_t + \text{Bank FE}_i + \epsilon_{i,t}.\end{aligned} \tag{19}$$

The results are summarized in Table 7. The coefficients of the minimum capitalization are negative meaning that a higher minimum capitalization and hence a smaller excess capitalization implies a lower market-to-book ratio, which is consistent with the mechanism outlined above. The result holds both when we measure excess capitalization using the orthogonalized excess capitalization or using the regulatory adjustment.

4.4 Cost of debt

Our results suggest that the effect of capital regulation is difficult to measure by looking at the risk of bank equity alone because the market has priced in the excess capitalization. However, a direct impact of the stricter capital requirement is that the recovery of debt holders in default is increased. Whether this effect can dominate the increased risk stemming from an increased default probability is an empirical question.

In this section, we test whether the riskiness of bank debt is decreasing in the stricter regulation. We measure the riskiness of bank debt by the spread of cost of interest over the one-year treasury rate - a measure intended to capture the overall cost of all debt classes of the bank. The regression is specified by:

$$\begin{aligned}\text{Cost of debt spread}_{i,t} = \beta_1 \text{Leverage}_{i,t} + \beta_2 \text{Minimum capitalization}_{i,t} + \delta \text{Treasury yield 1Y}_t \\ + \gamma_1 \text{Bank controls}_{i,t} + \gamma_2 \text{Bank industry controls}_t + \text{Bank FE}_i + \epsilon_{i,t}\end{aligned} \tag{20}$$

We conduct the regression using quarterly time series since the dependent variable uses data that are only updated quarterly. The results are shown in Table 8, column 1 and 2. We find that for fixed leverage, a higher minimum required capitalization will lead to a lower cost of debt, indicating a safer debt due to regulation. In column 3, we conduct the regression using both excess capitalization and minimum capitalization, and find both of them will lead to lower debt risk. Since excess capitalization is strongly correlated with (inverse) book leverage, this is what we would expect. Finally in column 4, we only include the minimum capitalization and the other covariates, we find a larger minimum capitalization alone can also lead to a lower cost of debt.

In parallel with our analysis of equity risk, we now use the estimates in Table 8 to investigate if the coefficients are in fact large enough to explain a decreased cost of debt. We first calculate the cross-sectional average of the independent variables: Book leverage and Minimum capitalization. Then we multiply the average level of Book leverage and Minimum capitalization by the coefficients that we find in Table 8 and sum them up. Figure 10 indicates that the reduced leverage (resulting in larger recovery in default) has in fact dominated the effect from smaller excess capitalization risk (which would imply a larger default probability).

5 Conclusion

Bank equity risk has not decreased after the tightening of bank capital requirements. We argue that this is because *excess* capitalization has not increased and has in fact decreased. A bank may have lower leverage than another bank with the same asset volatility, but have higher equity risk because it operates with a smaller excess capitalization. To support this argument, we use a modified version of Merton (1974) in which there is a difference between debt face value and the default boundary, and in which this difference depends on the capital requirement and the ratio of risk-weighted asset to total assets. We test the key implication of our model and confirm that equity risk increases as the excess capitalization decreases.

A reduction in excess capitalization also offers an additional explanation for decreasing market-to-book ratios of banks which Sarin and Summers (2016) attribute to eroding bank franchise values. In our model, keeping debt and asset value fixed, but increasing the capital requirement, and thus lowering excess capitalization, keeps the book value of equity constant but lowers the market value of equity. We confirm empirically that market-to-book values fall in response to lower excess capitalization.

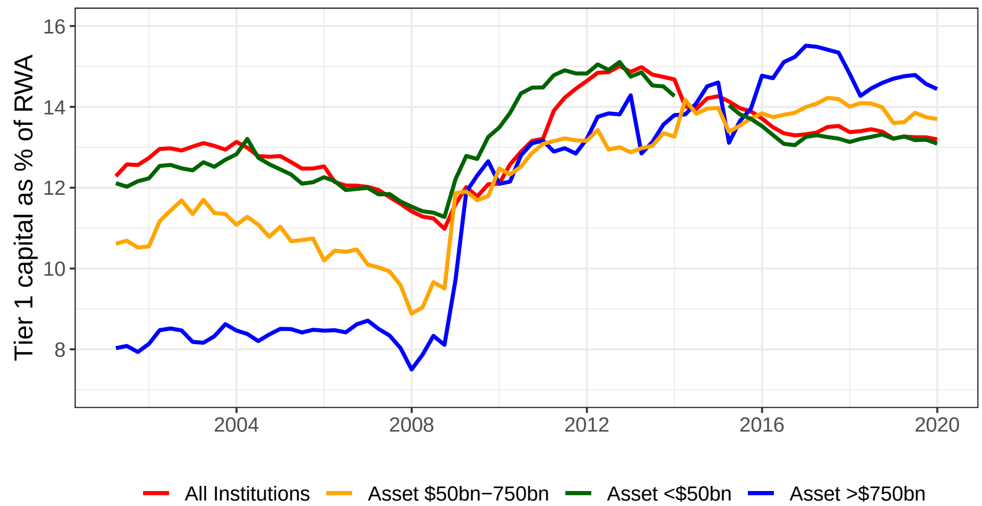
While a smaller distance to the regulatory default boundary implies a higher default probability, a higher minimum capitalization also implies a larger recovery in default, and the latter might dominate if loss of assets is small in default. We find that, empirically, the latter effect seems to dominate which can explain that bank debt is safer.

Overall, a main implication of our findings is that increased capital requirements are not sufficient to lower equity risk, because a reduction in excess capitalization, perhaps due to a constant risk tolerance, can undo the effect of increased capital requirements. This does not render increased capital requirements useless. Tightened capital regulation combined with efficient resolution regimes can still serve the purpose of lowering the risk to debtholders and to tax payers.

Figures and tables

Figure 1: Tier 1 capital ratio and the book equity ratio of US banks from 2001 to 2019. We collect the capital ratios from the Bank Regulatory Database and restrict the sample to publicly-listed BHCs. When calculating the mean statistics, we divide the full sample into three subgroups based on the asset size as of December 2019: the largest BHC group with total assets above $750bn, the medium BHC group with total assets between $50bn and $750bn, and the smallest BHC group with total assets below $50bn.

(a) Tier 1 capital ratio



(b) Book equity capital ratio

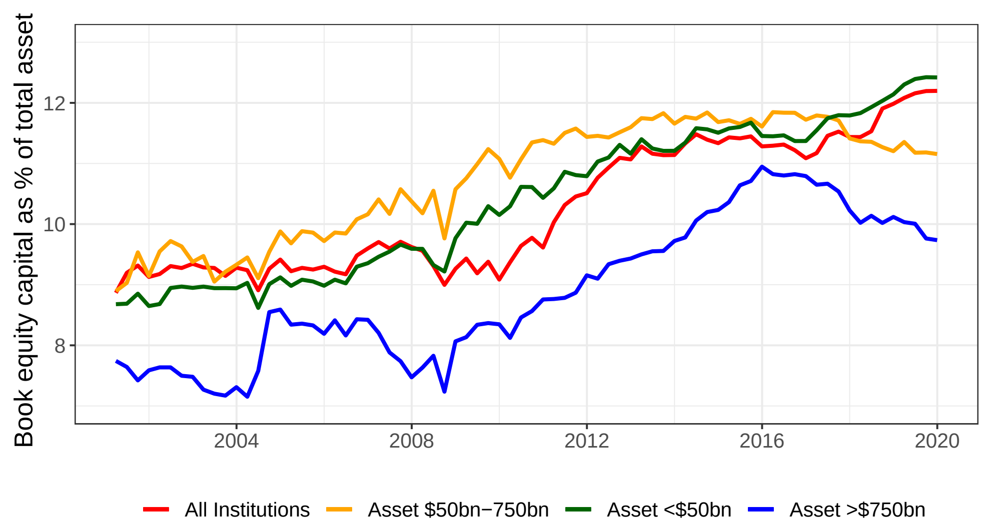
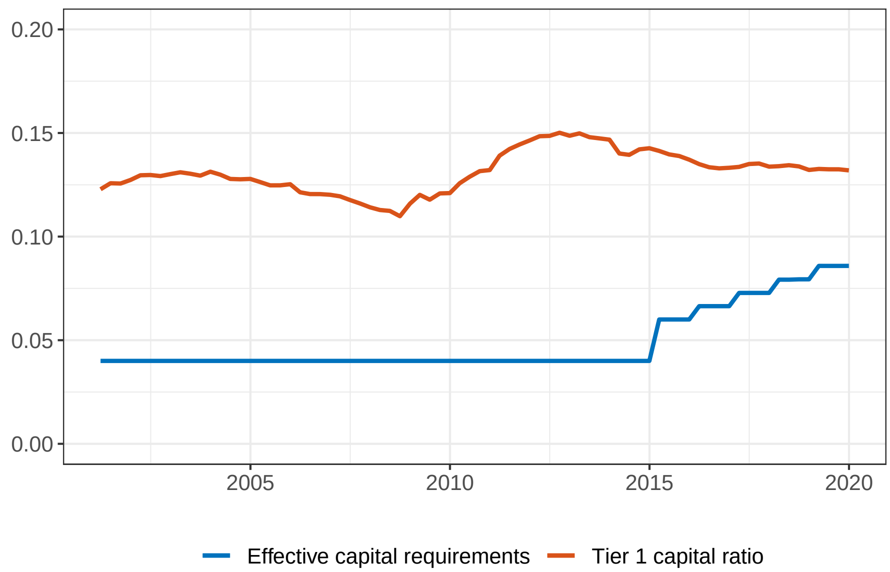


