Deposit Market Competition and Equity Capital Issuance *

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Abstract

This article investigates the relationship between equity capital and deposits in the U.S. banking industry. We find empirical evidence that the cost of deposits is a significant factor in a bank's equity capital issuance since higher deposit costs increase the bank's insolvency risk. Our analysis highlights that a bank with a well-diversified deposit base may face higher insolvency risk, especially when deposit costs are sufficiently high. We propose a structural model of deposit markets to incorporate our findings and illustrate how deposit competition affects banks' deposit costs and equity capital issuance. The counterfactuals imply that higher capital requirements may increase the likelihood of default for larger and more diversified banks, as the policy makes the local deposit market more competitive and raises deposit costs. Additional regulations, such as caps on deposit rates, may mitigate this effect while making equity issuance more frequent.

Keywords: Deposit Competition, Equity Issuance, Bank Competition

JEL Classification: E44; G21; G28

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1 Introduction

1.1 Motivation

This paper is an empirical study of the role of deposit market diversification in banks' capital structures. While earlier works have focused on the financing between deposits and equity capital, we additionally consider the geographical composition of these deposits. We consider the following question: How would the equity capital issuance decision differ for a bank whose depositors are concentrated in a single area and a bank whose depositors are based in multiple regions? If there are differences, what are their implications for policies aimed at improving financial stability, such as capital requirements?

This capital structure effect of depositor distribution is not obvious, as there is a tradeoff between its benefits and costs well highlighted in the literature. On the one hand, having a more dispersed deposit base can lead to a lower cost of capital through diversification (Aguirregabiria et al., 2016). On the other hand, operating branches across geographic regions is costly, subjecting bank headquarters to greater regulatory requirements as well as raising the difficulty of screening and monitoring their subsidiaries (Berger and DeYoung, 2001; Berger et al., 2005). On the margin, therefore, the decision to issue equity by a bank with a well-diversified depositor base will be substantially different from that of a bank with a less diversified depositor base. The net effect of diversification is thus an empirical question, and one that could be best asked with a quantitative model.

To answer this question, we build and structurally estimate a model of deposit market competition. We combine FR Y-9C, Call Reports, Summary of Deposits, and RateWatch to observe banks' equity capital issuance and county-level entry decisions, market shares, deposit rates, and deposit costs between 2001 and 2014.

The dataset allows us to study the determinants of equity issuance and offers motivating empirical evidence for the aforementioned tradeoff of diversification. We first study the determinants of bank holding companies' equity issuance through predictive regressions using bank-level profitability and cost measures. We find that banks' deposit costs positively predict their future equity issuance. This is therefore consistent with the notion that banks issue equity to fund their rising costs rather than expand their operations in good states. We then use the data to estimate a regression with multi-way fixed effects to study the determinants of the Z-score, a distance-to-default type measure of bank solvency (Lepetit and Strobel, 2015). When the cost of deposits is relatively lower at 1%, a 1% increase in the diversification index is associated with a 0.077% *increase* in the Z-score. However, when the cost of deposits is 3%, a 1% increase in banks' deposit diversification index is associated with a 0.055% *decrease* in the score. The result suggests that the deposit source diversification strategy may not always be risk-free if deposit costs are sufficiently high. Moreover, a well-diversified deposit funding source is able to amplify as well as diminish the effect of deposit costs on insolvency risk.

We proceed to build a structural model to study how deposit market competition can affect equity capital issuance. The model extends that of Egan et al. (2017) by incorporating multiple regional markets into deposit competition. If a bank collects deposits in multiple regions, it competes for deposits by playing a deposit rate setting game with competitors in each regional market. The cost of deposits is determined as a result of deposit market competition. For a given amount of deposits, the cost of deposits affects the bank's market value, leading bank shareholders to decide whether to default. The bank's shareholders raise additional funds through equity capital issuance if the market value of a distressed bank is high enough.

We use the simulated method of moments to estimate demand parameters based on depositors' preferences and supply parameters associated with profit shocks. The estimates show that a bank is less likely to issue equity capital when collecting deposits in more regional markets. To understand the mechanism behind the outcome, we simulate two scenarios to confirm that the main advantage of having a well-diversified deposit base is the ability to control the cost of deposits.

Our counterfactual analyses uncover new policy implications. Notably, our model shows that more restrictive capital requirements may *increase* the likelihood of default for large banks with well-diversified deposit bases. When the capital requirements are more strict, a bank faces a higher average return with lower volatility in loan investment. Therefore, a bank collecting deposits from multiple markets can encounter more competitors with good returns. Due to increased competition on the deposit market, the bank increases deposit rates across all regional markets. The bank instead loses deposit market share, resulting in higher deposit costs. The impact of a higher capital ratio is exacerbated by a diverse deposit funding base. The finding is consistent with our earlier observation that a well-diversified deposit funding base can amplify the negative impact of the cost of deposits on the Z-score when the cost of deposits is high. Imposing a ceiling on deposit rates, similar to the one in place by the Federal Deposit Insurance Corporation (FDIC), can mitigate this rise in default rates by limiting the intensity of rate competition, and thus reducing the cost of deposits.

1.2 Literature Review

With our paper, we aim to contribute to the following three areas of the banking literature. Firstly, we use insights from structural models of banking and tailor our model to understand the role of geographical deposit market competition on banks' equity issuance. We adopt the workhorse model by Egan et al. (2017), who study the role of deposit market competition on financial stability. We also relate to the model by Aguirregabiria et al. (2016), who utilize a banking market with oligopolistic competition and endogenous branch network choice to understand how banks diversify their deposit market risk. We combine the elements from earlier work to best answer our research question: introducing geographical risk to Egan et al. (2017), and incorporating financing and equity issuance to Aguirregabiria et al. (2016). At the same time, we are able to retain the simplicity and tractability of our model by considering bank branch networks as exogenous, under the assumption that geographical risk diversification is more slow-moving than banks' equity issuance.

Secondly, our work relates to the empirical work on banks' capital structure and equity issuance.

Baron (2020) finds what he calls 'countercyclical bank equity issuance', where implicit government guarantees to creditors lower banks' incentives to raise equity during credit expansions. Goetz et al. (2021) find that greater insider ownership leads to less equity capital issuance, as bank insiders do not want to dilute their private benefits. Our paper additionally highlights deposit market competition and geographical risk diversification as important drivers of equity capital issuance.

Thirdly, our model's counterfactual exercises with capital requirements and interest rate regulations have financial stability implications. Since the global financial crisis of 2008, a large literature has studied the role of capital requirements on financial stability (Van den Heuvel, 2008; De Nicolò et al., 2014; Begenau and Stafford, 2022; Corbae and D'Erasmo, 2021). We contribute by illustrating how a tighter capital requirement could counterfactually *increase* defaults of large banks while decreasing those of smaller banks due to greater competition.

The paper closest to ours to date is by Levine et al. (2021), who study how banks' geographical diversification affects their interest-bearing liabilities. The authors find that: banks' funding costs decreased the most when banks expanded into states whose economies are less correlated, and the costs of uninsured deposits were reduced. We corroborate their findings on deposit costs with our evidence on equities, and with a structural model of banking competition.

The remainder of the paper is laid out as follows: Section 2 constructs our sample, defines key variables, specifies econometric models, and discusses empirical evidence. Section 3 describes the banking industry model. Section 4 explains the calibration and estimation of parameters in the model, and Section 5 shows the simulation results. Section 6 concludes the paper.

2 Empirical Analysis

In this section, we present two novel observations showing a link between deposit market competition and equity capital issuance in the U.S. banking system. Our first empirical study, which uses binary choice models with two-way fixed effects (Fernández-Val and Weidner (2016)), shows that the cost of deposits is a significant predictor of equity capital issuance. The second empirical analysis further examines the results, demonstrating that a higher deposit cost increases the bank's likelihood of insolvency. As a result, the bank raises money through equity capital issuance to protect shareholder value. We also find that a bank with a diverse deposit base interacts with the cost of deposits and influences insolvency risk and equity capital issuance. The findings inspire us to construct a structural model in Section 3.

2.1 Data Construction

For our empirical analysis, we combine three data sources for the U.S. banking sector from 2001:Q1 to 2014:Q4. For some analyses, we divide the full sample into two sub-samples: before the financial crisis (from 2001:Q1 to 2007:Q4) and after the financial crisis (from 2008:Q1 to 2014:Q4). The entity in our sample is a bank holding company. The holding company may have multiple commercial banks as subsidiaries. Each commercial bank operates local branches to compete for deposits. The

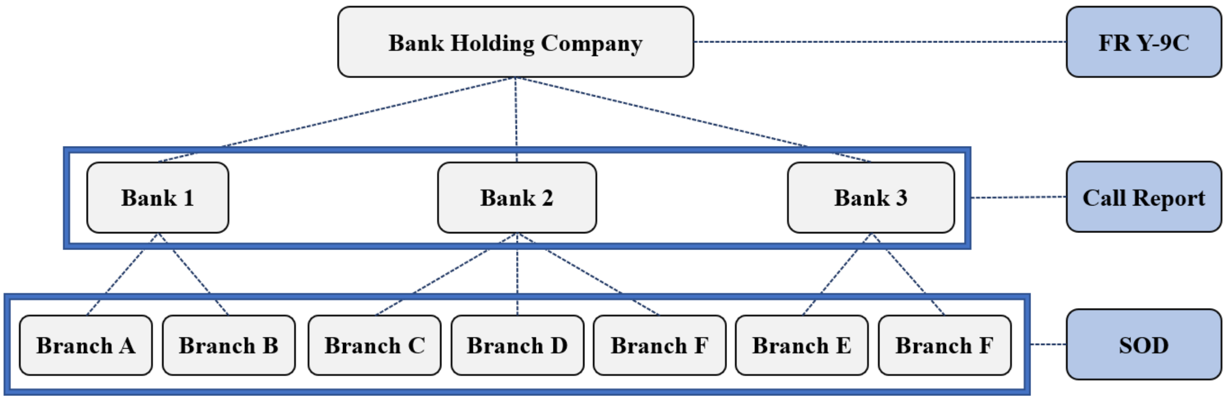


Figure 1: Organizational Structure of Bank Holding Companies and Data Sources

deposit rate is a branch-level decision that determines market share, whereas equity capital issuance is a decision made at the holding company level. The data sources cover variables associated with different decisions within a bank holding company. Figure 1 depicts an organizational structure within a bank holding company.

We collect equity capital issuance information from Consolidated Financial Statements for Holding Companies (FR Y-9C) quarterly provided by the Federal Reserve Board (FRB). Using information from the Federal Reserve Bank of New York, we only consider institutions that are publicly traded on the New York Stock Exchange or the NASDAQ. We link regulatory identification numbers (RSSD ID) from the National Information Center to the permanent company number (PERMCO) used in the Center for Research in Security Prices. We exclude a bank holding company whose RSSD ID is not linked to any PERMCO, because no link implies that the institution is not publicly traded on the stock exchanges.

Because a bank holding company can have multiple commercial banks as subsidiaries, we aggregate the balance sheets and income statements to define a representative variable for the bank holding company. For example, the total deposits of the bank holding company in Figure 1 are the sum of deposits from Banks 1, 2, and 3. We gather information on the balance sheets and income statements of commercial banks from the Report of Condition and Income quarterly issued by the FDIC, also known as the Call Report. In the Call Report, a commercial bank's holding company has a unique number called the RSSD ID. The ID variable enables us to put together information about commercial banks that are owned by the same holding company. In Appendix A, we show the bank capital structure and deposit composition of bank holding companies in our sample.

A commercial bank operates branches to collect deposits in multiple markets. Geographical information on deposits is from the Summary of Deposits (SOD), the annual survey of the FDIC. The geographical segmentation of deposit markets is a well-documented fact.[1] Each deposit mar-

[1] Drechsler et al. (2017) use county-level information to show that a branch in more concentrated deposit markets increases the deposit rate less due to its regional market power after the federal funds rate rises. Aguirregabiria et al. (2020) also use county-level deposit market information to investigate the geographical imbalance between deposits

ket has a different characteristic from the others. Figure A3 shows county-level deposit market concentrations in the U.S. in 2015, measured by the Herfindahl-Hirschman Index (HHI). A darker shade of blue indicates a more concentrated deposit market, or a higher level of HHI.

The SOD provides a bank's history of establishing its branches. For example, Figure A4 shows how Wells Fargo has expanded its deposit funding base as well as its county-level deposit market share over time. A darker shade of green indicates a higher deposit market share for Wells Fargo in a given county. Between 1995 and 2005, Wells Fargo established more branches across the country and acquired other financial institutions after the Riegle-Neal Interstate Banking and Branching Efficiency Act of 1994. A major reason behind the change in the deposit funding base from 2005 to 2015 is that Wells Fargo acquired Wachovia after the financial crisis of 2008. Since the unique institution reported in SOD is a subsidiary under a bank holding company, we aggregate the information of institutions with the same RSSD ID to define a variable for the bank holding company. We define the representative market share of the bank holding company in Figure 1 by using the weighted average market share over all branches.

Using RSSD ID, we merge FR Y-9C, Call Report, and SOD. We drop observations with negative capital ratios. We also exclude observations with negative values for deposits. After the initial cleaning process, we remain bank holding companies, with observations spanning at least three full calendar years. Our sample includes approximately 1,000 bank holding companies on average per year during the sample period. Annually, these institutions account for 70% of the total deposits reported in the Call Report. Most bank holding companies in our sample rely on deposits for their debt financing. Only some megabanks, such as Globally Systematically Important Banks (GSIB) and Domestically Systematically Important Banks (DSIB), finance a small portion of their projects through subordinated debt, a type of non-deposit financing.[2]

2.2 Definition of Variables

With the constructed sample, we expound on some key variables used in our main empirical analysis. The analysis using alternative definitions of the variables is displayed in Appendix B for robustness.

and loans. These articles assume that depositors only consider deposit-taking institutions in their proximity because of transportation costs. Honka et al. (2017) supports the supposition by providing evidence that the availability of nearby branches influences people's decisions to open new bank accounts. More recently, Abrams (2020) shows that customers are quite attentive to which banks are situated in their regions. Though Begenau and Stafford (2022) show that recently in the U.S. the majority of branches apply a uniform deposit pricing strategy, we can observe substantial variations in deposit rates across regions during our sample periods, particularly before quantitative easing.

[2]In the U.S. banking system, GSIB refers to JP Morgan Chase, Bank of America, Wells Fargo, Citi Group, State Street, and Bank of New York Mellon. These are designated by the Financial Stability Board. DSIBs are financial institutions that are not large enough to qualify for GSIB status but have a high enough level of domestic importance to be subject to the FRB's stress test. DSIB in our sample are Ally Financial, American Express, BB&T, Capital One, Comerica, Discover Financial Services, Fifth Third Bank, Huntington Bancshares, KeyCorp, M&T Bank, Northern Trust, PNC Bank, Regions Financial, Santander, SunTrust Banks, U.S. Bank, Unionbancal Corporation, and Zions Bancorporation.

First, equity capital issuance is defined as a binary variable,

$$\text{Issuance} = \mathbb{1}\{\underbrace{\text{Sale of Common Stock}}_{\text{BHCK3579}} + \underbrace{\text{Conversion or Retirement of Common Stock}}_{\text{BHCK3580}} > 0\},$$

following Baron (2020). Another binary variable is dividend payment,

$$\text{Dividend} = \mathbb{1}\{\underbrace{\text{Cash Dividends Declared on Common Stock}}_{\text{BHCK4460}} > 0\}.$$

These two binary variables are from FR Y-9C.

Using the Call Report, we measure variables associated with profitability and the cost of banking business. The return on assets (ROA) is calculated as

$$\text{ROA} = \frac{\text{Net Income}}{\text{Total Assets}}.$$

If multiple commercial banks are under the same holding company, we sum net incomes (RIAD4340) and total assets (RCON2170) to define the return on assets. To calculate the cost of deposits, we use three categories of deposits from the Call Report:

$$\begin{aligned}
\text{Time (CD)} &= \text{RCONA579} + \text{RCONA580} + \text{RCONA581} + \text{RCONA582} \\
&\quad \underbrace{+\text{RCONA584} + \text{RCONA585} + \text{RCONA586} + \text{RCONA587}}_{\text{during 2001:Q1-2009:Q4}} \\
&= \underbrace{\text{RCON6648} + \text{RCONJ473} + \text{RCONJ474}}_{\text{during 2010:Q1-2014:Q4}} \\
\text{Savings \& Money Market (MM)} &= \text{RCON6810} + \text{RCON0352} \\
\text{Checking} &= \text{RCON2385}.
\end{aligned}$$

The cost of deposits depends on the interest expenses, following Silverberg (1973):

$$\begin{aligned}
\text{Expense of Time} &= \text{RIADA517} + \text{RIADA5108} \\
\text{Expense of Savings \& MM} &= \text{RIAD0093} \\
\text{Expense of Checking} &= \text{RIAD4508}.
\end{aligned}$$

As a result,

$$\text{Cost of Deposits} = \frac{\text{Expense of Time (CD)} + \text{Expense of Savings \& MM} + \text{Expense of Checking}}{\text{Time (CD)} + \text{Savings \& MM} + \text{Checking}}$$

which is the per-unit cost of deposits. Noninterest expenses are not accounted for in the definition since they are included in the ROA (Egan et al. (2017)). Like ROA, we define the cost of deposits for each bank holding company if there are multiple commercial banks that are subsidiaries of the same holding company. For our empirical analysis, we annualize both ROA and the cost of deposits.

Finally, we use SOD to define variables reflecting how a bank holding company performs in deposit market competition. In the following explanation, we refer to a bank holding company as a bank or a financial institution. We consider an SOD sample as an economy with K banks, indexed by $k \in \{1, ..., K\} = \mathcal{K}$, and $t \in \{1, ..., T\} = \mathcal{T}$ over time. When considering entry and exit behavior, not every bank $k \in \mathcal{K}$ remains in the economy for all $t \in \mathcal{T}$. We denote each county-level deposit market with $m \in \{1, ..., M\} = \mathcal{M}$, where $\mathcal{M}$ is the set of all counties. Let $q^m_{k,t}$ denote the total amount of deposits collected by bank k in county m at time t. Then, we define the deposit market share of bank k in market m at time t as follows:

$$\text{MS}^m_{k,t} = \frac{q^m_{k,t}}{\sum_{k \in \mathcal{K}^m_t} q^m_{k,t}}$$

where $\mathcal{K}^m_t \subset \mathcal{K}$ is a set of financial institutions observed in market m at time t from SOD. In order to measure county-level deposit market share, we use all financial institutions in SOD, not the bank holding companies in our sample, after the procedure described in Section 2.1.