Figure 2: Average Tier 1 capital ratio and effective capital requirement of all banks (Panel a) as well as the 8 GSIBs (Panel b) in the US. The effective capital requirement consists of the minimum requirement (4% before 2015, 6% from 2015 and onwards), CCoB and CCyB buffer requirement, and GSIB surcharge. Both the buffer requirement and the GSIB surcharge follow a phase-in schedule from 2016 to 2019.

(a) All banks



(b) GSIBs

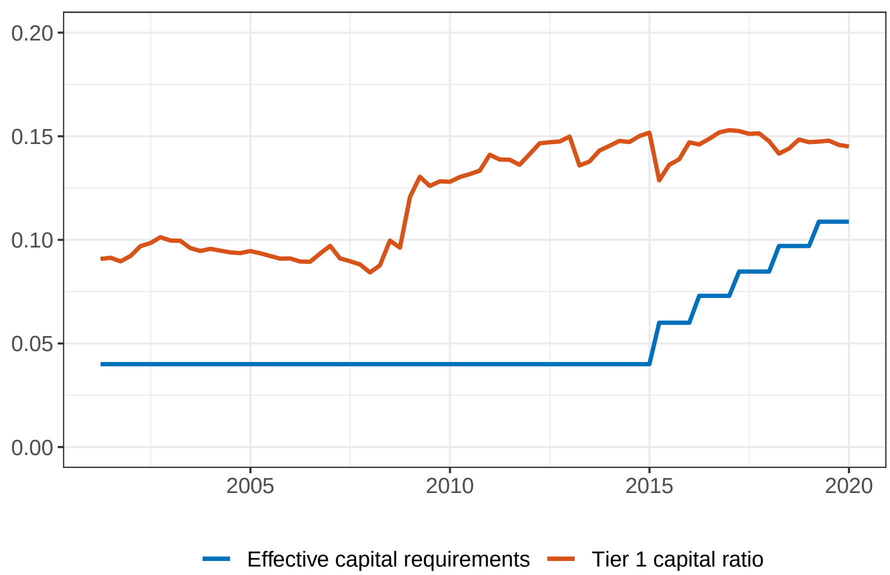


Figure 3: Illustration of the basic intuition. Two banks A and B have the same total value of assets and the same asset volatility, where Bank A has a larger face value of debt. Standard leverage measures would consider Bank A being riskier than Bank B, and one would expect A to have a higher equity volatility. However, a difference in capital requirement causes the actual default boundary of Bank A to be lower than that of B. As a consequence, Bank A may in fact have a lower equity volatility due to a larger excess capitalization.
A concrete example: Both banks have total asset value $V_0 = 100$, and asset volatility $\sigma = 0.02$. Bank A has $D^{BankA} = 96$, $\alpha^{BankA} = 0.5$, $\rho^{BankA} = 6\%$; Bank B has $D^{BankB} = 95$, $\alpha^{BankB} = 0.5$, $\rho^{BankB} = 9\%$. It turns out that the default boundary of Bank B is 99.476, larger than the default boundary of Bank A which is 98.969. Applying Equation 5, we find the equity volatility of Bank B is 0.556, higher than that of Bank A, 0.516.

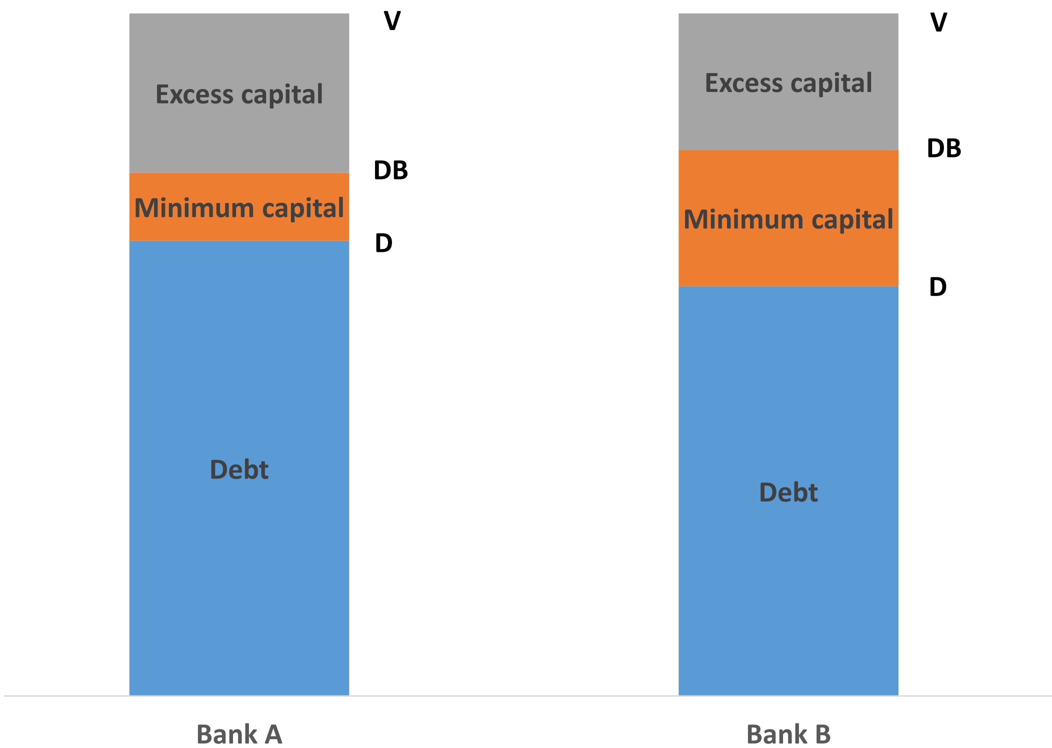


Figure 4: The figure shows how equity volatility depends on leverage, the effective capital requirement ρ and the asset risk density α. Asset volatility is held fixed at $\sigma = 0.02$ and we vary leverage by fixing $D = 95$ and varying V_0 between 95 and 105. We calculate the equity price E_0 and then the leverage is defined by $\frac{V_0}{E_0}$, we then find out the equity volatility σ_E. The top panel depicts the case that the risk density is fixed but the capital requirement is varying; the bottom panel depicts the case when the capital requirement is fixed but the risk density is varying. Since the effect of risk density and capital requirement on the equity price and equity volatility is only from the product of $\alpha\rho$, we can reach similar conclusion from the two cases.