If bank k competes for deposits in multiple counties, we define a set of counties where branches of bank k gather deposits at time t, $\mathcal{M}_{k,t} \subset \mathcal{M}$. We compute a weighted-average of the county-level deposit market share for bank k at time t,

$$\text{MS}_{k,t} = \sum_{m \in \mathcal{M}_{k,t}} \underbrace{(q^m_{k,t}/D_{k,t})}_{w^m_{k,t}} \text{MS}^m_{k,t} \tag{1}$$

where $D_{k,t} = \sum_{m \in \mathcal{M}_{k,t}} q^m_{k,t}$ is the total deposits of bank k at time t, so $\sum_{m \in \mathcal{M}_{k,t}} w^m_{k,t} = 1$. The weight reflects the importance of some counties, from which a bank secures a major portion of the deposits. For instance, Figure A4 shows a higher deposit market share for Wells Fargo in Alaska than California. However, Wells Fargo obtained much more deposits from California than Alaska because its corporate headquarters are located in San Francisco, California.

Although $\text{MS}_{k,t}$ simply gives us information on how well bank k is doing against the competitors across $m \in \mathcal{M}_{k,t}$, it does not show any spatial feature on deposit allocation of bank k. Suppose that there are two banks: k_1 and k_2. Bank k_1 collects 50% of deposits from county m_1 and county m_2, respectively. Bank k_1 has 20% market share in county m_1 and 30% market share in county m_2. On the other hand, bank k_2 collects 80% of deposits from county m_1 and 20% from county m_2. Bank k_2 has 25% market share in both county m_1 and county m_2. Using equation (1) without the time subscript, we get

$$\begin{aligned} \text{MS}_{k_1} &= 0.50 \times 0.20 + 0.50 \times 0.30 = 0.25 \\ \text{MS}_{k_2} &= 0.80 \times 0.25 + 0.20 \times 0.25 = 0.25, \end{aligned}$$

which implies that $\text{MS}_{k,t}$ cannot show dependence of bank k_2 on county m_1 as a deposit funding source.

Table 1: Sample Description on Bank Holding Companies

	Total Assets	**Total Deposits**	**Equity Issuance**	**Deposit Market Statistics**		
	Mean (Million)	Mean (Million)	Frequency	Avg Cost	Avg MS	Avg DIV
Bank Size						
Small BHC	\$322.3	\$266.4	35.20%	1.90%	17.28%	0.74
Medium BHC	\$708.4	\$575.1	43.12%	1.88%	14.79%	0.62
Large BHC	\$8,056.9	\$5,613.6	47.84%	1.71%	15.05%	0.45
Mega BHC	\$492,533.5	\$316,299.6	37.65%	1.26%	20.81%	0.20

Note: Our sample spans from 2001:Q1 to 2014:Q4 and only covers bank holding companies publicly listed on the stock market. The first two columns show the average assets and deposits within a size group over the sample period. Balance sheet information is from the Call Report. For each quarter over the sample period, we define the bottom 30% of banks as Small, the middle 40% of banks as Medium, the top 30% of banks excluding the top 1% of banks as Large, and the top 1% of banks as Mega. GSIB and DSIB are all included in the Mega category. The numbers are adjusted by the dollar value in 2011:Q1. The following two columns show the average deposit market share computed in equation (1) and the average diversification index in equation (2). Variables associated with deposit market statistics are from SOD at the FDIC.

Thus, we define a diversification index for a bank ($\text{DivIndex}_{k,t}$) as follows:

$$\text{DivIndex}_{k,t} = \left[\sum_{m \in \mathcal{M}_{k,t}} \left(\frac{q^m_{k,t}}{D_{k,t}} \right)^2 \right]^{-1}. \tag{2}$$

The index has a larger value if a bank has a more geographically diversified distribution of deposits. Using the index to the previous example,

$$\text{DivIndex}_{k_1} = \left[(0.50)^2 + (0.50)^2 \right]^{-1} = 2.0,$$
$$\text{DivIndex}_{k_2} = \left[(0.80)^2 + (0.20)^2 \right]^{-1} \approx 1.47,$$

which shows that bank k_1 has a more diversified deposit funding base than bank k_2. Table 1 displays summary statistics for the bank holding companies in our sample. We use total assets to define the bottom 30% of banks as Small, the middle 40% of banks as Medium, the top 30% of banks excluding the top 1% of banks as Large, and the top 1% of banks as Mega. GSIB and DSIB are all included in the Mega category. Although there is no evident relationship between the size of banks and their average deposit market share, bigger bank holding companies tend to have a more diversified allocation of deposits.

2.3 Regression Analysis

Our sample is an unbalanced panel, and for each quarter we observe a binary action, $\text{Issuance}_{k,t} \in \{0,1\}$. $k \in \{1, ..., K\}$ identifies a bank holding company in our sample, and $t \in \{1, ..., T\}$ denotes a quarter from 2001:Q1 to 2014:Q4. We provide Table B1 for the summary statistics of the key variables for regressions.

2.3.1 Common Stock Issuance and Cost of Deposits

We use logit and probit models with bank and time fixed effects to predict the probability that a bank holding company raises additional funds through common stock issuance. Our main specification is:

$$\Pr\left(\text{Issuance}_{k,t} = 1 | \boldsymbol{X}_k^T, \boldsymbol{\gamma}, \boldsymbol{\theta}, \boldsymbol{\delta}\right) = F\left(X_{k,t}'\boldsymbol{\gamma} + \theta_k + \delta_t\right) \tag{3}$$

where $F : \mathbb{R} \to [0,1]$ is the CDF for logit or probit. The model has bank-specific effects $\boldsymbol{\theta} = (\theta_1, ..., \theta_K)$ and time-specific effects $\boldsymbol{\delta} = (\delta_1, ..., \delta_T)$ to capture bank- and time-specific unobserved heterogeneity. The regressors $\boldsymbol{X}_k^T = (X_{k,1}, X_{k,2}, ..., X_{k,T})$ include

$$X_{k,t} = \begin{bmatrix}\text{ROA}_{k,t} & \text{Cost of Deposits}_{k,t} & \log(\text{CR}_{k,t-1}) & \log(\text{DTA}_{k,t-1}) & \text{Dividend}_{k,t}\end{bmatrix}'$$

where $\text{CR}_{k,t-1}$ is the total capital ratio in the percent value from BHCA7205 in FR Y-9C and $\text{DTA}_{k,t-1}$ is the deposit-to-asset ratio computed from the Call Report

$$\text{DTA}_{k,t-1} = \left(\frac{\text{Time}_{k,t} + \text{Savings}_{k,t} + \text{Checking}_{k,t}}{\text{Total Assets}_{k,t}}\right) \times 100.$$

$\text{ROA}_{k,t}$ and $\text{Cost of Deposits}_{k,t}$ are flow variables that are measured concurrently with $\text{Issuance}_{k,t}$. $\text{CR}_{k,t-1}$ and $\text{DTA}_{k,t-1}$ are stock variables that are predetermined with respect to $\text{Issuance}_{k,t}$. $\text{Dividend}_{k,t}$ is a binary variable observed over the same time period as $\text{Issuance}_{k,t}$.

An important caveat is that the fixed effects estimator $\hat{\boldsymbol{\gamma}}$ can be severely biased under the nonlinear panel data model in equation (3) due to the incidental parameter problem (Neyman and Scott (1948)). The estimator is asymptotically inconsistent when T is fixed and $K \to \infty$ when the model has bank-specific individual effects. The estimator is also asymptotically inconsistent when K is fixed and $T \to \infty$ when the model has time fixed effects. The problem arises because the number of parameters capturing unobserved heterogeneity increases with the sample size. The nonlinear nature of the model aggravates the problem by transmitting the inconsistency in the estimation of the bank and time fixed effects to $\hat{\boldsymbol{\gamma}}$. To handle the problem, we use the analytic bias correction developed by Fernández-Val and Weidner (2016).

Results

Table 2 shows estimated outcomes in equation (3) with the analytic bias correction from Fernández-Val and Weidner (2016). Columns (3) and (4) are our main results, which use the logit and probit models over the full sample periods. Columns (5) and (6) are estimated outcomes from the sub-sample from 2001:Q1 to 2007:Q4, whereas Columns (7) and (8) are from the sub-sample from 2008:Q1 to 2014:Q4. From Columns (3) to (8), we set the trimming parameter in Cruz-Gonzalez et al. (2017) as one to estimate spectral expectations since the econometric model in equation (3) has the predetermined variables, CR_{t-1} and DTA_{t-1}, with respect to the dependent variable.

Table 2: Prediction Models of Equity Capital Issuance

	(1) Issuance$_t$	(2) Issuance$_t$	(3) Issuance$_t$	(4) Issuance$_t$	(5) Issuance$_t$ (Before)	(6) Issuance$_t$ (Before)	(7) Issuance$_t$ (After)	(8) Issuance$_t$ (After)
ROA$_t$	0.039***	0.020***	0.039***	0.020***	0.052*	0.030*	−0.006	−0.002
	(0.010)	(0.006)	(0.010)	(0.006)	(0.027)	(0.016)	(0.015)	(0.008)
Cost of Deposits$_t$	0.121***	0.067**	0.125***	0.069***	0.152**	0.075**	0.201*	0.116*
	(0.047)	(0.027)	(0.047)	(0.027)	(0.065)	(0.035)	(0.112)	(0.063)
log(CR$_{t-1}$)	−0.035	−0.047	−0.024	−0.040	−0.798***	−0.438***	−0.166	−0.100
	(0.086)	(0.050)	(0.086)	(0.050)	(0.179)	(0.095)	(0.155)	(0.088)
log(DTA$_{t-1}$)	−1.291***	−0.682***	−1.303***	−0.689***	−1.611***	−0.870***	−1.440***	−0.740***
	(0.255)	(0.147)	(0.255)	(0.147)	(0.445)	(0.254)	(0.481)	(0.276)
Dividend$_t$	0.365***	0.202***	0.367***	0.203***	0.359***	0.197***	0.332***	0.182***
	(0.048)	(0.027)	(0.048)	(0.027)	(0.075)	(0.042)	(0.086)	(0.049)
Model	Logit	Probit	Logit	Probit	Logit	Probit	Logit	Probit
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Error Correction	Two-Way	Two-Way	Two-Way	Two-Way	Two-Way	Two-Way	Two-Way	Two-Way
Trimming	0	0	1	1	1	1	1	1
Pseudo R-Squared	0.374	0.373	0.374	0.373	0.346	0.345	0.384	0.384
Observations	36,770	36,770	36,770	36,770	19,102	19,102	12,115	12,115

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, and standard errors are in parentheses.

Note: Columns (3) and (4) are our major results which use the logit and probit models, respectively, over the full sample periods. Columns (5) and (6) are estimated outcomes from the sub-sample from 2001:Q1 to 2007:Q4, whereas Columns (7) and (8) are from the sub-sample from 2008:Q1 to 2014:Q4. From Column (3) to (8), we set the trimming parameter in Cruz-Gonzalez et al. (2017) as one to estimate spectral expectations since the econometric model in equation (3) has the predetermined variables, CR$_{t-1}$ and DTA$_{t-1}$, with respect to the dependent variable.

From Columns (3) and (4), we find that ROA$_t$ and Dividend$_t$ are statistically significant predictors of equity capital issuance. Dividend$_t$ maintains its statistical significance in both sub-sample regression outcomes, but ROA$_t$ does not do so after the financial crisis. The strong predictive power of Dividend$_t$ on Issuance$_t$ is consistent with a well-documented fact in corporate finance and financial accounting that a company raises additional funds through equity capital issuance when dividends are paid out as cash. The payout of cash dividends from retained earnings decreases the amount of shareholder equity on the company's balance sheet. Given that the banking industry is subject to capital requirements, banks may issue equity capital to abide by the laws, which CR$_{t-1}$ can capture. However, CR$_{t-1}$ is only significant in the sub-sample before the financial crisis. The outcome may be attributed to the fact that banks have increased their capital buffers as a result of more stringent regulatory regulations implemented after the financial crisis.

An intriguing finding is that Cost of Deposits$_t$ and log(DTA$_{t-1}$) are important predictors of equity capital issuance across all models and sample periods. The average marginal effect for the cost of deposits in Column (3) is 1.20% with a Z-value of 2.78. Similarly, the average marginal effect for the deposit-to-asset ratio on a logarithmic scale in Column (3) is -12.8% with a Z-value of -5.02. The result implies that the likelihood of equity capital issuance drops by 12.8% on average when there is a small increase in log(DTA).[3] The same description holds when there is a small increase in deposits for a given amount of assets due to log(DTA) = log(Deposits) − log(Assets) + log100.

The observation suggests that when the cost of deposits increases, it can have a negative impact on retained earnings, leading to a decrease in shareholder equity and an increase in the probability of bankruptcy. Thus, there may be a motivation to increase the issuance of equity capital in order to safeguard shareholder value and reduce the likelihood of bankruptcy. Furthermore, it is important to note that banks engage in rivalry for deposits within specific geographical markets, as depicted in Figure A3. The cost of deposits can significantly impact the level of competition within the deposit market, ultimately influencing the deposit amount. The interpretation is additionally discussed in econometric models in Section 2.3.2.

Table B2 displays the alternative estimation using the linear probability model with fixed effects. The same interpretation is obtained from our primary model estimates in Table 2. We also provide Table B3 to present the relationship between the cost of deposits and equity capital, focusing on the intensive margin of equity capital issuance. The findings confirm that higher deposit costs imply more equity capital issuance. Below, we offer more robustness checks.

Robustness Checks

To show that the cost of deposits and the deposit-to-asset ratio are strong predictors of equity capital issuance in different environments, we change some independent variables or econometric models. First, we use the ROE and the Tier 1 capital ratio to replace the ROA and the total capital ratio,

$$X_{k,t} = \begin{bmatrix} \text{ROE}_{k,t} & \text{Cost of Deposits}_{k,t} & \underbrace{\log(\text{Tier 1 CR}_{k,t-1})}_{\text{BHCA7206 (FR Y-9C)}} & \log(\text{DTA}_{k,t-1}) & \text{Dividend}_{k,t} \end{bmatrix}'$$

where ROE = Net Income/Total Equity and the total equity capital is RCON3210 from the Call Report. Estimated outcomes are reported in Table B5. Like our main results, Cost of Deposits_t and $\log(\text{DTA}_{t-1})$ are important factors to predict equity capital issuance over all different models and sample periods.

We also use a different definition of equity capital issuance. To account for total equity capital issuance, we additionally consider preferred stocks to common stock. We define the new dependent

[3] Likewise, we compute the average marginal effect for the cost of deposits in Column (4). From our computation, it is 1.20% with a Z-value of 2.72. Also, the average marginal effect for the deposit-to-asset ratio in a logarithmic scale in Column (4) is -11.8% with a Z-value of -4.68.

variable as follows:

$$\text{Issuance} = \mathbb{1}\{\underbrace{\text{Sale of Common Stock}}_{\text{BHCK3579}} + \underbrace{\text{Conversion or Retirement of Common Stock}}_{\text{BHCK3580}}$$
$$\underbrace{\text{Sale of Preferred Stock}}_{\text{BHCK3577}} + \underbrace{\text{Conversion or Retirement of Preferred Stock}}_{\text{BHCK3578}} > 0\}.$$

Table B6 shows estimated outcomes from using the new dependent variable. Unlike the main outcomes in Table 2, CR_{t-1} is a strong predictor of equity capital issuance. One reason is that many distressed or undercapitalized bank holding companies in our sample applied for the Capital Purchase Program (CPP) of the Troubled Asset Relief Program after the financial crisis of 2008. Under the CPP, financial institutions could apply for the capital injection in amounts between 1% and 3% of their risk-weighted assets. The capital infusions were implemented through preferred stock issuance in order to be non-dilutive to common shareholders. The finding is consistent with Bayazitova and Shivdasani (2012) showing that the probability of bank participation in the CPP is negatively related to capital adequacy. Also, these bank holding companies were not allowed to pay dividends on common shares while the preferred shares had been repaid, making Dividend_t less quantitatively important. Similar to the first two robustness tests, Table B7 is based on the new independent and dependent variables.

Finally, we add the costs of other liabilities: federal funds plus securities to repurchase, subordinated debt, and trading liabilities plus other money. Federal funds are excess reserves held by financial institutions over and above the FRB's mandated reserve requirements. Subordinated debt, for banks, refers to junior debt that banks repay after fully repaying their depositors. Trading liabilities usually consist of derivative liabilities, with the fair value of derivative instruments in a negative position as of the end of the most recent fiscal year, as recognized and measured in accordance with generally accepted accounting principles. Using the Call Report, we calculate the cost of each liability component as follows:

$$\text{Cost of Federal Funds \& Securities} = (\text{RIAD4180})/(\text{RCONB993} + \text{RCONB995})$$
$$\text{Cost of Subordinated Debt} = (\text{RIAD4200})/(\text{RCON3200})$$
$$\text{Cost of Trading Liabilities \& Other Money} = (\text{RIAD4185})/(\text{RCON3190} + \text{RCON3548}).$$

Table B8 shows that the cost of deposits, among banks' liabilities, is the only statistically significant factor that predicts equity capital issuance.

2.3.2 Insolvency Risk, Diversification, and Cost of Deposits

This section figures out the potential mechanism to explain the relationship between the deposit market and equity capital issuance. We discuss (i) whether the rising cost of deposits affects the risk of insolvency, (ii) the relationship between the insolvency risk and equity capital issuance, and (iii) the role of diversified deposit bases in the channel. Intuitively, these arguments imply a cost-benefit approach to the cost of deposits. Since the deposit market is compartmentalized into smaller regional units, we incorporate the diversification index in equation (2) into our regression models to reflect a comprehensive view of the deposit market competition.

Since the SOD data reports the deposit market structure annually, we use annualized variables for estimating models. We concentrate on bank holding companies that have provided reports for at least three consecutive years without any missing quarters. The selected sample comprises 1,824 banks and 14 years of observations.

We begin with the stylized fact that a higher cost of deposits, typically implied by higher deposit rates, corresponds to a larger deposit market share. Section B.3 in the Appendix uses (dynamic) panel regression models to verify the facts using our sample data. The results in Tables B11 and B12 demonstrate that banks can achieve a higher deposit market share by spending more on competing for deposits. However, the gain in market share diminishes if a bank competes for deposits through a well-diversified branch network.