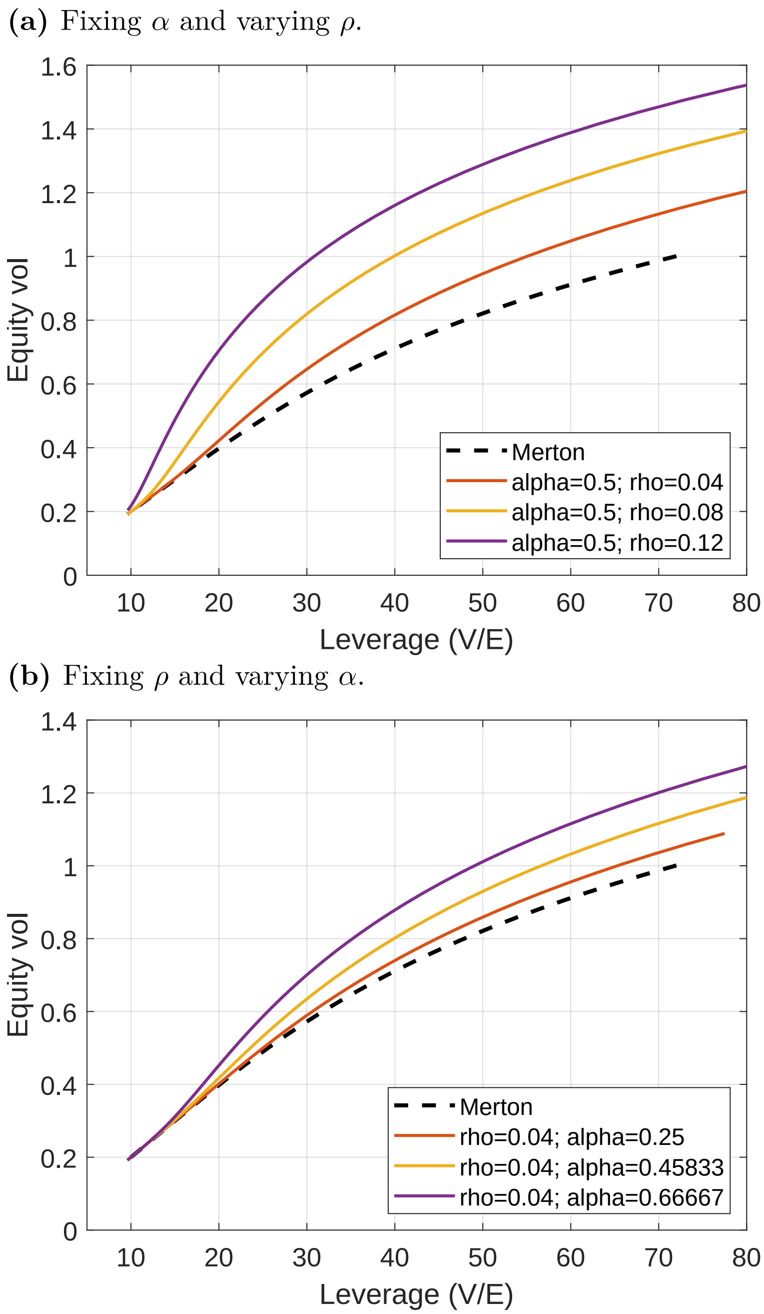


Figure 5: Effect of increased regulatory requirement on the capital ratio target and equity volatility. In the left panel, we assume that banks have a capital ratio which is a linear function on the regulatory requirement ρ. In this example, the function is specified as target $= 0.09 + 0.5\rho$, where the multiplier 0.5 is close to the empirical result in Couaillier (2021). In the right panel, we assume a bank with debt face value $D = 98$ and time to maturity $T = 1$, asset volatility $\sigma = 0.02$, risk free rate $r_f = 0.01$, risk weight $\alpha = 0.5$. The bank faces different regulation levels and thus targets at different capital ratios. We solve the asset value such that the bank ends up having the capital ratio equal to the target. Then we calculate the equity volatility given that initial asset value and plot the equity volatility against the regulatory requirement.

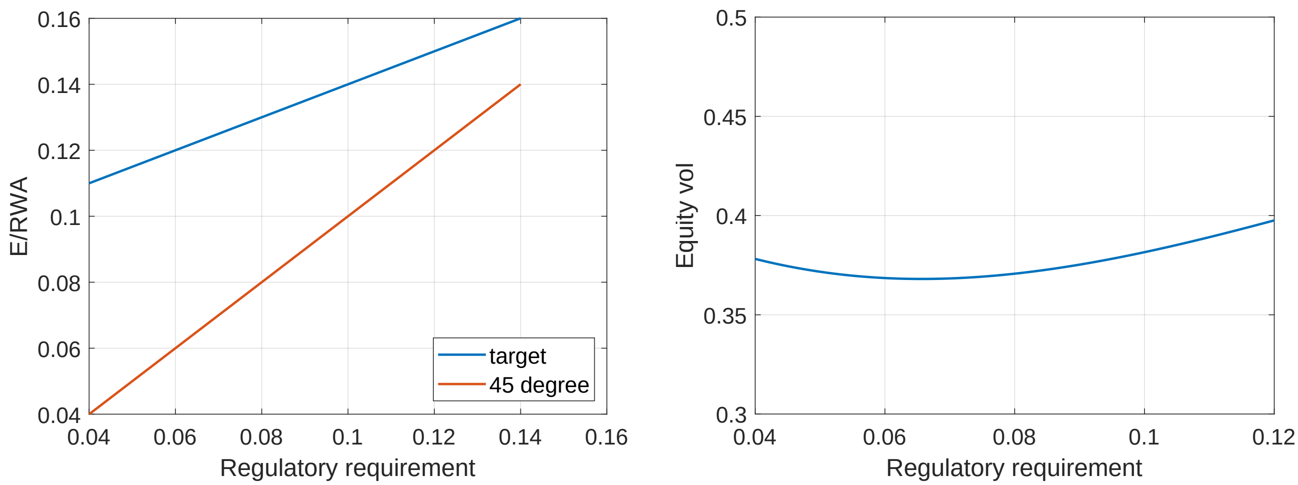


Figure 6: Average asset volatility of US banks measured by the quarterly percentage change of the book asset of banks.

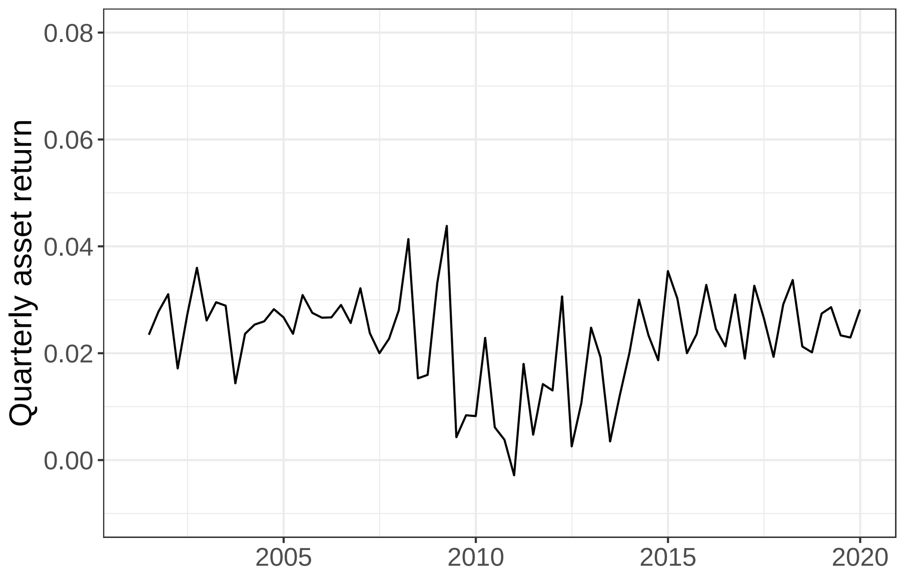


Figure 7: Average asset volatility of US banks measured by the standard deviation of the quarterly percentage change of the book asset using 5 years' observations.

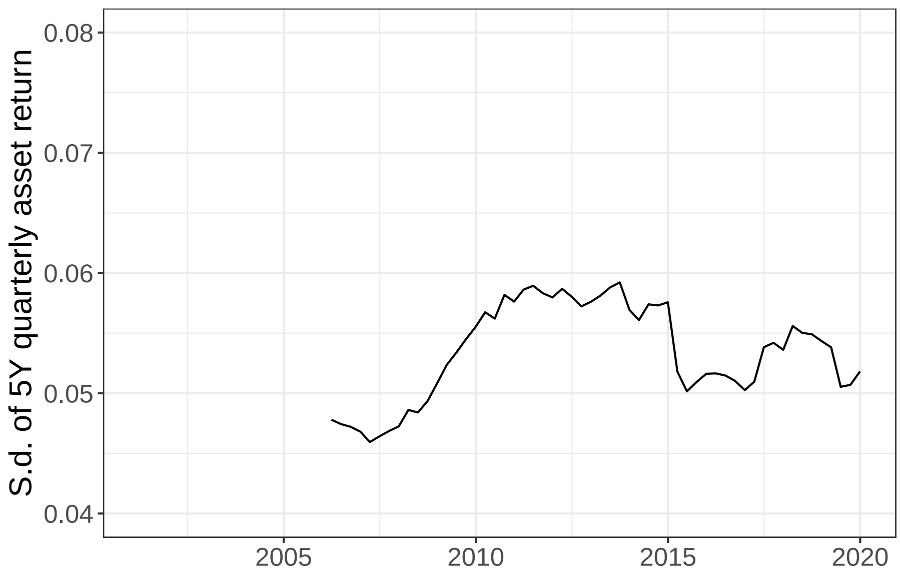


Figure 8: Average asset volatility of US banks measured by the implied volatility from the theoretical model in this paper. To imply the bank's asset volatility, we apply Equation 5. We use market value of equity to measure E_0, and measure V_0 by the sum of market value of equity and total liability. We take the average time to maturity of debt T as one year, and the risk free rate is approximated by one-year treasury rate. We take the backward-looking historical volatility of equity as a measure of σ_E, then we can back out the asset volatility σ.