In order to capture the side effect of higher deposit costs, we suggest an empirical design showing that rising deposit costs affect insolvency risk, which leads to equity capital issuance. We use the Z-score as a proxy for the bank's default or insolvency risk.[4] The bank's market-based value can be an alternative measure, but it reflects implicit government guarantees, potentially distorting our inference.[5] Following the World Bank's definition,

$$\text{Z-Score}_t = \frac{\overline{\text{ROA}_{(t-1,t)}} + \overline{\text{CR}_{(t-1,t)}}}{\text{STD}\left(\text{ROA}_{(t-1,t)}\right)}$$

where $\overline{x_{(t-1,t)}}$ is the average value of x between $t-1$ and t. For example, we use the quarterly data from the Call Report to calculate

$$\overline{\text{ROA}_{(2001,2002)}} = \frac{1}{4}\left(\text{ROA}_{2001:\text{Q3}} + \text{ROA}_{2001:\text{Q4}} + \text{ROA}_{2002:\text{Q1}} + \text{ROA}_{2002:\text{Q2}}\right)$$

since deposit market data from SOD reports observations in the middle of each year.

We consider the following high-dimensional 2SLS specification:

$$\text{EquityIssuance}_{k,t} = \log\left(\text{Z-Score}_{k,t-1}\right)\beta + W_{k,t}'\boldsymbol{\alpha} + \theta_{E,k} + \delta_{E,t} + \varepsilon_{k,t} \tag{4}$$

$$\log\left(\text{Z-Score}_{k,t}\right) = Z_{k,t}'\boldsymbol{\eta} + \theta_{Z,k} + \delta_{Z,t} + u_{k,t} \tag{5}$$

where both $W_{k,t}$ and $Z_{k,t}$ include Cost of $\text{Deposits}_{k,t}$, $\log(\text{DivIndex}_{k,t-1})$, Cost of $\text{Deposits}_{k,t}$ $\times$

[4] Lepetit and Strobel (2015) examine the probabilistic foundation of the link between Z-score measures and banks' probability of insolvency. They find that the log of the Z-score is shown to be negatively proportional to the log odds of insolvency.

[5] For example, Gandhi and Lustig (2015) find that the largest commercial bank stocks, ranked by the total size of the balance sheet, have significantly lower risk-adjusted returns than small- and medium-sized bank stocks. They explain that government bailouts in the financial sector can protect shareholders of large banks in disaster states and absorb some of their tail risks. Atkeson et al. (2019) demonstrate that the market-to-book ratio of U.S. banks is the sum of franchise value and the value of government bailouts. They find that a large portion of the variation in the ratio over time is due to changes in the value of government bailouts.

$\log(\text{DivIndex}_{k,t-1})$, $\text{MS}_{k,t-1}$, and $\text{DTA}_{k,t-1}$, while they have different Z-Score lag terms. The interaction term of the cost of deposits and the diversification index shows how a well-diversified deposit funding base impacts the dependent variables, given the same cost of deposits. $\theta_{E,k}$, $\theta_{Z,k}$ are the bank fixed effects, and $\delta_{E,t}$, $\delta_{Z,t}$ are the time fixed effects.

We use the 2SLS to estimate the parameters in equations (4) and (5) because the realized default risk in time $t-1$ may be correlated with the current year's equity capital issuance shock. For example, shareholders observing a low Z-score may put pressure on bank holding companies to issue equity capital, or depositors may move to safer banks in time t. Since the lagged cost of deposits and lagged diversification measures correlate with the Z-score but not with the current year's equity issuance shock, we use them as instrumental variables. We compute standard errors with clustered standard errors by bank holding company to account for serial correlation within each bank.

Results

Table 3 shows estimated outcomes. Columns (1) and (2) are from the first-stage regressions in equation (5). We find that Cost of Deposits_t is not only statistically significant but also quantitatively important to explain the change in Z-Score_t. For a financial institution collecting deposits from only one county ($\text{DivIndex}_t = 1$), an increase of one unit (1%) in Cost of Deposits_t is associated with a 33.1% decrease in Z-Score_t. Considering the negative correlation between the log of the Z-score and the log odds of insolvency from Lepetit and Strobel (2015), the first two columns in Table 3 validate our hypothesis that the rising cost of deposits increases insolvency risk. The risk reduces the shareholder value of bank holding companies.

DivIndex_t presents a degree of diversification in the branch network of a bank, as we show the branch network evolution of Wells Fargo in Figure A4. The impact of ΔCost of $\text{Deposits}_t > 0$ on Z-Score_t can be amplified through the network captured by the interaction term, Cost of $\text{Deposit}_t \times \log(\text{DivIndex}_t)$. Since $\log(\text{DivIndex}_t) > 0$ and the value is higher for a bank with a well-diversified branch network, Z-Score_t decreases by

$$\left(33.1 + 6.6 \times \underbrace{\log(\text{DivIndex})}_{>0}\right)\% > 33.1\%$$

for an increase of one unit in Cost of Deposits_t. The outcome implies that higher deposit costs and a diversified branch network can be more detrimental to insolvency risk.

On the other hand, having a well-diversified deposit base can reduce insolvency risk when Cost of Deposits_t is relatively low. For example, when Cost of Deposits_t is equal to 1%, a 1% increase in DivIndex_t, which is equivalent to a better-diversified deposit base, is associated with

$$\left.\frac{\partial \log(\text{Z-Score}_{k,t})}{\partial \log(\text{DivIndex}_{k,t})}\right|_{\text{Cost of Deposits}_{k,t}=1} = \hat{\eta}_3 + 1 \times \hat{\eta}_4 = 0.143 - 1 \times 0.066 = 0.077\%$$

Table 3: The Effect of Deposit Diversification and Cost of Deposits on Insolvency Risk and Equity Capital Issuance

	(1) $\log(\text{Z-Score}_t)$	(2) $\log(\text{Z-Score}_t)$	(3) Issuance_t	(4) Issuance_t
$\log(\text{Z-Score}_t)$			0.245^{**}	0.219^{**}
			(0.099)	(0.106)
$\log(\text{Z-Score}_{t-1})$		0.163^{***}	-0.125^{*}	-0.153^{*}
		(0.015)	(0.065)	(0.086)
$\text{Cost of Deposits}_t$	-0.331^{***}	-0.316^{***}	0.096^{***}	0.079^{**}
	(0.048)	(0.050)	(0.037)	(0.038)
$\log(\text{DivIndex}_{t-1})$	0.143^{**}	0.130^{**}	0.013	0.032
	(0.059)	(0.056)	(0.035)	(0.039)
$\text{Cost of Deposits}_t \times \log(\text{DivIndex}_{t-1})$	-0.066^{***}	-0.060^{***}	0.007	0.005
	(0.018)	(0.018)	(0.009)	(0.009)
MS_{t-1}	0.011^{**}	0.008	-0.001	-0.001
	(0.005)	(0.005)	(0.021)	(0.020)
DTA_{t-1}	-0.003	0.002	-0.004	-0.005
	(0.003)	(0.003)	(0.002)	(0.002)
Bank FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
STD	Cluster	Cluster	Cluster	Cluster
R-Squared	0.391	0.416		
Observations	14,383	12,554	12,544	10,493

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, and standard errors are in parentheses.

Note: Columns (1) and (2) are from the model in equation (5), and Columns (3) and (4) are from the model in equation (4). We compute standard errors with the clustered standard errors by bank holding company to account for serial correlation within each bank.

increase in Z-Score_t. The result shows a positive aspect of collecting deposits from a well-diversified deposit funding base. However, if $\text{Cost of Deposits}_t$ is high, having a better-diversified branch network could increase insolvency risk. For instance, when $\text{Cost of Deposits}_t$ is equal to 3%, a 1% increase in DivIndex_t is associated with

$$\left.\frac{\partial \log(\text{Z-Score}_{k,t})}{\partial \log(\text{DivIndex}_{k,t})}\right|_{\text{Cost of Deposits}_{k,t}=3} = \hat{\eta}_3 + 3 \times \hat{\eta}_4 = 0.143 - 3 \times 0.066 = -0.055\%$$

change in Z-Score_t. The estimate confirms the potential drawback of having a widespread branch network to collect deposits in more regions when the cost of deposits is high.

Columns (3) and (4) present the results obtained from the model specified in equation (4). The second-stage regression shows how the cost of deposits, the diversified deposit base, and the bank's insolvency risk interact in banks' equity issuance decisions. In Column (3), the model includes instrumental variables that are lagged by up to one year, while in Column (4), the model includes instrumental variables that are lagged by up to two years. For both specifications, the previous year's Z-score shows a significantly negative impact on equity capital issuance within a year. The estimate implies that the previous year's default risk led to banks issuing more equity capital. The cost of deposits still plays a significant role in issuing equity capital, even after controlling the insolvency risk channel. The deposit base diversification is not a significant regressor anymore, implying that the diversification affects the equity capital only through the bank's insolvency risk.

In addition, we would like to note that there is a substantial correlation between the cost of deposits and our diversification index DivIndex_t. The two variables are significantly negatively correlated at -0.1433. This is to be expected since: a more diversified deposit base should lower the *ex ante* marginal cost of deposits, and this should translate into the *ex post*, average cost of deposits.

As a robustness check, we estimate the econometric models in equations (4) and (5) with the sample used for Table 2. For the logit and probit models with two-way fixed effects in equation (3), bank holding companies that always issue or never issue are left out of the sample. These institutions are included for the models in Table 3. Table B9 in the Appendix shows estimated outcomes from the subsample used for Table 2. The results are qualitatively and quantitatively similar to Table 3.

We also provide a couple of simple reverse causality tests in Section B.2 in the Appendix to support a cause-and-effect link between the cost of deposits and the issuance of equity capital. Equity capital issuance is an insignificant regressor for the cost of deposits in various specifications. The results confirm the conclusions in Sections 2.3.1 and 2.3.2. The rising cost of deposits raises bank holding companies' insolvency risk. The higher the risk, the greater the chance of raising additional funds through equity capital issuance to protect financial institutions' shareholder value.

3 Model

In this section, we develop a structural model to show how deposit market competition can affect equity capital issuance. The model gives us a further explanation of the outcomes from Section 2 from a theoretical perspective. Our model is an extended version of Egan et al. (2017), incorporating multiple regional markets into deposit competition. However, unlike Egan et al. (2017) where banks compete for insured and uninsured deposits, our model does not differentiate between the two deposit products due to the limitations of the SOD dataset.[6]

The deposit market structure in our benchmark model is described in Figure 2. There are

[6]The design differs from Egan et al. (2017)'s setup, which found no sensitivity of insured depositors to the bank's riskiness. The simplification is still beneficial, as our focus is on the effect of the deposit market's branch network on equity capital issuance.

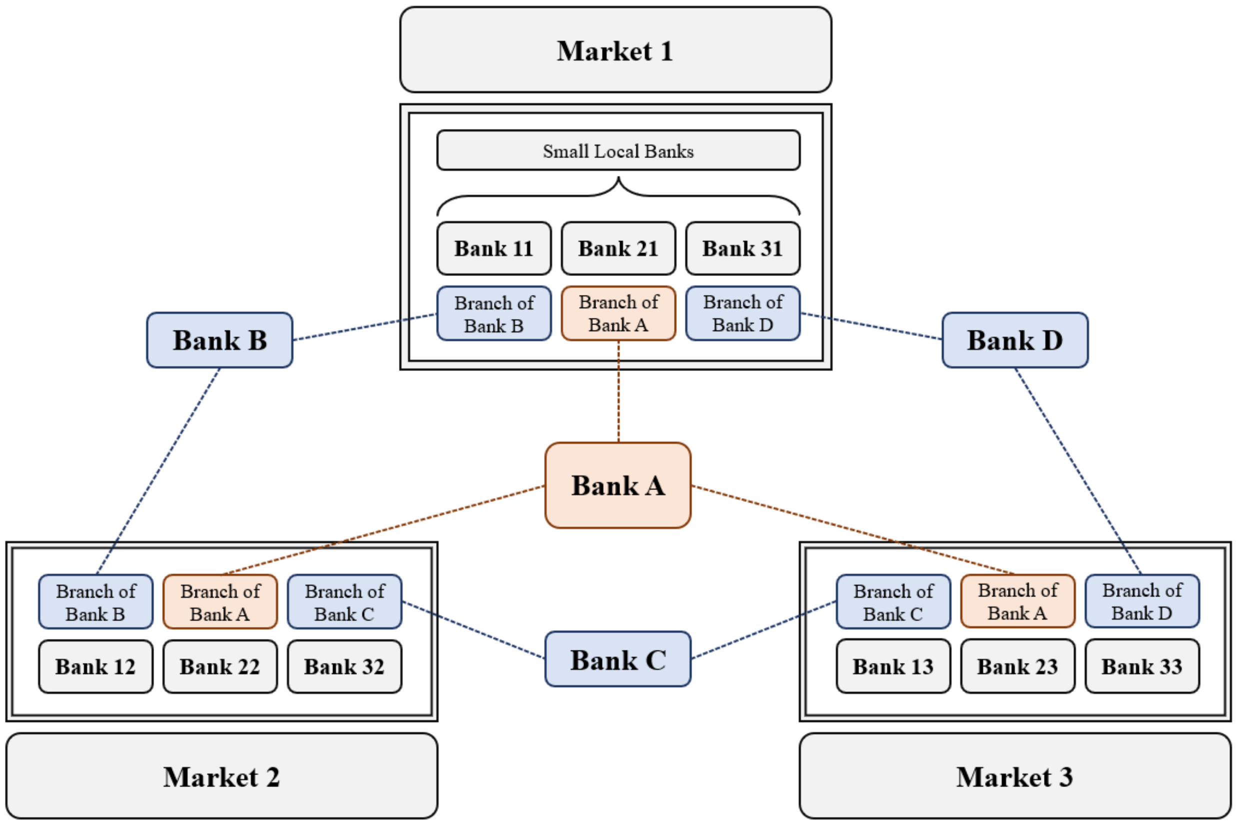


Figure 2: Deposit Market Structure

three regional deposit markets: Markets 1, 2, and 3. Depending on how many regional markets they operate branches in to collect deposits, there are three types of banks. Bank A, a 'Big Bank' holding company, operates branches in all three regional markets. Banks B, C, and D are all 'Medium-sized Bank' holding companies, and they all have branches in two regional markets. For example, Bank B has branches in Markets 1 and 2, while Bank C has branches in Markets 2 and 3. So, Bank A has a more diverse group of depositors than the medium-sized banks. There are three small bank holding companies in each regional market. Each small financial institution collects deposits from only one regional market. For notation purposes, we put two digits into small banks. The first digit denotes the distinctive identity of small banks in each regional market, and the second digit shows the regional market in which they are competing for deposits. As a result, there are six institutions in each regional market to compete for deposits. The model configuration was chosen to correspond with the empirical observation in Section 2 that the average county-level deposit market share from our entire sample period is around 15.8%.

The model is in discrete time. The timing of events within a period is as follows:

- Banks determine deposit rates for regional markets where they operate branches. We define i_k^m as a deposit rate set by Bank k in Market m. As shown in Figure 2, Bank A sets deposit rates i_A^1, i_A^2, and i_A^3, whereas Bank B sets deposit rates i_B^1 and i_B^2.

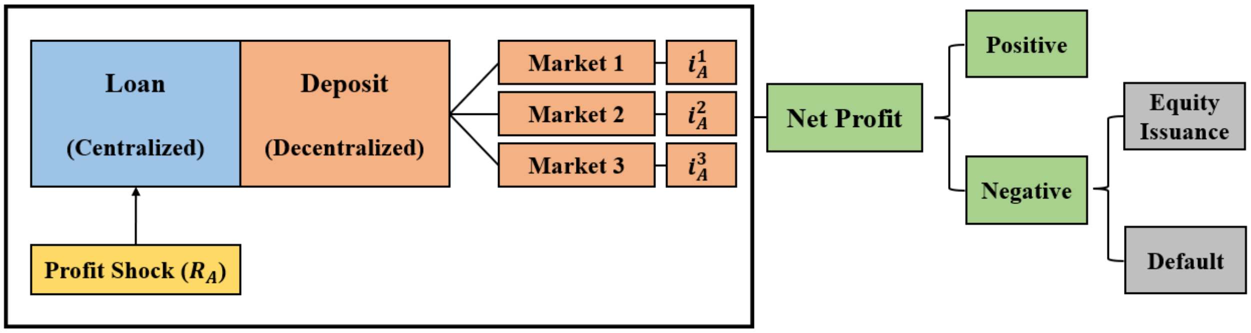


Figure 3: Model Environment of Bank A

- Depositors in each regional market choose where to save their funds.
- Banks invest deposits into loan projects, and profit shocks are realized. For Bank k, we define R_k as its profit shock.
- If the realized net profit is positive, Bank k can repay its deposit debt. Otherwise, Bank k can choose whether to issue equity capital or default.

Figure 3 illustrates the model environment of Bank A.

3.1 Depositor Preference

Let $\mathcal{M}_k$ represent a set of regional markets where Bank k operates branches to collect deposits. For instance, $\mathcal{M}_A = \{\text{Market } 1, \text{Market } 2, \text{Market } 3\}$, whereas $\mathcal{M}_B = \{\text{Market } 1, \text{Market } 2\}$. We assume that $\mathcal{M}_k$ is exogenously given for each $k \in \mathcal{K} = \{A, B, C, D, 11, ..., 33\}$. We do not consider the market entry-exit decisions.

For each regional market, there are depositors whose total funds are assumed to be one. A depositor has to decide whether to save the wealth in banks and, if so, which one. In the spirit of Hotbllino (1929) and Salop (1979), banks can only attract deposits in regional markets where they operate branches.[7] The banks provide differentiated deposit services, and the indirect utility for depositor n living in Market m derived from saving her wealth in Bank k at time t is defined as follows (Market $m \in \mathcal{M}_k$):

$$u^m_{n,k,t} = \alpha i^m_{k,t} + \beta \rho_{k,t} + \varepsilon^m_{n,k,t} \tag{6}$$

where $i^m_{k,t}$ is the deposit rate set by Bank k operating a branch in Market m at time t and $\alpha > 0$ is the marginal utility of income. Also, we assume that depositors care about banks' default probabilities denoted by $\rho_{k,t}$. $\beta < 0$ captures the marginal disutility of default risks. The term $\varepsilon^m_{n,k,t}$ represents

[7] Honka et al. (2017) show evidence of the importance of regional branch existence for depositors' decisions to open new bank accounts. Abrams (2020) also shows that depositors are attentive to which banks are present in their regions.

an idiosyncratic preference of depositor n living in Market m and choosing Bank k at time t. We assume that $\varepsilon^m_{n,k,t}$ are i.i.d. across markets, banks, and time following a Type I extreme value distribution (e.g., Berry et al. (1995)). We normalize the utility from an outside alternative (for example, credit unions or saving institutions) to zero.

3.2 Profit Function

We consider the problem of maximizing shareholder value. Suppose that the bank manager's incentive is well aligned with the interests of shareholders, so there is no agency conflict. Bank k's problem at time t is described as a two-part decision process:

(i) setting the deposit rates over regional markets ($i^m_{k,t}$ only for $m \in \mathcal{M}_k$) and

(ii) deciding to continue the business or declare bankruptcy.

Banks earn profits by lending out deposits through loan investments. Bank k earns $R_{k,t}$ on deposits at time t. $R_{k,t}$ includes costs for loan defaults, screening and monitoring loans, and other services provided to depositors. The stochastic returns specific to Bank k are i.i.d. across time as $R_{k,t} \sim N(\mu_k, \sigma_k)$.[8] If Bank k invests deposits in a bad loan portfolio, $R_{k,t}$ can turn out to be negative. To focus on the deposit competition mechanism, our model omits banks' risk choice in loan investment. Given that the stochastic returns of each bank vary and do not exhibit serial correlation over time, certain banks excel in deposit investment more than others. In our model, the difference is persistent. Some banks have better technology for screening or monitoring, or they lend based on relationships with a pool of borrowers who are more likely to pay back their loans.

Bank k's deposit market share is $\{s^m_{k,t}\}_{m\in\mathcal{M}_k}$, and the corresponding gross return on deposits is

$$\sum_{m\in\mathcal{M}_k} s^m_{k,t}(1 + R_{k,t}) = D_{k,t}(1 + R_{k,t}), \tag{7}$$

where $D_{k,t} = \sum_{m\in\mathcal{M}_k} s^m_{k,t}$ denotes the total amount of deposits. The costs of deposit debt financing decrease Bank k's profit. Bank k has to repay deposits at the cost of

$$\sum_{m\in\mathcal{M}_k} s^m_{k,t}(1 + i^m_{k,t}). \tag{8}$$

We implement capital requirements by requiring shareholders to invest a κ share of deposits in each period, leading to a capital ratio of $\omega = \kappa/(1 + \kappa)$. The additional capital is invested along with deposits and lost in bankruptcy. The setting is conceptually consistent with the Basel II regime. If a bank wants to collect more deposits, its shareholders should provide more equity capital. The

[8]The profit shocks can be arbitrarily correlated among banks. The setup accommodates an equilibrium outcome where there is a systematic banking crisis.

net period profit of Bank k is then

$$\pi_{k,t} = \sum_{m \in \mathcal{M}_k} s_{k,t}^m \left(R_{k,t} - i_{k,t}^m \right) + \underbrace{\kappa \sum_{m \in \mathcal{M}_k} s_{k,t}^m (R_{k,t} - r)}_{\text{capital requirement}}$$
$$= (1+\kappa) D_{k,t} R_{k,t} - \sum_{m \in \mathcal{M}_k} s_{k,t}^m (i_{k,t}^m + \kappa r) \quad (9)$$

where r is the cost of capital conceptually equivalent to the risk-free rate.[9] In each period, Bank k disburses $\pi_{k,t}$ to the shareholders after paying the depositors if $\pi_{k,t}$ is positive. Bank k suffers from operating losses in a given period if $\pi_{k,t}$ is negative. In this case, bank equity holders can decide whether to issue more equity capital (equivalent to injecting more funds) to repay the deposit debt or to declare bankruptcy. We assume that bank equity holders are deep-pocketed, following Leland (1994). However, we assume that there are no direct costs of bankruptcy to simplify our model and focus on how deposit market competition can affect equity capital issuance.

3.3 Equilibrium

We consider the pure strategy Bayesian Nash Equilibria[10]. The equilibria are characterized by the optimal behavior of banks and depositors in the model.

- Banks choose to default optimally given realized profit shocks, $R_{k,t}$.
- Depositors are fully rational, anticipating probabilities of default, $\rho_{k,t}$, and incorporating this belief when choosing where to save their funds.
- Banks choose optimal deposit rates, $\{i_{k,t}^m\}_{m \in \mathcal{M}_k}$, given the demand for deposits.

Bankruptcy places a failed bank under new ownership with the same deposit funding base. The equilibrium of the game is stationary since the profit shock is i.i.d. across time. In stationary equilibrium, banks compete with each other for deposits within periods but not across periods. Banks face the same deposit pricing and bankruptcy decisions in each period.

Deposit Demand

Given the distribution of $\varepsilon_{n,k,t}^m$ in equation (6), we employ a standard assumption in discrete choice models following Berry et al. (1995). We derive the demand function for bank k deposits in market

[9] When the additional capital is invested in the risk-free assets, the net period profit of Bank k is

$$\pi_{k,t} = \sum_{m \in \mathcal{M}_k} s_{k,t}^m \left(R_{k,t} - i_{k,t}^m \right) + \kappa \sum_{m \in \mathcal{M}_k} s_{k,t}^m (r - r) = D_{k,t} R_{k,t} - \sum_{m \in \mathcal{M}_k} s_{k,t}^m i_{k,t}^m.$$

The capital requirements reflect the Basel III regime.

[10] As in Egan et al. (2017), the economy may allow multiple equilibria instead of a unique equilibrium. We discuss the equilibrium selection process in Section 4.

m using offered deposit rates and given beliefs in default probabilities:

$$s_{k,t}^m(i_{k,t}^m, \mathbf{i}_{-k,t}^m) = \frac{\mathbb{1}\{m \in \mathcal{M}_k\} \cdot \exp\left(\alpha i_{k,t}^m + \beta \rho_{k,t}\right)}{1 + \sum_{k \in \mathcal{K}} \mathbb{1}\{m \in \mathcal{M}_{k,t}\} \cdot \exp\left(\alpha i_{k,t}^m + \beta \rho_{k,t}\right)} \tag{10}$$

where $\mathbb{1}\{\cdot\}$ is an indicator function such that $\mathbb{1}\{m \in \mathcal{M}_k\}$ indicates whether Bank k has a branch in Market m. Because depositors have rational expectations, their belief in default probabilities is consistent in equilibrium.

Default Choice

Bank shareholders endogenously choose whether to default or not. A bank does not declare bankruptcy simply due to a negative profit shock. If a distressed bank's market value is high enough, shareholders can raise more equity capital to finance its business even after negative profit shocks. A distressed bank decides to default when the market value is lower than the amount of additional funds that its shareholders should issue to support the business. Therefore, if the gross return of Bank k is lower than the required payment to its depositors after $R_{k,t}$ is realized, the shareholders have to provide additional funds through equity capital issuance in order to make up the shortfall to finance the bank. It happens if

$$D_{k,t}R_{k,t} + \kappa D_{k,t}(R_{k,t} - r) - \sum_{m \in \mathcal{M}_k} s_{k,t}^m i_{k,t}^m < 0.$$

In our model, banks have limited liability protection, so shareholders may decide not to finance a shortfall. If a bank defaults, the bank's shareholders lose their claim to cash flows from the next period onward since shareholders do not own the franchise. Let $E_{k,t+1}$ denote the market value of Bank k at time $t+1$. The shareholders of Bank k choose to support the bank as long as the value of staying in business is higher than the cost of default:

$$\underbrace{D_{k,t}R_{k,t} + \kappa D_{k,t}(R_{k,t} - r) - \sum_{m \in \mathcal{M}_k} s_{k,t}^m i_{k,t}^m + \frac{1}{1+r}E_{k,t+1}}_{\text{value of staying in business}} > -\kappa D_{k,t}.$$

We assume $R_{k,t}$ are i.i.d. across time. The above expression implies a cutoff strategy for the default decision of Bank k. If $R_{k,t}$ is below a certain level defined as $\overline{R}_k$, shareholders of Bank k will not issue additional equity capital, and the bank will declare bankruptcy. If $R_{k,t}$ is above $\overline{R}_k$, shareholders of Bank k will choose to repay depositors by issuing additional equity capital, and the bank will keep operating business in the next period. $\overline{R}_k$ is implicitly defined as the bank profit shock at which its shareholders are indifferent between declaring bankruptcy and issuing additional equity capital, satisfying

$$D_{k,t}R_{k,t} + \kappa D_{k,t}(R_{k,t} - r) - \sum_{m \in \mathcal{M}_k} s_{k,t}^m i_{k,t}^m + \frac{1}{1+r}E_{k,t+1} = -\kappa D_{k,t}.$$

Since $R_{k,t}$ follows a normal distribution, we define the default probability of Bank k at time t by

$$\rho_{k,t} = \Phi\left(\frac{R_{k,t} - \mu_k}{\sigma_k}\right),$$

where Φ is the standard normal CDF function. Following Egan et al. (2017), the optimal cutoff rule is directly related to the default probability

$$\begin{aligned}
&\kappa D_{k,t} - \underbrace{\left(D_{k,t}\overline{R}_k + \kappa D_{k,t}(\overline{R}_k - r) - \sum_{m\in\mathcal{M}_k} s^m_{k,t} i^m_{k,t}\right)}_{\text{shortfall}} \qquad (11)\\
=&\frac{1}{1+r}\left[-\kappa D_{k,t} + (1+\kappa)D_{k,t}\underbrace{\left(1 - \Phi\left(\frac{\overline{R}_k - \mu_k}{\sigma_k}\right)\right)}_{\text{survival probability}}\underbrace{\left((\mu_k - \overline{R}_k) + \sigma_k\lambda\underbrace{\left(\frac{\overline{R}_k - \mu_k}{\sigma_k}\right)}_{\text{limited liability}}\right)}_{\text{expected return on deposits}}\right]
\end{aligned}$$

where $\lambda(\cdot) \equiv \phi(\cdot)/\left(1 - \Phi(\cdot)\right)$ is the inverse Mills ratio. $\overline{R}_k$ is unique for a given deposit rate choice of Bank k, the equilibrium deposit market share derived in equation (10), and the bank's market value to shareholders. These choices are determined in equilibrium with the expectation of the bank's default strategy, $\overline{R}_k$.

The LHS of equation (11) is the amount of equity capital that shareholders have to issue at the default threshold. The capital requirements play an important role as a buffer, since the policy allows shareholders to raise additional funds for less than the actual shortfall to finance a distressed bank. The RHS of equation (11) represents the discounted future value of the bank in equilibrium. The value depends on the regulatory cost, the equilibrium survival probability, and the expected return on deposits. A portion of the future value for shareholders comes from their ability to declare bankruptcy in the future. The term associated with limited liability can be understood as the value of exercising the default option.

An important result of the bankruptcy cutoff condition is the possibility of multiple equilibria. Depositors are concerned about the default probabilities of banks in equation (6), and bank net profits depend on deposits in equation (9). So there is a potential feedback loop. For example, a decrease in demand for Bank k deposits makes Bank k increase deposit rates to collect more deposits, leading to a lower level of net profits. Then, Bank k's default probability increases, making the deposits to Bank k less attractive. The feedback loop makes depositors' beliefs in the default probability of Bank k self-fulfilling. Our solution algorithm applies the concept of optimal decisions to find a fixed point.

Deposit Pricing

The financial institutions in the model compete for deposits by playing a Bertrand-Nash price-setting game in each regional market. At the beginning of each period, given information on the demand for deposits in equation (10), banks optimally determine deposit rates for regional markets to maximize the expected return to shareholders. Due to limited liability, shareholders consider payoffs only if $R_{k,t}$ is realized above $\overline{R}_k$. The market value of equity at the beginning of time t is

$$E_{k,t} = \max_{\{i^m_{k,t}\}_{m\in\mathcal{M}_k}} \int_{\overline{R}_k}^{\infty} \left[(1+\kappa)D_{k,t}R_{k,t} - \sum_{m\in\mathcal{M}_k} s^m_{k,t}(i^m_{k,t}, \mathbf{i}^m_{-k,t})(i^m_{k,t} + \kappa r) + \frac{E_{k,t+1}}{1+r} \right] dF(R_{k,t})$$
$$- \int_{-\infty}^{\overline{R}_k} \kappa \underbrace{\sum_{m\in\mathcal{M}_k} s^m_{k,t}(i^m_{k,t}, \mathbf{i}^m_{-k,t})}_{D_{k,t}} dF(R_{k,t})$$

where the second integral reflects the expected loss to the shareholders under bankruptcy. Since $R_{k,t}$ follows a normal distribution and $E_{k,t}$ is stationary,

$$E_{k,t} = \max_{\{i^m_{k,t}\}_{m\in\mathcal{M}_k}} \left(1 - \Phi\left(\frac{\overline{R}_k - \mu_k}{\sigma_k}\right)\right) \left((1+\kappa)D_{k,t}\left(\mu_k + \sigma_k \lambda\left(\frac{\overline{R}_k - \mu_k}{\sigma_k}\right)\right)\right.$$
$$\left. - \sum_{m\in\mathcal{M}_k} s^m_{k,t}(i^m_{k,t}, \mathbf{i}^m_{-k,t})(i^m_{k,t} + \kappa r) + \frac{E_{k,t}}{1+r}\right) - \Phi\left(\frac{\overline{R}_k - \mu_k}{\sigma_k}\right)\kappa D_{k,t}.$$

The deposit rates can affect the market value of equity through the current perating profit in equation (9) and the bankruptcy threshold $\overline{R}_k$ in equation (11). Because shareholders choose to default optimally, we apply the envelope theorem,

$$\frac{\partial}{\partial i^m_{k,t}} \Phi\left(\frac{\overline{R}_k - \mu_k}{\sigma_k}\right) = 0 \quad \text{for all} \quad m \in \mathcal{M}_k. \tag{12}$$

Using equations (10) and (12), the first-order condition characterizing the optimal deposit pricing in a regional market m is

$$\left(1 - \Phi\left(\frac{\overline{R}_k - \mu_k}{\sigma_k}\right)\right) \left(\underbrace{(1+\kappa)\left(\mu_k + \sigma_k\lambda\left(\frac{\overline{R}_k - \mu_k}{\sigma_k}\right)\right)}_{\text{marginal benefit}} - \underbrace{(i^m_{k,t} + \kappa r)}_{\text{marginal cost}} \right) - \Phi\left(\frac{\overline{R}_k - \mu_k}{\sigma_k}\right)\kappa$$
$$= \left(1 - \Phi\left(\frac{\overline{R}_k - \mu_k}{\sigma_k}\right)\right) \underbrace{\frac{1}{\alpha(1 - s^m_{k,t}(i^m_{k,t}, \mathbf{i}^m_{-k,t}))}}_{\text{mark-up}}. \tag{13}$$

The condition is similar to the typical Bertrand-Nash pricing condition. The marginal benefit of deposits is the same across regional markets since the deposits are used to finance the same loan investment. Thus, the LHS of equation (13) is invariant to m. Because the equilibrium market shares are different across regions, the best deposit rates can be different for banks that take deposits from more than one region. A bank can provide a higher deposit rate in a region with a lower market share.

Equilibrium

The pure strategy Bayesian Nash Equilibria are characterized by the conditions describing the optimal behavior of banks and depositors. Demand for deposits is characterized by the choice of depositors among banks in the equation (10) for each bank in each regional market. Depositors anticipate the default risks of banks when choosing where to save their wealth. The optimal choice of bank shareholders determines the deposit supply. Each bank sets deposit rates to maximize the market value of equity, so the equation (13) holds for each bank in each regional market. Banks choose to default given a profit shock to loan investment, so equation (11) holds for each bank. Depositors have rational expectations, so the belief is consistent in equilibrium. The equilibrium conditions form the foundation of our estimation and calibration.

4 Calibration and Estimation

4.1 Calibration of Supply Parameters

In our benchmark model, we have one big bank (Bank A), three medium banks (Banks B, C, and D), and nine small banks, as depicted in Figure 2. Banks optimally set their deposit rates and choose whether to default. For simplicity, we assume that all banks in the model have the same deposit rate, denoted by i_{ss}, and default probability, denoted by ρ_{ss}, in a steady state. Using RateWatch from S&P Global Market Intelligence, we calculate i_{ss} based on a certificate of deposit with one-year maturity and $\$10,000$ minimum savings from 2001 to 2010. We also calculate the cost of deposits from the Call Report for the same period. Based on the calculation, we set $i_{ss} = 0.025$. ρ_{ss} is set based on the annual exit rate in the U.S. banking industry from 2001 to 2010 and Audrino et al. (2019). As a result, we get $\rho_{ss} = 0.025$. Finally, we set $\omega = 0.04$ from the Basel II regime and $r = 0.01$ as the risk-free rate.

For each bank, we analytically derive two parameters, μ_k and σ_k, from the optimal behavior of banks in the model. Since the default probability is endogenously determined as the optimal default strategy,

$$\rho_{ss} = \Phi\left(\frac{\overline{R}_k - \mu_k}{\sigma_k}\right). \tag{14}$$

The expression is inverted to obtain the normalized endogenous bankruptcy cutoff,

$$\frac{\overline{R}_k - \mu_k}{\sigma_k} = \Phi^{-1}(\rho_{ss}). \tag{15}$$

We start with the bankruptcy condition from equation (11) showing that shareholders of Bank k are indifferent between staying in business and defaulting. Using equations (14) and (15), equation (11) becomes

$$\begin{aligned}
&\Big[(1+\kappa)(\mu_k + \sigma_k \Phi^{-1}(\rho_{ss})) - i_{ss} - \kappa r - \kappa\Big] \underbrace{n(\mathcal{M}_k)\overline{s}}_{D_{k,t}} \\
=& \frac{1}{1+r}\Big[\kappa + \sigma_k(1+\kappa)\left(1-\rho_{ss}\right)\Big(\Phi^{-1}(\rho_{ss}) - \lambda\left(\Phi^{-1}(\rho_{ss})\right)\Big)\Big] n(\mathcal{M}_k)\overline{s} \qquad (16)
\end{aligned}$$

where $n(\mathcal{M}_k)$ is the number of regional markets in which Bank k operates branches to collect deposits. With i_{ss} and ρ_{ss}, $\overline{s}$ is from equation (10). $\overline{s}$ is a function of the demand-side parameters, α and β. Similarly, equation (13) becomes

$$(1-\rho_{ss})\Big((1+\kappa)\Big(\mu_k + \sigma_k \lambda\left(\Phi^{-1}(\rho_{ss})\right)\Big) - i_{ss} - \kappa r\Big) - \rho_{ss}\kappa = \frac{(1-\rho_{ss})}{\alpha(1-\overline{s})}. \qquad (17)$$

Using equations (16) and (17),

$$\sigma_k = \frac{\dfrac{1}{\alpha(1-\overline{s})} + \left(\dfrac{\rho_{ss}}{1-\rho_{ss}}\right)\kappa - (2+r)\kappa}{(1+r)(1+\kappa)(r+\rho_{ss})(\lambda\left(\Phi^{-1}(\rho_{ss})\right) - \Phi^{-1}(\rho_{ss}))} \qquad (18)$$

$$\mu_k = \frac{1}{1+\kappa}\left(i_{ss} + \kappa r + \frac{1}{\alpha(1-\overline{s})} + \left(\frac{\rho_{ss}}{1-\rho_{ss}}\right)\kappa\right) - \sigma_k \lambda\left(\Phi^{-1}(\rho_{ss})\right). \qquad (19)$$

Since $\overline{s}$ is a function of α and β, the supply-side parameters are determined once the demand-side parameters are estimated. The two parameters are the same for all banks in the model. Thus, Bank A in Figure 2 does not have an advantage on asset side as a big bank. Banks in our model have a unique source of heterogeneity only in the liability side, the number of regional deposit markets. One intuitive outcome with $\alpha > 0$ and $0 < \overline{s} < 1$ is

$$\frac{\partial}{\partial \kappa}\sigma_k \propto \left(\underbrace{\frac{\rho_{ss}}{1-\rho_{ss}} - 2}_{<0} - r - \frac{1}{\alpha(1-\overline{s})}\right) < 0,$$

which means the return on loan investment becomes less volatile as the capital requirements get more restrictive. Our model conceptually reflects the traditional implication of capital requirements on the riskiness of loan portfolios.