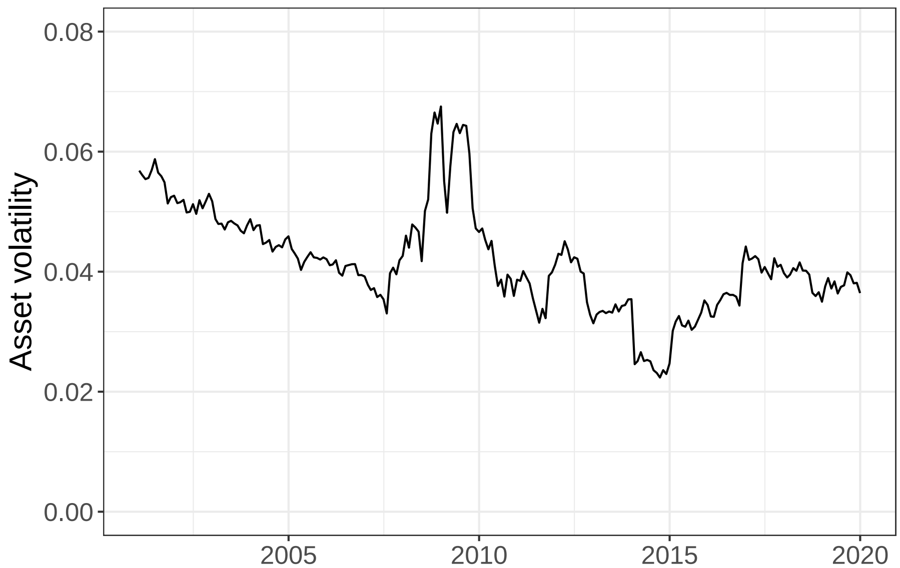


Figure 9: The combined effect of leverage and minimum capitalization on equity risk based on Table 4, the regression of equity risk on leverage and minimum capitalization. We firstly calculate the cross-sectional average of the independent variables: $\log book\ leverage$, $\log mincapital$. Then we multiply the average level of $\log book\ leverage$ and $\log mincapital$ by the coefficients that we find in Table 4 and sum them up. The left panel corresponds to the first two columns with dependent variables of $\log beta$ and $\log hist.vol$; the right-hand-side panel corresponds to the third and forth columns with dependent variables of $\log ICC$ and $\log impl.vol$. The figure indicates that after taking into account the excess capitalization, lowered leverage will not necessarily reduce the equity risk.

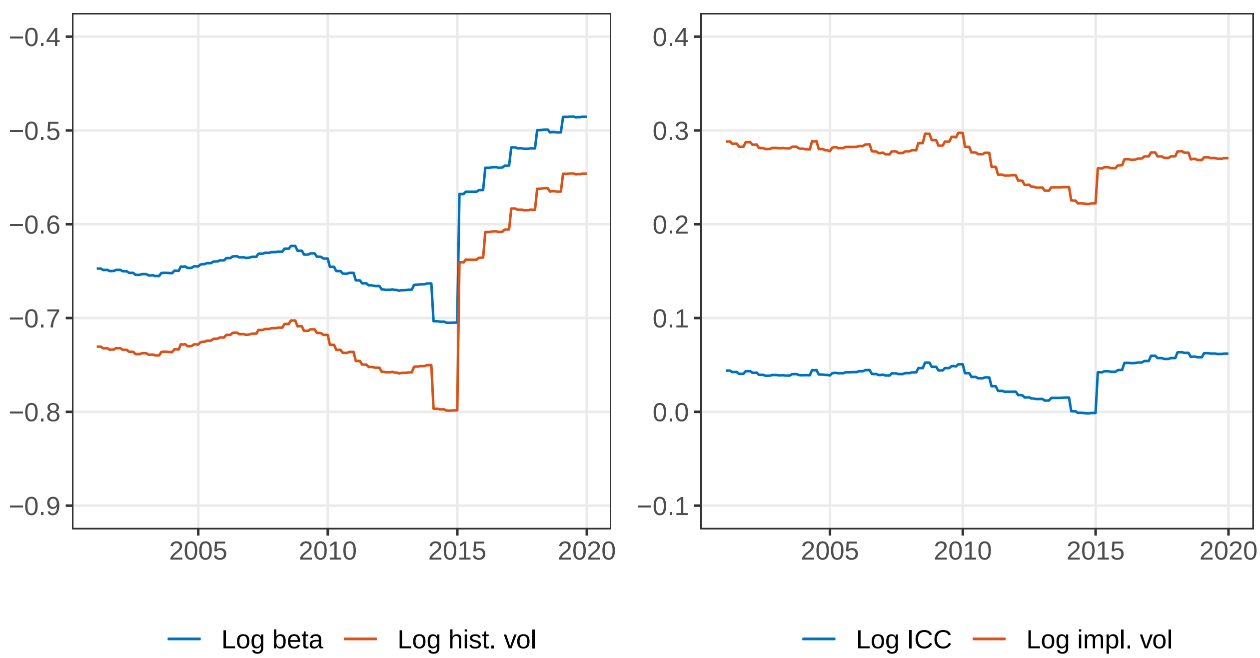


Figure 10: The combined effect of leverage and minimum capitalization on the cost of debt spread based on Table 8, the regression of cost of debt spread on leverage and minimum capitalization. We firstly calculate the cross-sectional average of the independent variables: *book leverage*, *mincapital*. Then we multiply the average level of *book leverage* and *mincapital* by the coefficients that we find in Table 8 and sum them up. The figure indicates that due to a reduced leverage and an increased buffer capitalization, the risk of debt has been decreasing over time.

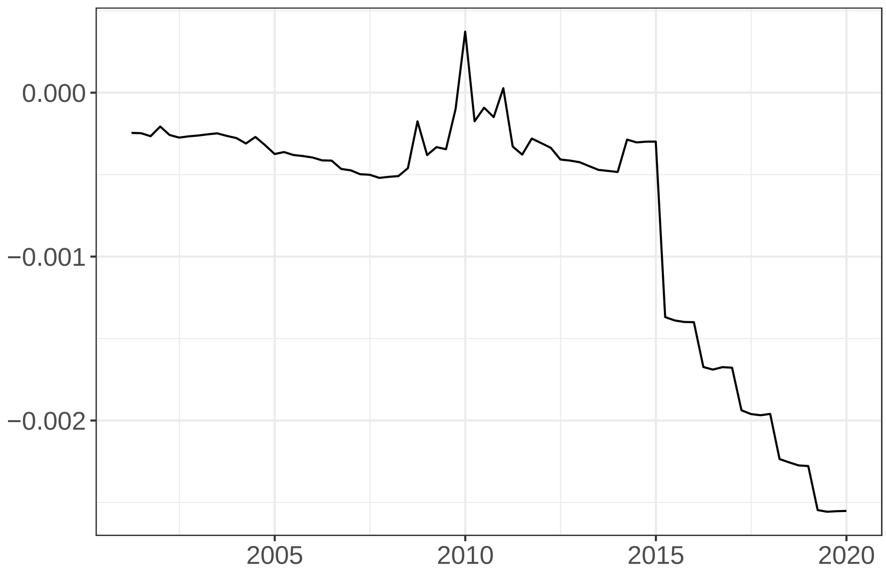


Table 1: Summary statistics of risk measures. The month-end equity beta and equity historical volatility are calculated using 252 daily stock returns. The monthly implied volatility of equity capital (ICC) is the average of Equation 7 and Equation 8. The monthly implied volatility of equity is obtained from the OptionMetrics database. Finally, we have one measurement of debt risk, the monthly cost of debt capital which is calculated from Equation 9.