4.2 Estimation of Demand Parameters

We use the simulated method of moments to estimate α and β in equation (6). The two demand parameters determine the supply parameters from equations (18) and (19) through the markup term. We define a two-dimensional parameter space,

$$(\alpha, \beta) \in [0.5, 1, ..., 49.5, 50] \times [-20, -19.5, ..., -0.5, 0],$$

and solve the model 50,000 times for each pair of (α, β) to obtain three moments: default rates, equity issuance rates, and deposit rates. The parameter space is designed to be consistent with empirical estimates in Table 3 from Egan et al. (2017). The empirical moments for default rates and deposit rates are both set by 0.025, which is from $\rho_{ss} = 0.025$ and $i_{ss} = 0.025$. The empirical moment for equity issuance rates is redefined from the dependent variable from 2001:Q1 to 2014:Q4 in Table 2 to exclude an effect of dividend payments on equity capital issuance,

$$\text{Issuance} = \mathbb{1}\{\underbrace{\text{Sale of Common Stock}}_{\text{BHCK3579}} + \underbrace{\text{Conversion or Retirement of Common Stock}}_{\text{BHCK3580}} \\ - \underbrace{\text{Cash Dividends Declared on Common Stock}}_{\text{BHCK4460}} > 0\},$$

and the estimated value is 0.41.

For each (α, β) in the parameter space, we solve the model as follows:

- Using the pre-determined parameters, we obtain σ_k and μ_k from equations (18) and (19). A return shock is generated from $N(\mu_k, \sigma_k)$ for each bank to define an initial default probability. Also, the initial deposit rate is defined as $i_{ss} = 0.025$ for all banks.

- Using equation (10), we calculate the deposit market share and use equation (13) to get $\overline{R}_k$. Since we use i_{ss} as the optimal pricing decision for all banks, we may have different values of $\overline{R}_k$ in equation (13) depending on deposit market shares of Bank k. The different values of $\overline{R}_k$ should converge to the optimal default cutoff as we iterate through the solution process.

- Using $\overline{R}_k$ from the previous step, if Bank k collects deposits from only one regional market, we find a new deposit rate from equation (11). If Bank k collects deposits from multiple regional markets, we need to use equations (13) and (11) to generate a system of equations. For example, Bank A has three types of equation (13) since it competes for deposits in three regional markets. We derive the following two equations:

$$i^1_{A,t} + \frac{1}{\alpha\left(1 - s^1_{A,t}(i^1_{A,t}, \mathbf{i}^1_{-A,t})\right)} = i^2_{A,t} + \frac{1}{\alpha\left(1 - s^2_{A,t}(i^2_{A,t}, \mathbf{i}^2_{-A,t})\right)}$$
$$i^2_{A,t} + \frac{1}{\alpha\left(1 - s^2_{A,t}(i^2_{A,t}, \mathbf{i}^2_{-A,t})\right)} = i^3_{A,t} + \frac{1}{\alpha\left(1 - s^3_{A,t}(i^3_{A,t}, \mathbf{i}^3_{-A,t})\right)}.$$

  We update the deposit rate pricing of Bank A by solving equation (11) and the above two equations simultaneously. If we have three different values of $\overline{R}_A$ from the previous step, we use the average value of them to define a value of $\overline{R}_A$ in equation (11).

- With the updated deposit rates, we go back to the second step and iterate the solution process

Table 4: Simulation Results

		Default (%)			Equity Issuance (%)			Deposit Rate (%)		
Benchmark Model										
# of Markets		Big	Mid	Small	Big	Mid	Small	Big	Mid	Small
3		1.74	1.90	2.60	39.50	41.98	45.49	2.50	2.50	2.54
4		1.56	1.89	2.61	36.59	42.47	45.70	2.52	2.50	2.53
5		1.33	1.95	2.59	33.62	42.63	45.72	2.53	2.49	2.53
Capital Requirement (Basel II Type)										
ω	#	Big	Mid	Small	Big	Mid	Small	Big	Mid	Small
6.0 %	3	1.47	1.60	2.50	37.43	40.25	44.62	2.50	2.50	2.54
	4	1.37	1.64	2.52	33.71	40.48	44.64	2.53	2.50	2.53
	5	1.16	1.65	2.49	31.02	40.56	44.61	2.54	2.50	2.53
8.0 %	3	2.99	2.64	2.27	30.57	35.60	42.15	2.70	2.64	2.60
	4	3.66	2.53	2.22	26.31	35.99	42.09	2.78	2.63	2.60
	5	4.29	2.49	2.18	22.55	36.16	41.99	2.85	2.62	2.59
8.0 % with $\bar{i}$	3	1.83	1.99	1.98	42.90	43.18	43.02	2.46	2.46	2.47
	4	2.04	2.03	1.97	43.37	43.08	42.96	2.46	2.46	2.47
	5	2.05	1.94	1.97	44.64	42.78	42.90	2.45	2.46	2.47
Capital Requirement (Basel III Type)										
ω	#	Big	Mid	Small	Big	Mid	Small	Big	Mid	Small
6.0 %	3	1.48	1.58	2.50	37.02	40.18	44.52	2.51	2.50	2.54
	4	1.38	1.65	2.52	34.23	40.49	44.56	2.54	2.50	2.53
	5	1.18	1.65	2.47	30.82	40.68	44.65	2.54	2.50	2.53
8.0 %	3	3.14	2.51	2.27	30.84	35.80	42.06	2.71	2.63	2.60
	4	3.83	2.53	2.23	27.01	35.93	42.04	2.83	2.63	2.60
	5	4.35	2.53	2.20	22.36	36.24	42.15	2.86	2.62	2.59
8.0 % with $\bar{i}$	3	2.04	1.93	1.93	42.83	43.16	43.05	2.46	2.46	2.47
	4	2.17	1.95	1.92	43.70	43.05	42.92	2.50	2.46	2.47
	5	2.03	1.99	1.94	44.63	42.88	42.94	2.45	2.46	2.47

until the optimal decisions of all banks converge. The process finds a fixed point.

- As in Egan et al. (2017), multiple equilibria play an essential role in the economy: there may be multiple sets of depositors' beliefs that are consistent with default probabilities.[11] We assume that the equilibrium is degenerate: we select the equilibrium that deviates the least from the target moments of average realized default rates and average equity issuance rates.

Based on the solution algorithm, we get $\alpha = 35$ and $\beta = -5$. The parameters derive the simulation outcomes in the first row of Table 4. In the model of three regional markets, we have one big bank, three medium banks, and nine small banks, so the average default probability from

[11]The presence of multiplicity does not always preclude model identification. Dynamic incomplete-information games are often estimated by assuming the existence of a one-to-one mapping between value functions and conditional choice probabilities (Bajari et al., 2007). De Paula (2013) reviews the recent work in the literature.

the simulation is

$$\frac{(1 \times 1.74 + 3 \times 1.9 + 9 \times 2.6)}{(1 + 3 + 9)} = 2.37\%,$$

which is close to 2.50% from $\rho_{ss} = 0.025$. Similarly, the average equity issuance rate from the model simulation is 44.2%, which is close to its empirical counterpart, 41.0%. The average deposit rate is 2.53% close to 2.50% from $i_{ss} = 0.025$. The estimates for the demand parameters make the simulated moments close enough to their corresponding empirical moments. As an external validity test, we calculate the average regional deposit market share from the estimated model at 16.1%, which is close to its empirical counterpart, 15.8%.

5 Simulation Results

5.1 Benchmark Model

We simulate the benchmark model 50,000 times using the parameter values from the last section. In Table 4, we report deposit rates, equity issuance rates, and deposit rates. Each reported number represents an average value within the same group of banks, depending on their size. For instance, the benchmark model has three medium banks (Banks B, C, and D). Each default rate under the "Mid" column with three regional markets in Table 4 is calculated from 150,000 default decisions of these banks. Likewise, each default rate under the "Small" column with three regional markets in Table 4 is calculated from 450,000 default decisions of the small banks.

The first row of Table 4 shows the simulated outcomes from the benchmark model described in Figure 2. As a bank operates branches in more regional markets to collect deposits, it is less likely to issue equity capital. In addition, a bank is less likely to default if it competes for deposits in more regional markets. Considering that the average deposit rates among the three different categories of banks from the benchmark model simulation are almost the same at around 2.50%, the smaller chances of declaring bankruptcy and issuing equity capital are associated with the number of regional markets as deposit funding sources.[12] To understand the mechanism behind the outcomes, we simulate two different scenarios. For each scenario, we fix a vector of returns for all banks except for one:

- Example I: Bank 1 (small) in Market 1,
- Example II: Bank B (medium) in Market 1 and Market 2.

We solve the benchmark model by changing the ROA of Bank 11 in Example I and for Bank B in Example II from 0.10 to 0.70 while maintaining a vector of the returns for the others,

$$[R_A, R_C, R_D, R_{21}, R_{31}, R_{12}, R_{22}, R_{32}, R_{13}, R_{23}, R_{33}]$$

[12] Since σ_k and μ_k are the same for all banks in the model, the result is hard to interpret as an asset-side ramification. The result justifies our approach to linking deposit market competition and equity capital issuance.

$$=[0.35, 0.47, 0.51, 0.21, 0.18, 0.18, -0.29, 0.17, -0.30, -0.80, 0.50].$$

We also define $R_B = 0.35$ in Example I and $R_{11} = 0.35$ in Example II to make two simulation scenarios comparable to each other. Figure C5 shows the optimal deposit rates (%) and the deposit market share (%) from two simulation scenarios.

Example I

As the ROA of Bank 11 increases, the bank chooses to provide a higher deposit rate in Market 1 to collect more deposits. In response to Bank 11, some banks in Market 1 (Banks A, B, and D) try to increase the deposit rates, but not as much as Bank 11 does if the returns are satisfactory enough. The other banks in Market 1 (Banks 21 and 31) provide lower deposit rates to minimize business losses. As a result, Bank 11 receives a higher market share in Market 1 by offering a higher deposit rate, while the other banks in Market 1 lose market share as the ROA of Bank 11 improves. The market structure puts upward pressure on the cost of deposits $((\sum_{m\in\mathcal{M}_k} s^m_{k,t} i^m_{k,t})/(\sum_{m\in\mathcal{M}_k} s^m_{k,t}))$ for Banks A, B, and D since they provide higher rates while losing market share.

Since Banks A, B, and D all have multiple branches, the outcomes in Market 1 directly influence their optimal decisions in the other regional markets. One common observation is that their market share is stable, even though their optimal deposit rates in Markets 2 and 3 have gone down. Depositors are concerned with default risks and deposit rates, and the ROA impacts the default risk. In our first simulation scenario,

$$R_A = R_B < R_C < R_D$$

among banks with multiple branches, so Bank D has a lower default risk. Bank D decreases the deposit rate in Market 3, while maintaining a stable deposit market share in Market 3. The market structure can put downward pressure on the cost of deposits for Bank D. A similar mechanism works for Bank A, as evidenced by how the bank sets deposit rates while protecting its market share in Markets 2 and 3. In addition to the direct influence, banks that do not compete with Bank 11 in Market 1 can be affected by Banks A, B, and D. For example, Bank C competes with Banks A and B in Market 2 and with Banks A and D in Market 3. The optimal pricing decision of Bank 11 has an indirect impact on Bank C through the branch networks of Banks A, B, and D.

Example II

As Bank B's ROA increases, it chooses to provide higher deposit rates in Markets 1 and 2 in order to collect more deposits. In response to Bank B, Bank A decreases deposit rates in Markets 1 and 3 but increases deposit rates in Market 2. As a result, Bank A can maintain the flow of deposits from its diversified funding base. On the other hand, Banks C and D increase deposit rates in the regional markets where they compete with Bank B so as not to lose too much market share. Bank B gains a larger market share in Markets 1 and 2 by offering higher deposit rates, whereas the other banks lose market share as Bank B's ROA improves.

The outcomes in Markets 1 and 2 directly influence Banks A, C, and D's optimal decisions in Market 3. Similar to Example I, the banks can protect their market share even though they decrease their deposit rates in Market 3. Again, the optimal decisions of Banks A, C, and D in Market 3 can affect banks that do not compete with Bank B in Markets 1 and 2. For example, Bank 33 increases its deposit rate to get a higher market share since Banks A, C, and D decrease deposit rates in Market 3. The optimal pricing decisions of Bank B have an indirect impact on Bank 33 through the branch networks of Banks A, C, and D.

Two simulation analyses show that the main advantage of having a well-diversified deposit funding base is the ability to control the cost of deposits. The ability is associated with managing the cost term in equation (9). Bank A has the lowest rate of declaring bankruptcy and the lowest rate of issuing equity capital, as shown in the first row of Table 4, because the bank can weaken the negative effect of the cost term in equation (9) on the market value. To quantify the ability to control the cost of deposits for each bank in Examples I and II, we compute the dispersion of the cost of deposits as follows:

$$\text{Dispersion}_k = \frac{\text{STD}\left(\frac{\sum_{m\in\mathcal{M}_k} s_{k,t}^m i_{k,t}^m}{\sum_{m\in\mathcal{M}_k} s_{k,t}^m}\right)}{\text{Mean}\left(\frac{\sum_{m\in\mathcal{M}_k} s_{k,t}^m i_{k,t}^m}{\sum_{m\in\mathcal{M}_k} s_{k,t}^m}\right)}.$$

Table 5 shows a quantitative version of our analyses in Figure C5. A pink-colored cell indicates that the ROA of a relevant bank is the source of variation in each panel. According to the left panel of Table 5, there are five banks directly influenced by Bank 11: Banks A, B, D, 21, and 31. Bank A has the lowest value of the dispersion, which means it is better than the other four banks at controlling the cost of deposits. According to the right panel of Table 5, Bank A does not have the lowest value of dispersion among the banks directly affected by Bank B. However, considering that Bank A competes with Bank B in Markets 1 and 2, the dispersion value is comparatively low.[13]

5.2 Additional Regional Markets

We add one or two more regional markets to the benchmark model as an extension based on the benchmark model. For each additional market, we include one more medium bank and three more small banks. For the four regional markets, Bank B has branches in Markets 1 and 2, Bank C has branches in Markets 2 and 3, Bank D has branches in Markets 3 and 4, and Bank E has branches in Markets 1 and 4. We keep Bank A as the only big bank in each extended model, but Bank A has an extra branch in a newly added regional market.

We simulate each extended benchmark model 50,000 times and report outcomes in the second

[13]Table 5 shows non-zero values of the dispersion for some banks not competing with Bank 11 in Example I and Bank B in Example II. The values imply that Banks 11 and B have an indirect impact through their competitors' branch networks.

Table 5: Dispersion of the Costs of Deposits

	Simulation Example I			**Simulation Example II**		
Big	Bank A: Market 1, Market 2, Market 3			Bank A: Market 1, Market 2, Market 3		
	0.20			0.61		
Mid	Bank B: Market 1, Market 2	Bank C: Market 2, Market 3	Bank D: Market 1, Market 3	Bank B: Market 1, Market 2	Bank C: Market 2, Market 3	Bank D: Market 1, Market 3
	0.30	0.07	0.79	4.65	1.13	0.72
Small	Bank 11 Market 1	Bank 12 Market 2	Bank 13 Market 3	Bank 11 Market 1	Bank 12 Market 2	Bank 13 Market 3
	4.00	0.01	0.00	0.72	0.44	0.01
	Bank 21 Market 1	Bank 22 Market 2	Bank 23 Market 3	Bank 21 Market 1	Bank 22 Market 2	Bank 23 Market 3
	0.34	0.00	0.00	0.35	0.05	0.00
	Bank 31 Market 1	Bank 32 Market 2	Bank 33 Market 3	Bank 31 Market 1	Bank 32 Market 2	Bank 33 Market 3
	0.30	0.01	0.10	0.30	0.42	0.25

row of Table 4 for the case of four regional markets and in the third row of the same table for the case of five regional markets. As Bank A has additional branches to collect deposits in more regional markets, it becomes less likely to default and less likely to issue equity capital. The result reaffirms the branch network mechanism, a novel link between deposit market competition and equity capital issuance, through which having additional branches makes Bank A better at controlling the cost of deposits. The simulation result is consistent with our empirical analysis in Table 3 showing a positive aspect of collecting deposits from a well-diversified deposit base when the deposit cost is moderate.

5.3 Different Capital Requirements

The capital requirements in our model affect default and equity capital issuance rates through the optimal default decision in equation (11) and the optimal deposit pricing in equation (13). If everything else is constant, having a higher capital ratio $\omega = \kappa/(1+\kappa)$ makes a bank less likely to declare bankruptcy or necessitate additional equity capital. However, as we show in equations (18) and (19), a different capital ratio can reshape the distribution of stochastic returns. The change in capital ratio affects the optimal behavior of banks in the model. We change the capital ratio in the benchmark model from 4.0% to 6.0% and 8.0% to understand the impacts of different capital requirements on default and equity capital issuance rates.