Time: 2002 - 07 (583 BHCs)	N(of bank-month)	Mean	S.D.	Min	1st Qu.	3rd Qu.	Max
Equity beta	29372	0.681	0.628	-1.97	0.12	1.178	3.262
Equity historical vol	29372	0.307	0.15	0.041	0.221	0.347	3.237
ICC	14814	0.092	0.016	0.018	0.084	0.099	0.605
Implied volatility of equity	NaN	NaN	NaN	NaN	NaN	NaN	NaN
Cost of debt	30275	0.059	0.022	0.004	0.042	0.074	0.152
Time: 2010 - 14 (466 BHCs)							
Equity beta	20288	0.824	0.539	-1.404	0.321	1.219	2.968
Equity historical vol	20288	0.35	0.212	0.092	0.221	0.406	2.147
ICC	7365	0.087	0.023	0.003	0.075	0.1	0.283
Implied volatility of equity	3221	0.287	0.132	0.07	0.208	0.323	1.736
Cost of debt	20326	0.025	0.016	0.001	0.013	0.033	0.23
Time: 2015 - 19 (381 BHCs)							
Equity beta	16494	0.989	0.447	-1.454	0.705	1.27	6.54
Equity historical vol	16494	0.299	0.162	0.087	0.223	0.299	5.286
ICC	5754	0.088	0.018	0.006	0.077	0.097	0.189
Implied volatility of equity	5672	0.264	0.086	0.042	0.216	0.288	1.384
Cost of debt	17085	0.015	0.009	0.001	0.009	0.019	0.069
Regression sample period: 2012 - 19 (466 BHCs)							
Equity beta	29129	0.893	0.476	-1.454	0.613	1.192	6.54
Equity historical vol	29129	0.288	0.155	0.087	0.215	0.296	5.286
ICC	10400	0.086	0.02	0.003	0.075	0.096	0.236
Implied volatility of equity	8191	0.263	0.095	0.042	0.211	0.289	1.736
Cost of debt	27576	0.016	0.01	0.001	0.009	0.02	0.209

Table 2: Summary statistics of the balance sheet data. We obtain the quarterly balance sheet data of BHCs from FR Y-9C reports. We then span the quarterly data to monthly in order to match the bank risk data.

Time: 2002 - 07 (583 BHCs)	N (of bank-month)	Mean	S.D.	Min	1st Qu.	3rd Qu.	Max
Tier 1 ratio (%)	31062	12.59	7.18	0.57	10.07	13.24	150.55
Book equity to asset ratio (%)	31072	9.33	5	1.71	7.53	10.1	83
Market equity to asset ratio (%)	31072	17.61	15.2	1.04	12.51	20.31	600.83
Market equity to book equity ratio (%)	31072	190.81	69.22	16.2	142	225.64	865.11
Deposit to liability ratio (%)	31072	81.33	14.6	0	76.11	90.69	99.89
Loan to asset ratio (%)	31072	64.49	13.98	0	58.17	73.55	93.54
Time: 2010 - 14 (466 BHCs)							
Tier 1 ratio (%)	15887	14.25	5.16	-13.48	11.84	15.64	97.74
Book equity to asset ratio (%)	21138	10.72	4.44	-7.9	8.7	12.2	78.19
Market equity to asset ratio (%)	21138	11.33	11.72	0.09	6.67	13.97	268
Market equity to book equity ratio (%)	21138	100.05	63.91	-3259.68	67.89	124.32	543.55
Deposit to liability ratio (%)	21138	85.27	14.17	0.83	82.79	93.09	99.77
Loan to asset ratio (%)	21138	62.62	13.25	0.08	57.93	71.09	95.46
Time: 2015 - 19 (381 BHCs)							
Tier 1 ratio (%)	17101	13.48	3.8	-5.99	11.26	14.57	41.39
Book equity to asset ratio (%)	17212	11.53	2.94	-5.15	9.74	12.89	38.38
Market equity to asset ratio (%)	17212	15.96	6.47	0.96	11.93	18.65	68.57
Market equity to book equity ratio (%)	17212	139.52	48.61	-70.21	109.25	159.93	473.21
Deposit to liability ratio (%)	17212	85.93	12.34	1.55	83.3	92.8	99.67
Loan to asset ratio (%)	17212	67.43	14.21	0.07	63.5	76.17	94.03
Regression sample period: 2012 - 19 (466 BHCs)							
Tier 1 ratio (%)	24958	13.91	4.25	-5.99	11.51	15.15	58.74
Book equity to asset ratio (%)	30317	11.38	3.55	-5.15	9.43	12.75	68.09
Market equity to asset ratio (%)	30317	14.49	8.87	0.32	10.3	17.31	230.59
Market equity to book equity ratio (%)	30317	126.71	51.2	-70.21	95.71	149.3	498.55
Deposit to liability ratio (%)	30317	85.99	12.85	0.83	83.44	93.12	99.77
Loan to asset ratio (%)	30317	65.34	14.17	0.07	60.39	74.22	95.46

Table 3: Univariate regression of equity risk measures on excess capitalization (Panel A) and on total capitalization (Panel B). The regression formula is specified by: $\log \text{Equity risk}_{i,t} = \beta \log \text{Capitalization}_{i,t} + \text{Bank FE}_i + \epsilon_{i,t}$. We use four different methods to measure the equity risk, which are the forward-looking equity beta, forward-looking historical volatility, implied cost of equity capital (ICC) and implied equity volatility from options. The excess capitalization is defined as $\frac{V-D_B}{V}$, where $D_B = \frac{D}{1-\alpha\rho}$, and α is the ratio of risk-weighted asset to total book asset, ρ is the effective capital requirement. The total capitalization is the book equity ratio, defined as $\frac{V-D}{V}$. We include a bank fixed effect to control for the bank asset volatility.

	Dependent variable:			
Panel A	Log beta	Log hist. vol	Log ICC	Log impl. vol
	(1)	(2)	(3)	(4)
Log excess capital	-0.2140^{***}	-0.2299^{***}	-0.0986^{***}	-0.0787^{***}
	(0.0116)	(0.0069)	(0.0109)	(0.0126)
Bank FE	Yes	Yes	Yes	Yes
Observations	23,333	23,841	8,821	7,166
R^2	0.6073	0.3923	0.3626	0.3371
Adjusted R^2	0.5998	0.3808	0.3447	0.3147
Panel B				
Log total capital	-0.0272	-0.0605^{***}	-0.0665^{***}	-0.2013^{***}
	(0.0265)	(0.0148)	(0.0239)	(0.0296)
Bank FE	Yes	Yes	Yes	Yes
Observations	28,298	29,107	10,251	8,111
R^2	0.6184	0.4038	0.3661	0.3385
Adjusted R^2	0.6123	0.3945	0.3503	0.3187
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 4: Regression of equity risk measures on leverage and minimum capitalization. The regression formula is specified by: $\log \text{Equity risk}_{i,t} = \beta_1 \log \text{Leverage}_{i,t} + \beta_2 \log \text{Minimum capitalization}_{i,t} + \text{Bank FE}_i + \epsilon_{i,t}$. We use four different methods to measure the equity risk, which are the forward-looking equity beta, forward-looking historical volatility, implied cost of equity capital (ICC) and implied equity volatility from options. For the independent variable leverage, we use two measurements: the book leverage is defined as total book asset over total book equity; the risk leverage is defined as risk-weighted asset over Tier 1 equity capital. The minimum capitalization is defined as $\frac{D_B - D}{V}$, where $D_B = \frac{D}{1-\alpha\rho}$, and α is the ratio of risk-weighted asset to total book asset, ρ is the effective capital requirement. We include the bank fixed effect to control for the bank asset volatility.

	Dependent variable:							
	Log beta	Log hist. vol	Log ICC	Log impl. vol	Log beta	Log hist. vol	Log ICC	Log impl. vol
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log book leverage	0.0564**	0.0712***	0.1215***	0.2088***				
	(0.0283)	(0.0168)	(0.0256)	(0.0326)				
Log risk leverage					0.1124***	0.1012***	0.1958***	0.0507
					(0.0282)	(0.0166)	(0.0247)	(0.0324)
Log mincapital	0.2160***	0.2489***	0.0703***	0.0624***	0.1920***	0.2262***	0.0300***	0.0479***
	(0.0100)	(0.0060)	(0.0081)	(0.0100)	(0.0112)	(0.0067)	(0.0092)	(0.0108)
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	23,378	23,889	8,821	7,166	23,378	23,889	8,821	7,166
R^2	0.6090	0.4110	0.3631	0.3401	0.6092	0.4115	0.3661	0.3364
Adjusted R^2	0.6014	0.3999	0.3452	0.3177	0.6016	0.4004	0.3482	0.3139

Note: *p<0.1; **p<0.05; ***p<0.01

Table 5: Regression of equity risk measures on leverage and orthogonalized excess capitalization or regulatory adjustment. The regression formula is specified by: $\log \text{Equity risk}_{i,t} = \beta_1 \log \text{Leverage}_{i,t} + \beta_2 \text{Meausres of excess capitalization}_{i,t} + \text{Bank FE}_i + \epsilon_{i,t}$. We use four different methods to measure the equity risk, which are the forward-looking equity beta, forward-looking historical volatility, implied cost of equity capital (ICC) and implied equity volatility from options. For the independent variable leverage, we use two measurements: the book leverage is defined as total book asset over total book equity; the risk leverage is defined as risk-weighted asset over Tier 1 equity capital. In Panel A, the excess capitalization is measured by taking the residuals from the simple linear regression of excess capitalization ($\frac{V-D_B}{V}$) on the total capitalization($\frac{V-D}{V}$). We denote the residuals from the regression as the orthogonalized excess capitalization and use them to single out the effect solely stemming from excess capitalization. In Panel B, the excess capitalization is measured by the regulatory adjustment defined as $\log(1-\alpha\rho)$, where α is the ratio of risk-weighted asset to total book asset, ρ is the effective capital requirement. We include a bank fixed effect to control for the bank asset volatility.