Given the number of regional markets, which range from three to five, we simulate the model 50,000 times with a new capital ratio. The first six rows in the second panel of Table 4 show our simulation outcomes. When $\omega = 6.0\%$, there is a decrease in the number of default and equity capital issuance cases for all banks of different sizes. Considering that the average deposit rates are almost the same at around 2.50%, the higher capital ratio improves the capital buffer without increasing the cost of deposits. The optimal decision in equation (13) is not affected as much as

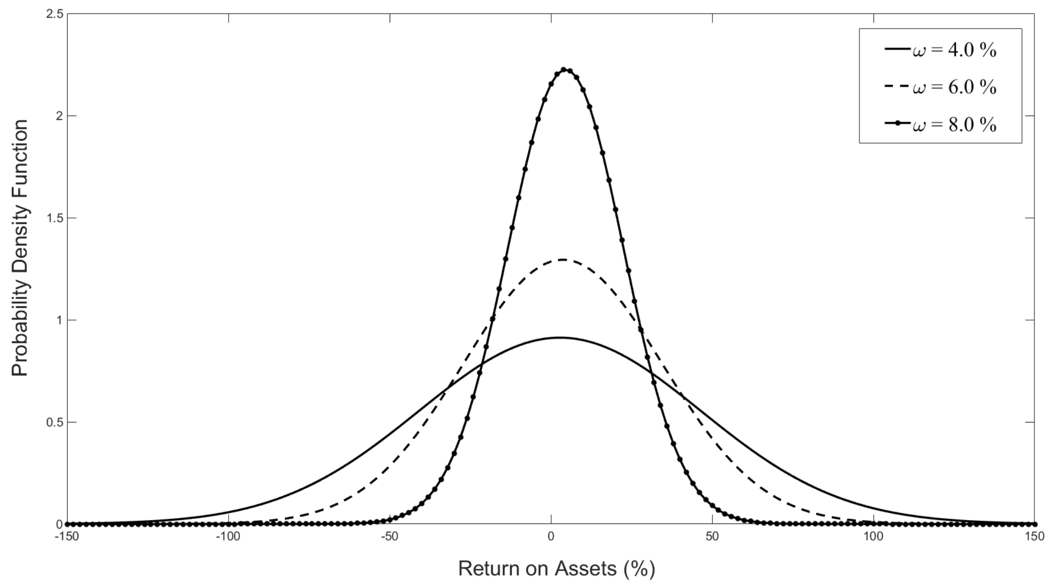


Figure 4: Capital Requirements and Distributions of the Return on Assets

in equation (11). As Bank A operates additional branches in more regional markets, the default and equity capital issuance rates decrease further. The result indicates that the branch network mechanism is still working positively for the bank by efficiently controlling the cost of deposits.

When $\omega = 8.0\%$, the higher capital ratio makes banks less likely to issue equity capital through the improved capital buffer. The policy shift also makes small banks less likely to default. However, unlike the small banks, the banks with multiple branches are more likely to default under $\omega = 8.0\%$. The branch network mechanism turns out to work negatively for Bank A when the bank is distressed since Bank A has a higher default rate than the medium banks. The result can be explained by an increasing level of deposit market competition, as reflected in the higher average deposit rates.

Figure 4 shows how $\kappa = \omega/(1-\omega)$ can reshape the distribution of R_k. According to the parameter values we calibrate and estimate, a higher capital ratio implies a higher average return with lower volatility. The lower volatility has a more significant impact than the increased average returns. The result implicitly captures a key idea behind capital requirements, which make assets in the banking system safer. Thus, Bank A encounters a number of competitors with favorable returns through the branch network mechanism. For example, if these smaller banks locate their branches in all regional markets, Bank A will face higher competition pressure since the competitors will increase deposit rates in response to their good returns. Bank A optimally increases deposit rates to compete, but it can lose market share in all regional markets. Bank A's deposit costs will eventually increase. The unintended consequence of a higher capital ratio on Bank A gets worse through the branch network mechanism as Bank A operates additional branches in more regional markets. Therefore, the outcome can provide a theoretical explanation of our empirical analysis in Table 3, showing the potential disadvantage of having a wide branch network to collect deposits when the cost of deposits is higher.

In another variation of the benchmark model, we replace the Basel II capital requirements with the Basel III requirements. We describe the optimal decisions of banks under the new regime in Appendix C. We set $\omega = 6.0\%$ and $\omega = 8.0\%$ to understand the impacts of different capital requirements under the Basel III regime on default and equity capital issuance rates. Given the number of regional markets, which range from three to five, we simulate the model 50,000 times with a new capital ratio. The first six rows in the third panel of Table 4 show our simulation outcomes. Similar to the capital requirements under the Basel II regime, Bank A does not benefit from its branch network when its capital ratio becomes quite high.

5.4 FDIC Rate Cap

In the previous simulation, we showed how a safer banking system can paradoxically lead a big bank to get into trouble due to increased competition in the deposit market. To remedy a potential default of Bank A under $\omega = 8.0\%$, we incorporate a rate cap rule into the model to alleviate unnecessarily intense competition. The FDIC implements a similar rule in the U.S. banking system to prevent a less-capitalized financial institution from soliciting deposits by offering rates that significantly exceed those in its prevailing market.

To simplify our analysis, we set $\bar{i} = 3.25\%$ as the rate cap rule follows the calculation by the FDIC: the national rate, $i_{ss} = 2.50\%$, plus 75 basis points. With $\omega = 8.0\%$ and the cap, we simulate the model 50,000 times for each capital requirements regime. The last three rows in the second and third panels of Table 4 show our simulation outcomes. Under both Basel II and Basel III regimes, the rate cap rule reduces the average deposit rates, resulting in lower default rates for all banks of different sizes. That is, the rate cap rule can make the branch network mechanism work positively. The outcome is also empirically supported by Table 3 demonstrating that having a well-diversified deposit funding base can reduce insolvency risk when the cost of deposits is relatively low. The consequences justify the need for policy coordination between the FRB and FDIC in the U.S. banking system.

Since banks with multiple branches under the rate cap rule have a limited ability to utilize their branch networks to collect deposits, they do not have enough funds to invest in loan portfolios. However, due to the lower default risk under the rate cap rule and the higher average return shown in Figure 4, the banks are more likely to enjoy a higher value from staying in business than the cost of default. Therefore, bank shareholders provide additional funds to finance loan investments more often, as reflected by the higher equity capital issuance rates.

6 Conclusion

In our paper, we discuss the relationship between deposits and equity capital. We demonstrate that the cost of deposits plays a significant role in bank holding companies' equity capital issuance. According to the estimates, a one-unit increase in deposit costs corresponds to a 1.20% increase in the probability of equity capital issuance. We also show that the increase in deposit costs is associated with more than a 33.1% decrease in the Z-score. The further estimates from the high-dimensional 2SLS estimation support our hypothesis that the rising cost of deposits increases insolvency risk, so shareholders are more likely to raise additional funds through equity capital issuance to protect financial institutions' shareholder value. Depending on the degree of diversification of deposit funding sources, the impact of the cost of deposits on the Z-score can either increase or decrease.

The empirical findings inspire us to develop a structural model to demonstrate how deposit market competition can affect equity capital issuance. Our structural model is a variation of Egan et al. (2017) by incorporating multiple regional markets into deposit competition. We use the simulated method of moments to estimate demand parameters, which determine supply parameters. We show that a bank is less likely to issue equity capital when competing for deposits in more regional markets. With two simulation scenarios, we explain that the main advantage of having a well-diversified deposit funding base is the ability to control the cost of deposits. We also present a potential negative impact of having a diversified branch network under more restrictive capital requirements. The result is consistent with our empirical analysis, which found that the diversified branch network is not always helpful in decreasing default risk when the cost of deposits is already high enough.

There are several ways to extend our empirical analysis and structural model. We can investigate the relationship between deposit market competition and bank equity valuation. Some articles empirically show that the possibility of government guarantees is priced into the stock values of large financial institutions (e.g., Gandhi and Lustig (2015) and Atkeson et al. (2019)). Our paper demonstrates the potential benefit or cost of having a well-diversified branch network for large financial institutions. Understanding how diversification through branch networks is priced into stock values is interesting future work. We can also revise our structural model to reflect the entry-exit decisions of financial institutions in regional markets. Our model uses the assumption that the deposit-taking branch is exogenously given. Considering a recent report that large bank holding companies are closing numerous branches in the U.S., the extension enables us to understand how deposit market competition affects the formation of branch networks. We leave the topics for future research.

Appendix

A Sample Description on Bank Holding Companies

Figure A1: Bank Capital Structure (Mean from 2001:Q1 to 2014:Q4)

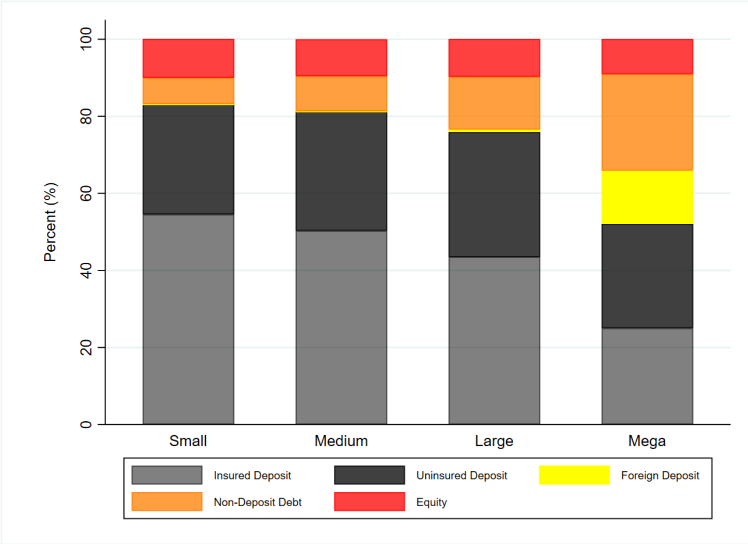
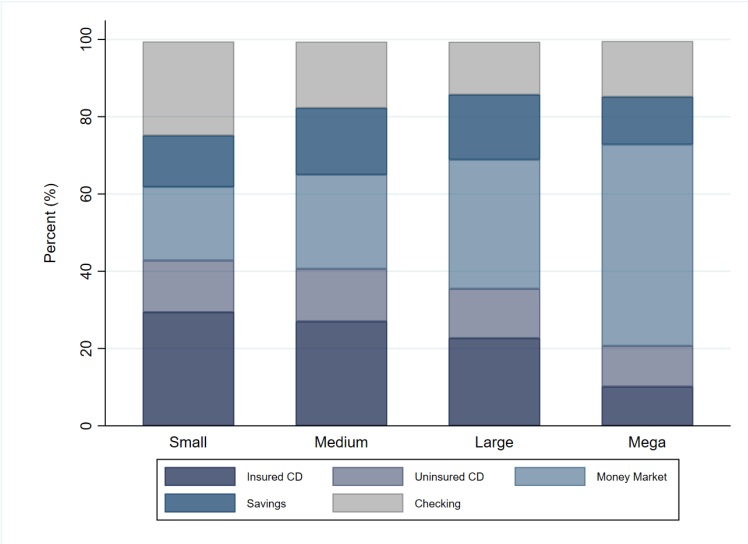


Figure A2: Deposit Composition (Mean from 2001:Q1 to 2014:Q4)



Note: Balance sheet information is from the Call Report. For each quarter over the sample period, we define the bottom 30% of banks as Small, the middle 40% of banks as Medium, the top 30% of banks excluding the top 1% of banks as Large, and the top 1% of banks as Mega. GSIB and DSIB are all included in the Mega category. Information on the insured status of each category of deposits is only available for time deposits (CD) from the Call Report.

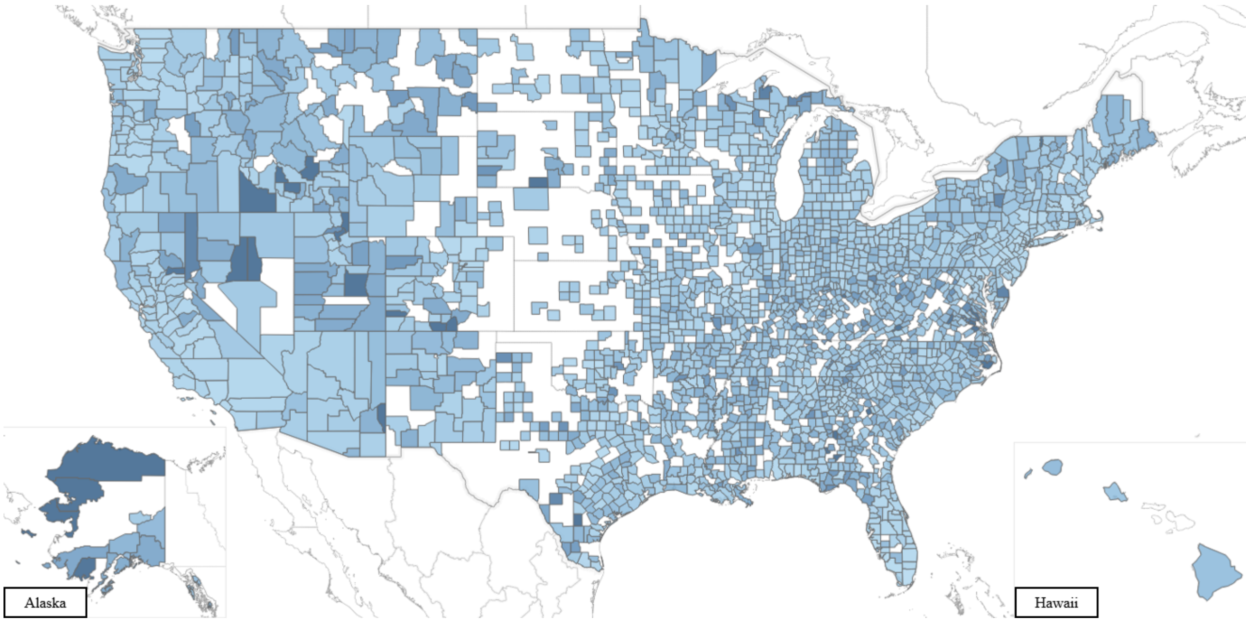


Figure A3: Deposit Market Concentrations of the U.S. in 2015

We borrow the figure from Figure A1 of Li et al. (2024). Branch-level deposit information is from the SOD issued by the FDIC. For calculating HHI in each county, we consider all financial institutions insured by the FDIC, including credit unions if their information is reported in SOD. A darker shade of blue means a more concentrated deposit market, which has a higher level of HHI. Non-shaded areas are where there is no deposit-taking institution insured by the FDIC. However, there may be an institution insured by the National Credit Union Administration.

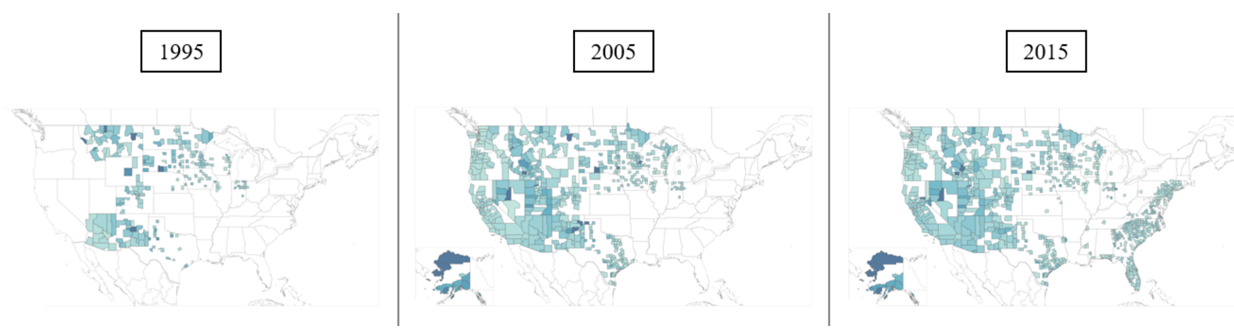


Figure A4: County-Level Deposit Market Share of Wells Fargo

We borrow the figure from Figure A2 of Li et al. (2024). A darker shade of green means a higher deposit market share for Wells Fargo in a county. Wells Fargo has expanded its deposit funding base over time. Between 1995 and 2005, the bank established more branches across the country and acquired other financial institutions after the Riegle-Neal Interstate Banking and Branching Efficiency Act of 1994. After the financial crisis of 2008, Wells Fargo acquired Wachovia, which had operated branches mainly in the Southeast.

B Empirical Analysis and Robustness Checks

B.1 Summary Statistics and Estimation Tables

Table B1: Summary Statistics

Quarterly Variables (%)	Mean	Std. Dev	P10	P50	P90	*N*
Cost of Deposits	1.84	1.08	0.47	1.72	3.35	57,676
Deposit to-Asset Ratio	80.44	8.1	69.91	82.03	88.97	57,676
Capital Ratio	15.01	16.95	10.62	13.58	20.1	57,676
Return on Asset	91.53	152.84	25.98	103.64	174.41	57,676
Annual Variables	Mean	Std. Dev	P10	P50	P90	*N*
log Diversification Index	0.75	0.72	0	0.57	1.78	14,419
log Z-Score	4.39	1.27	2.82	4.53	5.72	14,383

Note: The above table presents summary statistics (sample mean, standard deviation, 10th, 50th, and 90th percentiles) of key variables used in the empirical analysis of the paper. For readability, quarterly variables are presented in annualized percents (×400). Annual variables used in Table 3 are presented in logs as they are used the regression equations. Please refer to Section 2 for the variables' definitions.

Table B2: Prediction Models of Equity Capital Issuance (Linear Regression)

	(1) Equity Capital Issuance_t	(2) Equity Capital Issuance_t (Before)	(3) Equity Capital Issuance_t (After)
ROA_t	0.0044***	0.0063***	0.0001
	(0.0010)	(0.0016)	(0.0012)
Cost of Deposits_t	0.0167***	0.0194***	0.0197**
	(0.0046)	(0.0055)	(0.0091)
$\log(\text{CR}_{t-1})$	−0.0038	−0.0710***	−0.0204
	(0.0086)	(0.0136)	(0.0126)
$\log(\text{DTA}_{t-1})$	−0.1346***	−0.1764***	−0.1319***
	(0.0259)	(0.0386)	(0.0413)
Dividend_t	0.0302***	0.0249***	0.0275***
	(0.0043)	(0.0055)	(0.0070)
Bank FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
Adjusted R-Squared	0.570	0.594	0.654
Observations	55,852	35,198	20,654

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, standard errors are in parentheses.

Note: The table presents the linear probability model estimates with two-way fixed effects. The regressors correspond to Table 2.

Table B3: Prediction Models of Equity Capital Issuance (Intensive Margin)

	(1)	(2)	(3)
	Equity Capital_t	Equity Capital_t	Equity Capital_t
		(Before)	(After)
ROA_t	0.0015^{***}	0.0074^{***}	-0.0013^{***}
	(0.0002)	(0.0002)	(0.0003)
Cost of Deposits_t	0.0023^{***}	0.0023^{***}	-0.0028
	(0.0009)	(0.0008)	(0.0024)
$\log(\text{CR}_{t-1})$	-0.0031	-0.0068^{***}	-0.0128^{***}
	(0.0016)	(0.0019)	(0.0033)
$\log(\text{DTA}_{t-1})$	-0.0268^{***}	-0.0108^{**}	-0.0560^{***}
	(0.0049)	(0.0055)	(0.0108)
Dividend_t	-0.0005	-0.0012	0.0002
	(0.0008)	(0.0008)	(0.0018)
Bank FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
Adjusted R-Squared	0.150	0.264	0.207
Observations	55,740	35,163	20,577

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, standard errors are in parentheses.

Note: The table presents the linear regression model estimates with two-way fixed effects. The dependent variable is the standardized value of equity capital. The regressors correspond to Table 2. The estimation excludes 112 outlier observations (0.23% of the full sample) to present stable results. The outlier's equity capital value is greater than 685,000 or less than -685,000, and the standardized value is greater than 2.

Table B4: Prediction Models of Equity Capital Issuance without the Bias Correction

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Issuance_t	Issuance_t	Issuance_t	Issuance_t	Issuance_t	Issuance_t	Issuance_t	Issuance_t
ROA_t	-0.078^{***}	-0.039^{***}	0.000	-0.001	-0.047^{***}	-0.024^{***}	0.043^{***}	0.025^{***}
	(0.007)	(0.003)	(0.008)	(0.005)	(0.007)	(0.004)	(0.010)	(0.006)
Cost of Deposits_t	-0.207^{***}	-0.122^{***}	-0.204^{***}	-0.116^{***}	-0.164^{***}	-0.096^{***}	0.132^{***}	0.073^{***}
	(0.009)	(0.006)	(0.016)	(0.009)	(0.018)	(0.011)	(0.047)	(0.027)
$\log(\text{CR}_{t-1})$	-1.188^{***}	-0.709^{***}	0.027	-0.003	-1.232^{***}	-0.725^{***}	-0.038	-0.049
	(0.036)	(0.021)	(0.082)	(0.048)	(0.037)	(0.021)	(0.086)	(0.050)
$\log(\text{DTA}_{t-1})$	-2.461^{***}	-1.497^{***}	-1.150^{***}	-0.613^{***}	-2.436^{***}	-1.469^{***}	-1.328^{***}	-0.704^{***}
	(0.083)	(0.050)	(0.234)	(0.136)	(0.084)	(0.051)	(0.255)	(0.147)
Dividend_t	0.283^{***}	0.162^{***}	0.367^{***}	0.206^{***}	0.296^{***}	0.174^{***}	0.390^{***}	0.234^{***}
	(0.020)	(0.012)	(0.046)	(0.026)	(0.020)	(0.012)	(0.048)	(0.027)
Model	Logit	Probit	Logit	Probit	Logit	Probit	Logit	Probit
Bank FE	No	No	Yes	Yes	No	No	Yes	Yes
Time FE	No	No	No	No	Yes	Yes	Yes	Yes
Error Correction	No	No	No	No	No	No	No	No
Observations	55,852	55,852	36,770	36,770	55,852	55,852	36,770	36,770

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, and standard errors are in parentheses.

Table B5: Prediction Models of Equity Capital Issuance (ROE and Tier 1 CR)

	(1)	(2)	(3)	(4)	(5)	(6)
	Issuance_t	Issuance_t	Issuance_t (Before)	Issuance_t (Before)	Issuance_t (After)	Issuance_t (After)
ROE_t	0.0027***	0.0015***	0.0046**	0.0026*	0.0004	0.0003
	(0.0006)	(0.0003)	(0.0024)	(0.0014)	(0.0008)	(0.0005)
Cost of Deposits_t	0.128***	0.071***	0.140**	0.068*	0.216*	0.124**
	(0.047)	(0.027)	(0.065)	(0.035)	(0.112)	(0.063)
$\log(\text{Tier 1 CR}_{t-1})$	0.041	0.000	−0.818***	−0.485***	−0.052	−0.041
	(0.074)	(0.043)	(0.160)	(0.090)	(0.127)	(0.072)
$\log(\text{DTA}_{t-1})$	−1.251***	−0.663***	−1.543***	−0.845***	−1.397***	−0.718***
	(0.253)	(0.146)	(0.443)	(0.253)	(0.479)	(0.275)
Dividend_t	0.361***	0.200***	0.364***	0.201***	0.322***	0.176***
	(0.048)	(0.027)	(0.075)	(0.042)	(0.086)	(0.049)
Model	Logit	Probit	Logit	Probit	Logit	Probit
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Error Correction	Two-Way	Two-Way	Two-Way	Two-Way	Two-Way	Two-Way
Trimming	1	1	1	1	1	1
Pseudo R-Squared	0.374	0.374	0.346	0.345	0.384	0.384
Observations	36,770	36,770	19,102	19,102	12,115	12,115

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, and standard errors are in parentheses.

Note: ROE = Net Income/Total Equity and the total equity capital is RCON3210 from the Call Report. The tier 1 capital ratio is BHCA7206 from FR Y-9C. Columns (1) and (2) are the logit and probit models, respectively, over the full sample periods. Columns (3) and (4) are estimated outcomes from the sub-sample from 2001:Q1 to 2007:Q4, whereas Columns (5) and (6) are from the sub-sample from 2008:Q1 to 2014:Q4. For all results, we set the trimming parameter in Cruz-Gonzalez et al. (2017) as one to estimate spectral expectations since the econometric model in equation (3) has the predetermined variables, Tier 1 CR_{t-1} and DTA_{t-1}, with respect to the dependent variable.

Table B6: Prediction Models of Equity Capital Issuance (Another Definition of Equity Capital)

	(1)	(2)	(3)	(4)	(5)	(6)
	Issuance_t	Issuance_t	Issuance_t	Issuance_t	Issuance_t	Issuance_t
			(Before)	(Before)	(After)	(After)
ROA_t	0.035^{***}	0.018^{***}	0.047^{*}	0.028^{*}	-0.015	-0.008
	(0.010)	(0.006)	(0.025)	(0.015)	(0.014)	(0.008)
Cost of Deposits_t	0.149^{***}	0.082^{***}	0.153^{**}	0.074^{**}	0.320^{***}	0.186^{***}
	(0.046)	(0.026)	(0.064)	(0.035)	(0.100)	(0.056)
$\log(\text{CR}_{t-1})$	-0.186^{**}	-0.137^{***}	-0.861^{***}	-0.468^{***}	-0.540^{***}	-0.312^{***}
	(0.087)	(0.049)	(0.179)	(0.094)	(0.145)	(0.082)
$\log(\text{DTA}_{t-1})$	-1.060^{***}	-0.550^{***}	-1.433^{***}	-0.786^{***}	-1.188^{**}	-0.610^{**}
	(0.252)	(0.145)	(0.444)	(0.252)	(0.475)	(0.271)
Dividend_t	0.288^{***}	0.159^{***}	0.326^{***}	0.179^{***}	0.165^{**}	0.086^{*}
	(0.046)	(0.026)	(0.074)	(0.042)	(0.081)	(0.046)
Model	Logit	Probit	Logit	Probit	Logit	Probit
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Error Correction	Two-Way	Two-Way	Two-Way	Two-Way	Two-Way	Two-Way
Trimming	1	1	1	1	1	1
Pseudo R-Squared	0.374	0.373	0.349	0.348	0.388	0.388
Observations	38,141	38,141	19,335	19,335	13,534	13,534

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, and standard errors are in parentheses.

Note: Issuance_t is redefined to combine common and preferred stock issuance. Columns (1) and (2) are the logit and probit models, respectively, over the full sample periods. Columns (3) and (4) are estimated outcomes from the sub-sample from 2001:Q1 to 2007:Q4, whereas Columns (5) and (6) are from the sub-sample from 2008:Q1 to 2014:Q4. For all results, we set the trimming parameter in Cruz-Gonzalez et al. (2017) as one to estimate spectral expectations since the econometric model in equation (3) has the predetermined variables, CR_{t-1} and DTA_{t-1}, with respect to the dependent variable.

Table B7: Prediction Models of Equity Capital Issuance (ROE, Tier 1 CR, and Another Definition of Equity Capital)

	(1)	(2)	(3)	(4)	(5)	(6)
	Issuance_t	Issuance_t	Issuance_t (Before)	Issuance_t (Before)	Issuance_t (After)	Issuance_t (After)
ROE_t	0.0029***	0.0016***	0.0042*	0.0024*	0.0007	0.0004
	(0.0006)	(0.0003)	(0.0023)	(0.0014)	(0.0007)	(0.0004)
Cost of Deposits_t	0.153***	0.086***	0.140**	0.067*	0.347***	0.201***
	(0.046)	(0.026)	(0.064)	(0.035)	(0.100)	(0.055)
$\log(\text{Tier 1 CR}_{t-1})$	−0.107	−0.089**	−0.894***	−0.525***	−0.371***	−0.221***
	(0.073)	(0.042)	(0.160)	(0.090)	(0.121)	(0.068)
$\log(\text{DTA}_{t-1})$	−1.006***	−0.524***	−1.364***	−0.763***	−1.147**	−0.590**
	(0.251)	(0.144)	(0.442)	(0.251)	(0.472)	(0.269)
Dividend_t	0.281***	0.155***	0.331***	0.184***	0.157*	0.082*
	(0.046)	(0.026)	(0.074)	(0.042)	(0.081)	(0.046)
Model	Logit	Probit	Logit	Probit	Logit	Probit
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Error Correction	Two-Way	Two-Way	Two-Way	Two-Way	Two-Way	Two-Way
Trimming	1	1	1	1	1	1
Pseudo R-Squared	0.374	0.373	0.349	0.348	0.388	0.388
Observations	38,141	38,141	19,335	19,335	13,534	13,534

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, and standard errors are in parentheses.

Note: Issuance_t is redefined to combine common and preferred stock issuance. ROE = Net Income/Total Equity and the total equity capital is RCON3210 from Call Report. The tier 1 capital ratio is BHCA7206 from FR Y-9C. Columns (1) and (2) are the logit and probit models, respectively, over the full sample periods. Columns (3) and (4) are estimated outcomes from the sub-sample from 2001:Q1 to 2007:Q4, whereas Columns (5) and (6) are from the sub-sample from 2008:Q1 to 2014:Q4. For all results, we set the trimming parameter in Cruz-Gonzalez et al. (2017) as one to estimate spectral expectations since the econometric model in equation (3) has the predetermined variables, Tier 1 CR_{t-1} and DTA_{t-1}, with respect to the dependent variable.

Table B8: Prediction Models of Equity Capital Issuance (Costs of Other Liabilities)

	(1)	(2)	(3)	(4)	(5)	(6)
	Issuance_t	Issuance_t	Issuance_t	Issuance_t	Issuance_t	Issuance_t
			(Before)	(Before)	(After)	(After)
ROA_t	0.038***	0.020***	0.054**	0.030**	−0.006	−0.002
	(0.010)	(0.006)	(0.026)	(0.015)	(0.014)	(0.008)
Cost of Deposits_t	0.125***	0.069***	0.174***	0.084**	0.194*	0.113*
	(0.047)	(0.027)	(0.064)	(0.035)	(0.112)	(0.063)
Cost of Federal Funds & Securities_t	0.00092*	0.00053	0.00105	0.00058	0.00079	0.00045
	(0.00055)	(0.00033)	(0.00144)	(0.00086)	(0.00067)	(0.00041)
Cost of Subordinated Debt_t	−0.00064	−0.00033	0.00132	0.00083	−0.01020	−0.00618
	(0.00106)	(0.00055)	(0.00123)	(0.00076)	(0.02180)	(0.00954)
Cost of Trading Liabilities & Other Money_t	−0.00027	−0.00016	−0.00020	−0.00012	−0.00018	−0.00009
	(0.00031)	(0.00019)	(0.00030)	(0.00019)	(0.00119)	(0.00066)
$\log(\text{DTA}_{t-1})$	−1.299***	−0.678***	−1.394***	−0.751***	−1.377***	−0.706***
	(0.253)	(0.146)	(0.441)	(0.252)	(0.477)	(0.273)
Dividend_t	0.367***	0.202***	0.335***	0.185***	0.329***	0.179***
	(0.048)	(0.027)	(0.075)	(0.042)	(0.086)	(0.049)
Model	Logit	Probit	Logit	Probit	Logit	Probit
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Error Correction	Two-Way	Two-Way	Two-Way	Two-Way	Two-Way	Two-Way
Trimming	1	1	1	1	1	1
Pseudo R-Squared	0.374	0.373	0.345	0.344	0.385	0.385
Observations	36,770	36,770	19,102	19,102	12,115	12,115

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, and standard errors are in parentheses.

Note: We add the costs of other liabilities: federal funds plus securities to repurchase, subordinated debt, and trading liabilities plus other money. Federal funds are excess reserves held by financial institutions, over and above the mandated reserve requirements set by the FRB. For banks, subordinated debt is junior debt that is repaid after depositors are repaid in full. Trading liabilities usually consist of derivative liabilities, the fair value of derivative instruments in a negative position as of the end of the most recent fiscal year end, as recognized and measured following generally accepted accounting principles. Columns (1) and (2) are the logit and probit models, respectively, over the full sample periods. Columns (3) and (4) are estimated outcomes from the sub-sample from 2001:Q1 to 2007:Q4, whereas Columns (5) and (6) are from the sub-sample from 2008:Q1 to 2014:Q4. For all results, we set the trimming parameter in Cruz-Gonzalez et al. (2017) as one to estimate spectral expectations since the econometric model in equation (3) has the predetermined variable, DTA_{t-1}, with respect to the dependent variable.

Table B9: The Effect of Deposit Diversification and Cost of Deposits on Insolvency Risk and Equity Capital Issuance (Subsample with varying equity capital issuance decisions)

	(1) $\log(\text{Z-Score}_t)$	(2) $\log(\text{Z-Score}_t)$	(3) Issuance_t	(4) Issuance_t
$\log(\text{Z-Score}_t)$			0.413^{**}	0.276^{*}
			(0.186)	(0.147)
$\log(\text{Z-Score}_{t-1})$		0.186^{***}	-0.211^{*}	-0.209
		(0.018)	(0.121)	(0.130)
Cost of Deposits_t	-0.327^{***}	-0.294^{***}	0.143^{**}	0.097^{**}
	(0.061)	(0.060)	(0.064)	(0.053)
$\log(\text{DivIndex}_{t-1})$	0.178^{***}	0.162^{***}	-0.015	-0.005
	(0.068)	(0.062)	(0.054)	(0.051)
Cost of $\text{Deposits}_t \times \log(\text{DivIndex}_{t-1})$	-0.072^{***}	-0.065^{***}	0.014	0.004
	(0.018)	(0.018)	(0.014)	(0.011)
MS_{t-1}	0.015^{**}	0.009	-0.002	-0.001
	(0.006)	(0.006)	(0.003)	(0.003)
DTA_{t-1}	-0.002	0.003	-0.007	-0.007
	(0.004)	(0.004)	(0.003)	(0.003)
Bank FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
STD	Cluster	Cluster	Cluster	Cluster
R-Squared	0.391	0.416		
Observations	9,356	8,312	8,312	7,167

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, and standard errors are in parentheses.

Note: Columns (1) and (2) are from the model in equation (5), and Columns (3) and (4) are from the model in equation (4). We compute standard errors with the clustered standard errors by bank holding company to account for serial correlation within each bank.

B.2 Reverse Causality Tests

We use the same composition of bank holding companies as in Table 2 to ensure the consistency of the sample used in our analysis and variations in $\text{Issuance}_{k,t}$ for each institution over time. Consider the following model:

$$\text{Cost of Deposits}_{k,t} = \nu_0 + \nu_1 \text{Issuance}_{k,t} + \nu_2 \log(\text{DTA}_{k,t-1}) + \theta_k + \delta_t + \epsilon_{k,t} \tag{20}$$

where θ_k is the bank fixed effect for removing unobserved heterogeneity among bank holding companies. Similarly, δ_t is the time-fixed effect for removing unobserved heterogeneity over time. If the estimated value of the coefficient associated with $\text{Issuance}_{k,t}$ is statistically different from zero, we confirm that the rising cost of deposits causes the higher probability of equity capital issuance. We estimate the model in equation (20), and compute standard errors with two methods: clustering standard errors by bank holding company and bootstrapping with 2,500 samples.

In addition to that, we use a different version of equation (20) to do a reverse causality test with a different estimator. Specifically, we estimate the following model:

$$\begin{aligned}\text{Cost of Deposits}_{k,t} = \upsilon_0 + \upsilon_1 \text{Issuance}_{k,t} + \upsilon_2 \text{Cost of Deposits}_{k,t-1} \\ + \upsilon_3 \log(\text{DTA}_{k,t-1}) + \theta_k + \delta_t + \epsilon_{k,t}\end{aligned} \tag{21}$$

by using the two-step estimator with GMM-type instrumental variables, including lagged deposit-to-asset ratios from L^2 to L^5 and lagged cost of deposits and equity capital issuance from L^3 to L^6 for the difference equation,

$$\begin{aligned}\Delta\text{Cost of Deposits}_{k,t} = \upsilon_1 \Delta\text{Issuance}_{k,t} + \upsilon_2 \Delta\text{Cost of Deposits}_{k,t-1} \\ + \upsilon_3 \Delta\log(\text{DTA}_{k,t-1}) + \Delta\delta_t + \Delta\epsilon_{k,t}.\end{aligned} \tag{22}$$

The robust standard errors for the two-step GMM estimators are calculated using the Windmeijier biased-corrected (WC) estimator.

Table B10 shows that equity capital issuance is not statistically significant enough to explain the cost of deposits. The result backs up what we already thought about the link between the cost of deposits and the issuance of equity capital. Column (3) determines whether the estimated model provides strong evidence against the null hypothesis of zero autocorrelation in first-differenced errors, $\Delta\epsilon_{k,t}$, at order 1. The idiosyncratic errors in equation (21) are independent and identically distributed. Also, the estimated model in Column (3) shows that the overidentifying restrictions are valid, so the null hypothesis of the Sargan test is not rejected. The result supports the validity of the instrumental variables in the two-step estimator.

Table B10: Reverse Causality Tests

	(1)	(2)	(3)
	Cost of Deposits_t	Cost of Deposits_t	Cost of Deposits_t
Issuance_t	0.010	0.010	0.023
	(0.009)	(0.009)	(0.022)
Cost of Deposits_{t-1}			0.863^{***}
			(0.014)
$\log(\text{DTA}_{t-1})$	0.402^{***}	0.402^{***}	0.251
	(0.112)	(0.116)	(0.154)
Model	Simple Panel	Simple Panel	Dynamic Panel
Bank FE	Yes	Yes	
Time FE	Yes	Yes	Yes
STD	Cluster	Bootstrap	WC-Robust
Sargan Test			Valid IVs
Arellano-Bond Test			I.I.D. Errors
R-Squared	0.893	0.893	
Observations	36,770	36,770	35,720

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, and standard errors are in parentheses.