	Dependent variable:							
Panel A	Log beta	Log hist. vol	Log ICC	Log impl. vol	Log beta	Log hist. vol	Log ICC	Log impl. vol
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log book leverage	0.0695**	0.1049***	0.1365***	0.2091***				
	(0.0284)	(0.0166)	(0.0257)	(0.0327)				
Log risk leverage					0.1272***	0.0745***	0.1889***	0.0669**
					(0.0276)	(0.0161)	(0.0237)	(0.0317)
Orthogonal excesscapital	−5.5412***	−7.3004***	−1.9229***	−1.3643***	−4.8831***	−6.8099***	−1.0099***	−0.9670***
	(0.2531)	(0.1500)	(0.2010)	(0.2424)	(0.2750)	(0.1627)	(0.2177)	(0.2564)
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	23,378	23,889	8,821	7,166	23,378	23,889	8,821	7,166
R^2	0.6092	0.4259	0.3643	0.3394	0.6095	0.4255	0.3669	0.3359
Adjusted R^2	0.6017	0.4151	0.3464	0.3170	0.6020	0.4146	0.3491	0.3134
Panel B								
Log book leverage	0.0844***	0.1272***	0.1343***	0.2088***				
	(0.0285)	(0.0167)	(0.0257)	(0.0329)				
Log risk leverage					0.1337***	0.0777***	0.1848***	0.0796**
					(0.0276)	(0.0161)	(0.0241)	(0.0319)
Regulatory adjustment	−5.1785***	−6.9381***	−1.8916***	−1.0845***	−4.4938***	−6.4027***	−0.9905***	−0.6207**
	(0.2400)	(0.1422)	(0.1936)	(0.2345)	(0.2590)	(0.1531)	(0.2137)	(0.2483)
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	23,378	23,889	8,821	7,166	23,378	23,889	8,821	7,166
R^2	0.6090	0.4262	0.3646	0.3384	0.6092	0.4254	0.3669	0.3352
Adjusted R^2	0.6015	0.4154	0.3467	0.3160	0.6017	0.4145	0.3491	0.3126
Note:								*p<0.1; **p<0.05; ***p<0.01

Table 6: Robustness regression of equity risk measures on leverage and orthogonalized excess capitalization. The regression formula is specified by: $\log \text{Equity risk}_{i,t} = \alpha_{i,t} + \beta_1 \log \text{Leverage}_{i,t} + \beta_2 \text{Orthogonalized excess capitalization}_{i,t} + \theta \text{Asset volatility}_{i,t} + \gamma_1 \text{Bank controls}_{i,t} + \gamma_2 \text{Bank industry controls}_t + \epsilon_{i,t}$. We use the standard deviation of five-year observations of quarterly asset return as a proxy of asset volatility. In addition, we include three bank-specific characteristics: loan to asset ratio, deposit to liability ratio and cash to asset ratio. We also add two bank industry factors: the average loan tightening index and the average interest margin in the regressions to control for the general trends that can affect the banking sector.

	Dependent variable:							
	Log beta	Log hist. vol	Log ICC	Log impl. vol	Log beta	Log hist. vol	Log ICC	Log impl. vol
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log book leverage	-0.6255^{***}	0.2782^{***}	0.0149	0.0144				
	(0.0206)	(0.0096)	(0.0135)	(0.0161)				
Log risk leverage					0.1178^{***}	0.0853^{***}	0.0171	-0.2611^{***}
					(0.0251)	(0.0118)	(0.0158)	(0.0185)
Orthogonal excesscapital	-6.2492^{***}	-5.5206^{***}	-2.5721^{***}	-1.3168^{***}	-6.8420^{***}	-4.6421^{***}	-2.5012^{***}	-2.5243^{***}
	(0.3582)	(0.1708)	(0.2045)	(0.2591)	(0.3782)	(0.1790)	(0.2172)	(0.2685)
Asset return s.d.	0.2441^{***}	0.3735^{***}	0.3851^{***}	0.3881^{***}	0.5473^{***}	0.1966^{***}	0.3738^{***}	0.4405^{***}
	(0.0737)	(0.0351)	(0.0400)	(0.0550)	(0.0750)	(0.0357)	(0.0396)	(0.0533)
Loan to asset ratio	-0.6074^{***}	-0.1971^{***}	0.0796^{***}	-0.0207	-0.6828^{***}	-0.2230^{***}	0.0714^{**}	0.1160^{***}
	(0.0457)	(0.0218)	(0.0271)	(0.0309)	(0.0480)	(0.0228)	(0.0279)	(0.0319)
Deposit to liability ratio	-0.7017^{***}	0.3025^{***}	-0.5234^{***}	0.3132^{***}	-0.7478^{***}	0.3342^{***}	-0.5222^{***}	0.2991^{***}
	(0.0417)	(0.0200)	(0.0227)	(0.0271)	(0.0426)	(0.0203)	(0.0227)	(0.0267)
Cash to asset ratio	-0.3556^{***}	0.4326^{***}	-0.1728^{***}	-0.0241	-0.6928^{***}	0.5798^{***}	-0.1670^{***}	0.0356
	(0.1050)	(0.0501)	(0.0558)	(0.0806)	(0.1067)	(0.0507)	(0.0554)	(0.0784)
Loan tightening index	0.0152^{***}	0.0095^{***}	0.0009^{**}	0.0028^{***}	0.0154^{***}	0.0094^{***}	0.0009^{**}	0.0026^{***}
	(0.0006)	(0.0003)	(0.0004)	(0.0005)	(0.0006)	(0.0003)	(0.0004)	(0.0005)
Interest rate margin	0.0438	0.7684^{***}	0.1164^{***}	-0.0975^{***}	0.0745^{**}	0.7670^{***}	0.1182^{***}	-0.1468^{***}
	(0.0328)	(0.0156)	(0.0210)	(0.0265)	(0.0335)	(0.0159)	(0.0210)	(0.0263)
Constant	2.1273^{***}	-4.5088^{***}	-2.5214^{***}	-4.0358^{***}	0.4891^{***}	-4.0649^{***}	-2.5249^{***}	-3.3969^{***}
	(0.1195)	(0.0565)	(0.0747)	(0.0971)	(0.1232)	(0.0581)	(0.0763)	(0.0978)
Bank FE	No	No	No	No	No	No	No	No
Observations	20,869	21,288	7,929	6,612	20,869	21,288	7,929	6,612
R^2	0.1275	0.1925	0.1093	0.0655	0.0898	0.1629	0.1093	0.0929
Adjusted R^2	0.1272	0.1922	0.1084	0.0643	0.0895	0.1626	0.1084	0.0918

Note: *p<0.1; **p<0.05; ***p<0.01

Table 7: Regression of ME/BE ratio on leverage and minimum capitalization, orthogonalized excess capitalization or regulatory adjustment. The regression formula is specified by: $\Delta(\text{ME/BE ratio})_{i,t} = \beta_1 \Delta\text{Leverage}_{i,t} + \beta_2 \Delta\text{Measures of excess capitalization}_{i,t} + \gamma_1 \Delta\text{Bank controls}_{i,t} + \gamma_2 \Delta\text{Bank industry controls}_t + \text{Bank FE}_i + \epsilon_{i,t}$. We take the first difference regression to mitigate the concern of non-stationary MB/BE ratio and we include the bank fixed effect to control for the bank asset volatility.

	Dependent variable:					
	Δ ME/BE ratio					
	(1)	(2)	(3)	(4)	(5)	(6)
ΔBook leverage	0.0226***		0.0329***		0.0325***	
	(0.0015)		(0.0015)		(0.0015)	
ΔRisk leverage		0.0022*		0.0047***		0.0047***
		(0.0013)		(0.0014)		(0.0014)
ΔMincapital	−6.9377***	−6.8338***				
	(0.7188)	(0.7233)				
ΔOrthogonal excesscapital			10.2251***	10.7186***		
			(0.3776)	(0.3826)		
ΔRegulatory adjustment					9.7442***	10.3044***
					(0.3633)	(0.3678)
ΔLoan to asset ratio	0.2904***	0.2619***	0.5635***	0.5363***	0.5869***	0.5663***
	(0.0868)	(0.0873)	(0.0816)	(0.0825)	(0.0818)	(0.0828)
ΔDep. to liability ratio	−0.2124***	−0.2744***	−0.2128***	−0.3022***	−0.1962***	−0.2824***
	(0.0588)	(0.0590)	(0.0595)	(0.0600)	(0.0596)	(0.0601)
ΔCash to asset ratio	−0.3451***	−0.2213***	−0.2811***	−0.1146	−0.3032***	−0.1405*
	(0.0833)	(0.0834)	(0.0806)	(0.0811)	(0.0806)	(0.0811)
ΔLoan tight index	−0.0016***	−0.0016***	−0.0018***	−0.0018***	−0.0018***	−0.0018***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
ΔInterest margin	0.0864***	0.0829***	0.1732***	0.1792***	0.1738***	0.1794***
	(0.0186)	(0.0187)	(0.0152)	(0.0154)	(0.0152)	(0.0153)
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	24,221	24,221	24,478	24,478	24,478	24,478
R^2	0.0308	0.0212	0.0751	0.0558	0.0746	0.0558
Adjusted R^2	0.0118	0.0021	0.0573	0.0376	0.0568	0.0376

Note: *p<0.1; **p<0.05; ***p<0.01

Table 8: Regression of cost of debt spread on the capital requirement. The regression is specified by $\text{Cost of debt spread}_{i,t} = \beta_1 \text{Leverage}_{i,t} + \beta_2 \text{Minimum capitalization}_{i,t} + \delta \text{Treasury yield 1Y}_t + \gamma_1 \text{Bank controls}_{i,t} + \gamma_2 \text{Bank industry controls}_t + \text{Bank FE}_i + \epsilon_{i,t}$. The dependent variable cost of debt spread is calculated by the cost of interest expenses over the total liability, subtract the one-year treasury yield. We include the one-year treasury rate to control for the general variation in the interest rate. We use quarterly data sample in this regression because the dependent variable cost of debt is a quarterly time series. We include the bank fixed effect to control for the bank asset volatility.

	Dependent variable:			
	Cost of debt spread			
	(1)	(2)	(3)	(4)
Book leverage	0.0001***			
	(0.00004)			
Risk leverage		0.0002***		
		(0.00005)		
Excesscapital			−0.0126***	
			(0.0038)	
Mincapital	−0.0556***	−0.0630***	−0.0683***	−0.0559***
	(0.0107)	(0.0109)	(0.0114)	(0.0107)
Treasury yield 1Y	−0.5371***	−0.5324***	−0.5365***	−0.5399***
	(0.0164)	(0.0165)	(0.0164)	(0.0164)
Loan to asset ratio	0.0075***	0.0066***	0.0073***	0.0077***
	(0.0014)	(0.0014)	(0.0014)	(0.0014)
Deposit to liability ratio	−0.0420***	−0.0418***	−0.0421***	−0.0424***
	(0.0014)	(0.0014)	(0.0014)	(0.0014)
Cash to asset ratio	0.0113***	0.0119***	0.0113***	0.0122***
	(0.0022)	(0.0022)	(0.0022)	(0.0022)
Loan tightening index	−0.00003***	−0.00003***	−0.00003***	−0.00003***
	(0.00001)	(0.00001)	(0.00001)	(0.00001)
Interest rate margin	0.0118***	0.0118***	0.0119***	0.0119***
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Bank FE	Yes	Yes	Yes	Yes
Observations	7,626	7,626	7,626	7,626
R^2	0.8603	0.8604	0.8604	0.8602
Adjusted R^2	0.8518	0.8519	0.8519	0.8517
Note:				*p<0.1; **p<0.05; ***p<0.01

6 Bibliography

Admati, A. R., DeMarzo, P. M., Hellvig, M., and Pfleiderer, P. (2013). Fallacies, irrelevant facts, and myths in the discussion of capital regulation: Why bank equity is not expensive. *Stanford University Working Paper 2065*. Available at https://www.gsb.stanford.edu/faculty-research/working-papers/fallacies-irrelevant-facts-myths-discussion-capital-regulation-why.

Basten, M. and Sánchez Serrano, A. (2019). European banks after the global financial crisis: a new landscape. *Journal of Banking Regulation*, 20(1):51–73.

Bennett, R. L. and Unal, H. (2015). Understanding the components of bank failure resolution costs. *Financial Markets, Institutions and Instruments*, 24:349–389.

Berger, A. N., DeYoung, R., Flannery, M. J., Lee, D., and Öztekin, Ö. (2008). How do large banking organizations manage their capital ratios? *Journal of Financial Services Research*, 34(2-3):123–149.

Black, F. and Cox, J. (1976). Valuing corporate securities: Some effects of bond indenture provisions. *Journal of Finance*, 31:351–367.

Board of Governors of the Federal Reserve System (FRB) (2022). Report form of FR Y-9C. Available at https://www.federalreserve.gov/apps/reportforms/reportdetail.aspx?sOoYJ+5BzDal8cbqnRxZRg==.

Chan-Lau, J. A. and Sy, A. N. R. (2007). Distance-to-default in banking: A bridge too far? *Journal of Banking Regulation*, 9(1):14–24.

Choi, D. B., Holcomb, M. R., and Morgan, D. P. (2020). Bank leverage limits and regulatory arbitrage: Old question-new evidence. *Journal of Money, Credit and Banking*, 52(S1):241–266.

Chousakos, K. T. and Gorton, G. B. (2017). Bank health post-crisis. *National Bureau of Economic Research Working Paper 23167*. Available at https://www.nber.org/papers/w23167.

Couaillier, C. (2021). What are banks' actual capital targets? *ECB Working Paper No. 2618*. Available at `https://papers.ssrn.com/abstract=3975940`.

Dick-Nielsen, J., Gyntelberg, J., and Thimsen, C. (2022). The cost of capital for banks: Evidence from analyst earnings forecasts. *The Journal of Finance*, 77(5):2577–2611.

Duarte, F. and Eisenbach, T. M. (2021). Fire-sale spillovers and systemic risk. *The Journal of Finance*, 76(3):1251–1294.

Federal Reserve Bank of New York (2021). Report form of FR Y-9C. Available at `https://www.newyorkfed.org/research/banking_research/datasets.html`.

Fernholz, R. T. and Koch, C. (2017). Big banks, idiosyncratic volatility, and systemic risk. *American Economic Review*, 107(5):603–607.

Glasserman, P. and Nouri, B. (2012). Contingent capital with a capital-ratio trigger. *Management Science*, 58(10):1816–1833.

Greenwood, R., Landier, A., and Thesmar, D. (2015). Vulnerable banks. *Journal of Financial Economics*, 115(3):471–485.

Gropp, R. and Heider, F. (2010). The determinants of bank capital structure. *Review of Finance*, 14(4):587–622.

Kovner, A. and Van Tassel, P. (2022). Evaluating regulatory reform: Banks' cost of capital and lending. *Journal of Money, Credit and Banking*, 54(5):1313–1367.

Kroen, T. (2022). Payout restrictions and bank risk-shifting. *Working Paper*. Available at `https://papers.ssrn.com/abstract=4057374`.

Lee, C. M., So, E. C., and Wang, C. C. (2021). Evaluating firm-level expected-return proxies: Implications for estimating treatment effects. *The Review of Financial Studies*, 34(4):1907–1951.

Merton, R. (1974). On the pricing of corporate debt: The risk structure of interest rates. *Journal of Finance*, 29:449–470.

Nagel, S. and Purnanandam, A. (2020). Banks' risk dynamics and distance to default. *The Review of Financial Studies*, 33(6):2421–2467.

Pierret, D. and Steri, R. (2020). Stressed banks. *Working Paper*. Available at https://papers.ssrn.com/abstract=3066403.

Salas-Pérez, R. (2018). Western commercial G-SIBs and the TBTF mentality: Has the designation policy been effective to make global banks safer? *Working Paper*. Available at https://papers.ssrn.com/abstract=3166961.

Sarin, N. and Summers, L. H. (2016). Have big banks gotten safer? *Brookings Papers on Economic Activity*.

Walter, J. R. (2019). U.S. bank capital regulation: History and changes since the financial crisis. *Economic Quarterly*, 105(1):1–40.

Welch, I. and Goyal, A. (2008). A comprehensive look at the empirical performance of equity premium prediction. *The Review of Financial Studies*, 21(4):1455–1508.

WRDS Research (2017). WRDS Option Suite: Data overview and construction manual. Available at https://wrds-www.wharton.upenn.edu/pages/get-data/option-suite-wrds/us-stock-level-output/.

Appendices

A.1 Details in solving equity volatility

Take partial derivative on Equation 4 with respect to V:

$$\frac{\partial E}{\partial V} = \Phi(d_1^{D_B}) + \underbrace{V_0\varphi(d_1^{D_B})\frac{\partial d_1^{D_B}}{\partial V} - De^{-rT}\varphi(d_2^{D_B})\frac{\partial d_2^{D_B}}{\partial V}}_{\lambda} \tag{A.1}$$

Denote the terms apart from $\Phi(d_1^{D_B})$ as λ, we can further simplify it. First find out the partial derivative of $d_1^{D_B}$ and $d_2^{D_B}$ with respect to V:

$$\frac{\partial d_1^{D_B}}{\partial V} = \frac{\partial d_2^{D_B}}{\partial V} = \frac{1}{V_0\sigma\sqrt{T}} \tag{A.2}$$

Then rewrite the multiplier of $\frac{\partial d_2^{D_B}}{\partial V}$ in the last term in Equation A.1:

$$\begin{aligned}
De^{-rT}\varphi(d_2^{D_B}) &= De^{-rT}\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}(d_2^{D_B})^2} \\
&= De^{-rT}\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}(d_1^{D_B}-\sigma\sqrt{T})^2} \\
&= De^{-rT}\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}(d_1^{D_B})^2}e^{d_1^{D_B}\sigma\sqrt{T}-\frac{1}{2}\sigma^2 T} \\
&= De^{-rT}\varphi(d_1^{D_B})e^{d_1^{D_B}\sigma\sqrt{T}-\frac{1}{2}\sigma^2 T} \\
&= De^{-rT}\varphi(d_1^{D_B})e^{\log\frac{V_0}{D_B}+rT+\frac{1}{2}\sigma^2 T-\frac{1}{2}\sigma^2 T} \\
&= \frac{V_0 D}{D_B}\varphi(d_1^{D_B})
\end{aligned} \tag{A.3}$$

Combine the above equations, we can solve λ and $\frac{\partial E}{\partial V}$:

$$\lambda = \left(V_0 - \frac{V_0 D}{D_B}\right)\varphi(d_1^{D_B})\frac{1}{V_0\sigma\sqrt{T}} = \frac{D_B - D}{D_B}\varphi(d_1^{D_B})\frac{1}{\sigma\sqrt{T}} \tag{A.4}$$

A.2 Additional tables and figures

Table A.I: Regression of equity risk measures on leverage and orthogonalized excess capitalization (control for the standard deviation of asset returns and other bank/bank industry specific characteristics as well as macro variables). The regression formula is specified by: $\log \text{Equity risk}_{i,t} = \alpha_{i,t} + \beta_1 \log \text{Leverage}_{i,t} + \beta_2 \log \text{Orthogonalized excess capitalization}_{i,t} + \theta \text{Asset volatility}_{i,t} + \gamma_1 \text{Bank controls}_{i,t} + \gamma_2 \text{Bank industry controls}_t + \gamma_3 \text{Other macro controls}_t + \epsilon_{i,t}$.

	Dependent variable:							
	Log beta	Log hist. vol	Log ICC	Log impl. vol	Log beta	Log hist. vol	Log ICC	Log impl. vol
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log book leverage	−0.6303***	0.3121***	0.0080	0.0294*				
	(0.0206)	(0.0090)	(0.0136)	(0.0153)				
Log risk leverage					0.1680***	0.1128***	−0.0023	−0.2419***
					(0.0266)	(0.0117)	(0.0171)	(0.0194)
Orthogonal excesscapital	−6.4690***	−3.5893***	−3.3320***	0.8852**	−2.8338***	−2.8705***	−3.4073***	−2.3576***
	(0.6996)	(0.3129)	(0.4140)	(0.4173)	(0.7915)	(0.3546)	(0.4701)	(0.4768)
Asset return s.d.	0.2460***	0.4114***	0.3797***	0.3961***	0.5347***	0.2054***	0.3763***	0.4342***
	(0.0730)	(0.0323)	(0.0395)	(0.0516)	(0.0743)	(0.0332)	(0.0392)	(0.0503)
Loan to asset ratio	−0.6079***	−0.1064***	0.0677**	0.0669**	−0.5758***	−0.1550***	0.0659**	0.1041***
	(0.0492)	(0.0219)	(0.0299)	(0.0323)	(0.0504)	(0.0225)	(0.0297)	(0.0319)
Dep. to liability ratio	−0.7188***	0.3164***	−0.5294***	0.2655***	−0.7536***	0.3515***	−0.5294***	0.2732***
	(0.0414)	(0.0185)	(0.0225)	(0.0257)	(0.0423)	(0.0189)	(0.0225)	(0.0253)
Cash to asset ratio	−0.3492***	0.4357***	−0.1416**	0.0005	−0.6388***	0.5953***	−0.1373**	0.0252
	(0.1041)	(0.0463)	(0.0552)	(0.0759)	(0.1059)	(0.0473)	(0.0548)	(0.0742)
Loan tight index	0.0095***	0.0042***	0.0015***	0.0013**	0.0096***	0.0041***	0.0015***	0.0013**
	(0.0009)	(0.0004)	(0.0005)	(0.0007)	(0.0009)	(0.0004)	(0.0005)	(0.0006)
Interest margin	0.1623**	0.4029***	−0.1495***	−0.2325***	0.1168	0.4287***	−0.1488***	−0.2456***
	(0.0754)	(0.0336)	(0.0468)	(0.0549)	(0.0770)	(0.0344)	(0.0468)	(0.0543)
Macro dp	2.0096***	−0.2375**	−1.0014***	1.7368***	2.0346***	−0.2402**	−1.0021***	1.6599***
	(0.2164)	(0.0957)	(0.1245)	(0.1626)	(0.2210)	(0.0981)	(0.1245)	(0.1609)
Macro ep	−0.3869***	0.0261	0.2912***	0.4402***	−0.5526***	0.0286	0.2941***	0.5638***
	(0.1132)	(0.0505)	(0.0679)	(0.0814)	(0.1161)	(0.0520)	(0.0682)	(0.0809)
Macro bm	2.6816***	−1.2092***	0.6378*	−2.9847***	2.6072***	−1.2577***	0.6393*	−2.7557***
	(0.5731)	(0.2547)	(0.3315)	(0.3934)	(0.5853)	(0.2613)	(0.3317)	(0.3893)
Macro ntis	−1.6031**	12.3706***	−3.7596***	−4.2924***	−0.5159	11.9613***	−3.7657***	−4.4026***
	(0.7887)	(0.3506)	(0.5107)	(0.5607)	(0.8049)	(0.3594)	(0.5106)	(0.5540)
Macro tbl	13.8465***	−19.7463***	1.9122	−2.8298*	17.1142***	−20.2096***	1.8701	−4.4287***
	(2.4098)	(1.0726)	(1.5282)	(1.6426)	(2.4646)	(1.1018)	(1.5291)	(1.6281)
Macro tms	−0.5139	−26.5324***	1.7132*	−1.9927**	−3.6188**	−25.8010***	1.7589*	−1.0381
	(1.4048)	(0.6249)	(0.9489)	(0.9970)	(1.4377)	(0.6422)	(0.9521)	(0.9866)
Macro dfy	−13.8144***	39.5321***	8.8510***	−32.0969***	−11.5433***	38.8231***	8.8331***	−32.5400***
	(3.1139)	(1.3859)	(1.9639)	(2.3117)	(3.1800)	(1.4216)	(1.9641)	(2.2853)
Macro svar	−46.2797***	−14.9734***	9.5877***	−60.1484***	−45.5105***	−14.7771***	9.5745***	−60.3015***
	(4.1553)	(1.8521)	(2.5785)	(2.8760)	(4.2445)	(1.9002)	(2.5790)	(2.8433)
Constant	7.7281***	−3.5479***	−5.0709***	5.7504***	5.7860***	−3.1563***	−5.0450***	6.3200***
	(1.0815)	(0.4792)	(0.6179)	(0.7792)	(1.1064)	(0.4923)	(0.6191)	(0.7706)
Bank FE	No	No	No	No	No	No	No	No
Observations	20,869	21,288	7,929	6,612	20,869	21,288	7,929	6,612
R^2	0.1459	0.3140	0.1329	0.1792	0.1093	0.2782	0.1328	0.1978
Adjusted R^2	0.1453	0.3135	0.1311	0.1772	0.1086	0.2777	0.1311	0.1958
Note:								*p<0.1; **p<0.05; ***p<0.01