Note: Columns (1) and (2) are from the model in equation (20) estimated by the two-way fixed effects estimator. We compute standard errors with two methods: clustered standard errors by bank holding company and bootstrapping with 2,500. Column (3) from the model in equation (21) estimated by following Arellano and Bond (1991) and standard errors are computed by the Windmeijier biased-corrected (WC) estimator for the robust variance-covariance matrix of two-step GMM estimators. The estimated model in Column (3) presents strong evidence against the null hypothesis of zero autocorrelation in the first-differenced errors at order 1, which means that the idiosyncratic errors in equation (24) are i.i.d. The null hypothesis of the Sargan test is not rejected, which supports the validity of the instrumental variables in the two-step estimator.

B.3 Market Share Effect

Banks compete for deposits by setting deposit rates, so we use deposit market share in equation (1) as the dependent variable capturing quantity information. Unlike Z-Score$_{k,t}$ in equation (3), MS$_{k,t}$ is measured by stock variables. Since the independent variable of our interest, Cost of Deposits$_{k,t}$, is a flow variable, we take $\Delta\text{MS}_{k,t} = \text{MS}_{k,t} - \text{MS}_{k,t-1}$ and estimate

$$\Delta\text{MS}_{k,t} = X'_{k,t}\boldsymbol{\vartheta} + \theta_k + \delta_t + \epsilon_{k,t} \tag{23}$$

where $X_{k,t}$ includes the same covariates with equation (5) except that log(Z-Score$_{k,t-1}$) is replaced by log(Z-Score$_{k,t}$).

We also estimate a dynamic panel model to describe how the market share responds to the cost of deposits and diversification measures.

$$\text{MS}_{k,t} = \text{MS}_{k,t-1}\rho + X'_{k,t}\boldsymbol{\varphi} + \theta_k + \delta_t + \epsilon_{k,t}. \tag{24}$$

Since $X_{k,t}$ includes MS$_{k,t-1}$, the model can be estimated in the spirit of Arellano and Bond (1991). The Windmeijier biased-corrected (WC) estimator is used to find the standard errors for the robust variance-covariance matrix of two-step GMM estimators, as explained in Windmeijer (2005). We estimate the model in equation (23) and report the results in Tables B11 and B12.

In both models, an increase in the cost of deposits is associated with a positive outcome for deposit market share. In Columns (1) and (2), for instance, an increase of one unit in Cost of Deposits$_t$ leads a bank to get an additional 0.445% increase in ΔMS$_t$ deposit market share increment. Similarly, in Column (3), an increase of one unit in Cost of Deposits$_t$ is associated with an increase in MS$_t$ by 0.610%. We verify that the estimated model in equation (24) presents strong evidence against the null hypothesis of zero autocorrelation in the first-differenced errors, $\Delta\epsilon_{k,t}$, at order 1. The result indicates that the idiosyncratic errors are i.i.d. in equation (24).

Table B11: The Effect of Deposit Diversification and Cost of Deposits on Market Share

	(1)	(2)	(3)
	Δ MS_t	Δ MS_t	MS_t
log(Z-Score$_t$)	0.045^{**}	0.045^{**}	0.019
	(0.019)	(0.020)	(0.097)
Cost of Deposits$_t$	0.445^{***}	0.445^{***}	0.610^{***}
	(0.127)	(0.124)	(0.183)
log(DivIndex$_{t-1}$)	-0.390^{***}	-0.390^{***}	-1.878^{*}
	(0.121)	(0.120)	(1.048)
Cost of Deposits$_t$ $\times$ log(DivIndex$_{t-1}$)	0.052	0.052	0.070^{*}
	(0.033)	(0.033)	(0.041)
MS_{t-1}	-0.293^{***}	-0.293^{***}	0.649^{***}
	(0.021)	(0.020)	(0.059)
DTA_{t-1}	-0.016^{**}	-0.016^{**}	0.002
	(0.008)	(0.008)	(0.012)
Bank FE	Yes	Yes	
Time FE	Yes	Yes	Yes
STD	Cluster	Bootstrap	WC-Robust
R-Squared	0.160	0.160	
Observations	12,588	12,588	10,761

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, and standard errors are in parentheses.

Note: Columns (1) and (2) are from the model in equation (23). We compute standard errors with two methods: clustering standard errors by bank holding company to account for serial correlation within each bank, leading to a theoretical distribution, and bootstrapping with 2,500 samples for an empirical distribution. Column (3) is the model in equation (24) as a robustness check for the model in equation (23). The model is estimated by following Arellano and Bond (1991) and standard errors are computed by the Windmeijier biased-corrected (WC) estimator for the robust variance-covariance matrix of two-step GMM estimators. The estimated model in Column (3) presents strong evidence against the null hypothesis of zero autocorrelation in the first-differenced errors at order 1.

Table B12: The Effect of Deposit Diversification and Cost of Deposits on Market Share (Subsample with varying equity capital issuance decisions)

	(1)	(2)	(3)
	Δ MS_t	Δ MS_t	MS_t
log(Z-$Score_t$)	0.052^{**}	0.052^{**}	0.043
	(0.022)	(0.022)	(0.088)
Cost of $Deposits_t$	0.458^{***}	0.458^{***}	0.405^{**}
	(0.147)	(0.147)	(0.198)
log($DivIndex_{t-1}$)	-0.315^{**}	-0.315^{**}	-0.967
	(0.125)	(0.123)	(0.792)
Cost of $Deposits_t$ $\times$ log($DivIndex_{t-1}$)	0.061	0.061	0.060
	(0.037)	(0.039)	(0.045)
MS_{t-1}	-0.286^{***}	-0.286^{***}	0.694^{***}
	(0.024)	(0.025)	(0.060)
DTA_{t-1}	-0.021^{**}	-0.021^{**}	-0.001
	(0.009)	(0.009)	(0.014)
Bank FE	Yes	Yes	
Time FE	Yes	Yes	Yes
STD	Cluster	Bootstrap	WC-Robust
R-Squared	0.154	0.154	
Observations	9,370	9,370	8,148

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, and standard errors are in parentheses.

Note: As a robustness check, we use the sample used for Table 2 to estimate the econometric models in equations (23) and (24). This is because bank holding companies with the constant dependent variable (always issuing or not issuing) are excluded for the logit and probit models with two-way fixed effects in equation (3), but these institutions are included for the models in Table 3. Columns (1) and (2) are from the model in equation (23). We use the fixed effects estimator to estimate the models. We compute standard errors with two methods: clustering standard errors by bank holding company and bootstrapping with 2,500 samples. Column (3) is the model in equation (24). The model is estimated by following Arellano and Bond (1991) and standard errors are computed by the Windmeijier biased-corrected (WC) estimator for the robust variance-covariance matrix of two-step GMM estimators. Also, the estimated model in Column (3) presents strong evidence against the null hypothesis of zero autocorrelation in the first-differenced errors at order 1, which means that the idiosyncratic errors in equation (24) are i.i.d.

C Model with the Risk-Free Capital Requirements

C.1 Profit Function

Under the risk-free capital requirements by the Basel III regime, shareholders are required to invest a κ share of deposits in the risk-free asset. The net period profit of Bank k is then

$$\begin{aligned}\pi_{k,t} &= \sum_{m\in\mathcal{M}_k} s_{k,t}^m\left(R_{k,t} - i_{k,t}^m\right) + \underbrace{\kappa\sum_{m\in\mathcal{M}_k} s_{k,t}^m(r-r)}_{\text{capital requirement}} \\ &= D_{k,t}R_{k,t} - \sum_{m\in\mathcal{M}_k} s_{k,t}^m i_{k,t}^m \end{aligned} \tag{25}$$

which is identical to the case in the benchmark model with $\kappa = 0$.

C.2 Default Choice

Bank shareholders endogenously choose whether to default or not. Because banks are protected by limited liability in our model, shareholders can decide not to finance a shortfall, and let a distressed bank default. If a bank defaults, shareholders of the bank lose their claim to cash flows from the next period onward since they do not own the franchise. Let $E_{k,t+1}$ denote the market value of Bank k at time $t+1$. Therefore, shareholders of Bank k choose to support the bank as long as the value of staying in business is higher than the cost of default,

$$\underbrace{D_{k,t}R_{k,t} - \sum_{m\in\mathcal{M}_k} s_{k,t}^m i_{k,t}^m + \frac{1}{1+r}E_{k,t+1}}_{\text{value of staying in business}} > -\kappa D_{k,t}.$$

Since shareholders must forfeit the required capital in the event of a default, the risk-free capital requirements still make bankruptcy more costly. Following Egan et al. (2017), the optimal cutoff rule is

$$\begin{aligned}&\kappa D_{k,t} - \left(D_{k,t}\overline{R}_k - \sum_{m\in\mathcal{M}_k} s_{k,t}^m i_{k,t}^m\right) \\ =&\frac{1}{1+r}\left[-\kappa D_{k,t} + D_{k,t}\left(1-\Phi\left(\frac{\overline{R}_k-\mu_k}{\sigma_k}\right)\right)\left((\mu_k - \overline{R}_k) + \sigma_k\lambda\left(\frac{\overline{R}_k-\mu_k}{\sigma_k}\right)\right)\right]\end{aligned} \tag{26}$$

where $\lambda(\cdot) \equiv \phi(\cdot)/\left(1-\Phi(\cdot)\right)$ is the inverse Mills ratio.

C.3 Deposit Pricing

Banks compete for deposits by offering a differentiated product Bertrand-Nash price-setting game in each regional market. At the beginning of each period, banks figure out the best deposit rates for the local markets where they have branches so that shareholders can get the most money back.

Due to limited liability, shareholders consider payoffs only if $R_{k,t}$ exceeds $\overline{R}_k$. Therefore, the market value of equity at the beginning of time t is

$$E_{k,t} = \max_{\{i^m_{k,t}\}_{m\in\mathcal{M}_k}} \int_{\overline{R}_k}^{\infty} \left[D_{k,t}R_{k,t} - \sum_{m\in\mathcal{M}_k} s^m_{k,t}(i^m_{k,t}, \mathbf{i}^m_{-k,t}) i^m_{k,t} + \frac{E_{k,t+1}}{1+r} \right] dF(R_{k,t})$$
$$- \int_{-\infty}^{\overline{R}_k} \kappa \underbrace{\sum_{m\in\mathcal{M}_k} s^m_{k,t}(i^m_{k,t}, \mathbf{i}^m_{-k,t})}_{D_{k,t}} dF(R_{k,t}).$$

Applying the normal distribution of $R_{k,t}$ and the stationarity of $E_{k,t}$, we obtain

$$E_{k,t} = \max_{\{i^m_{k,t}\}_{m\in\mathcal{M}_k}} \left(1 - \Phi\left(\frac{\overline{R}_k - \mu_k}{\sigma_k}\right)\right) \left(D_{k,t} \left(\mu_k + \sigma_k \lambda \left(\frac{\overline{R}_k - \mu_k}{\sigma_k} \right) \right) \right.$$
$$\left. - \sum_{m\in\mathcal{M}_k} s^m_{k,t}(i^m_{k,t}, \mathbf{i}^m_{-k,t})(i^m_{k,t} + \kappa r) + \frac{E_{k,t}}{1+r} \right) - \Phi\left(\frac{\overline{R}_k - \mu_k}{\sigma_k}\right) \kappa D_{k,t}.$$

The choice of deposit rates can affect the market value of equity through its influence on the current period operating profit in equation (25) and the bankruptcy threshold $\overline{R}_k$ in equation (26). Using equation (10) and (12), the first order condition characterizing the optimal deposit pricing is regional market m is

$$\left(1 - \Phi\left(\frac{\overline{R}_k - \mu_k}{\sigma_k}\right)\right) \left(\left(\mu_k + \sigma_k \lambda \left(\frac{\overline{R}_k - \mu_k}{\sigma_k} \right) \right) - i^m_{k,t} \right) - \Phi\left(\frac{\overline{R}_k - \mu_k}{\sigma_k}\right) \kappa$$
$$= \left(1 - \Phi\left(\frac{\overline{R}_k - \mu_k}{\sigma_k}\right)\right) \frac{1}{\alpha(1 - s^m_{k,t}(i^m_{k,t}, \mathbf{i}^m_{-k,t}))}. \tag{27}$$

C.4 Calibration of Supply Parameters

For each bank, we analytically derive two parameters, μ_k and σ_k, from the optimal behavior of banks in the model. We start with the bankruptcy condition from equation (26) showing that shareholders of Bank k are indifferent between staying in business and defaulting. Using equation (14) and (15), equation (26) becomes

$$\left[(\mu_k + \sigma_k \Phi^{-1}(\rho_{ss})) - i_{ss} - \kappa \right] \underbrace{n(\mathcal{M}_k)\overline{s}}_{D_{k,t}}$$
$$= \frac{1}{1+r} \left[\kappa + \sigma_k (1 - \rho_{ss}) \left(\Phi^{-1}(\rho_{ss}) - \lambda \left(\Phi^{-1}(\rho_{ss}) \right) \right) \right] n(\mathcal{M}_k)\overline{s} \tag{28}$$

where $n(\mathcal{M}_k)$ is the number of regional markets in which Bank k operates branches to collect deposits. With i_{ss} and ρ_{ss}, $\overline{s}$ is from equation (10), which is a function of the demand-side parameters,

α and β. Similarly, equation (27) becomes

$$(1-\rho_{ss})\left(\left(\mu_k+\sigma_k\lambda\left(\Phi^{-1}(\rho_{ss})\right)\right)-i_{ss}\right)-\rho_{ss}\kappa=\frac{(1-\rho_{ss})}{\alpha(1-\overline{s})}. \tag{29}$$

Using equation (28) and (29),

$$\sigma_k=\frac{\dfrac{1}{\alpha(1-\overline{s})}+\left(\dfrac{\rho_{ss}}{1-\rho_{ss}}\right)\kappa-(2+r)\kappa}{(1+r)(r+\rho_{ss})(\lambda\left(\Phi^{-1}(\rho_{ss})\right)-\Phi^{-1}(\rho_{ss}))} \tag{30}$$

$$\mu_k=i_{ss}+\frac{1}{\alpha(1-\overline{s})}+\left(\frac{\rho_{ss}}{1-\rho_{ss}}\right)\kappa-\sigma_k\lambda\left(\Phi^{-1}(\rho_{ss})\right). \tag{31}$$

Similar to the benchmark model,

$$\frac{\partial}{\partial\kappa}\sigma_k\propto\left(\underbrace{\frac{\rho_{ss}}{1-\rho_{ss}}-1}_{<0}-2r-\frac{1}{\alpha(1-\overline{s})}\right)<0.$$

Under the risk-free capital requirements,

$$\frac{\partial}{\partial\kappa}\mu_k\propto\frac{\rho_{ss}}{1-\rho_{ss}}>0.$$

So, as capital requirements get stricter, not only does the return on loan investments become less volatile, but the banks also become more profitable on average.

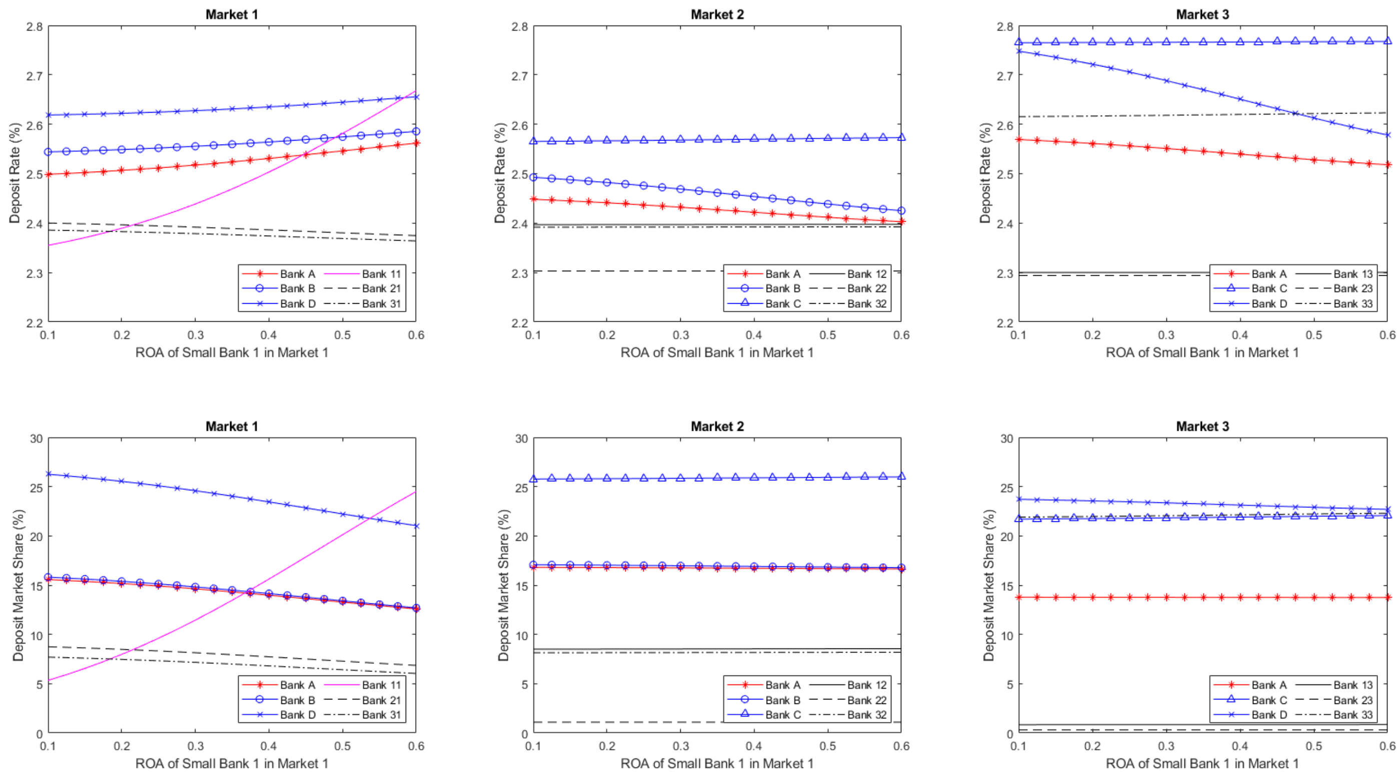


Figure C5: Simulation Example I

The upper panel shows the optimal deposit rates (%) in each regional market as the ROA of Bank 11 increases from 0.10 to 0.70. The lower panel shows the deposit market share (%) derived from the depositor preferences under the simulation scenario. The values relevant to Bank A (big) are in red, while the values relevant to Banks B, C, and D (medium) are in blue. Bank 11 is represented with pink lines, and the other small banks are described with black lines.

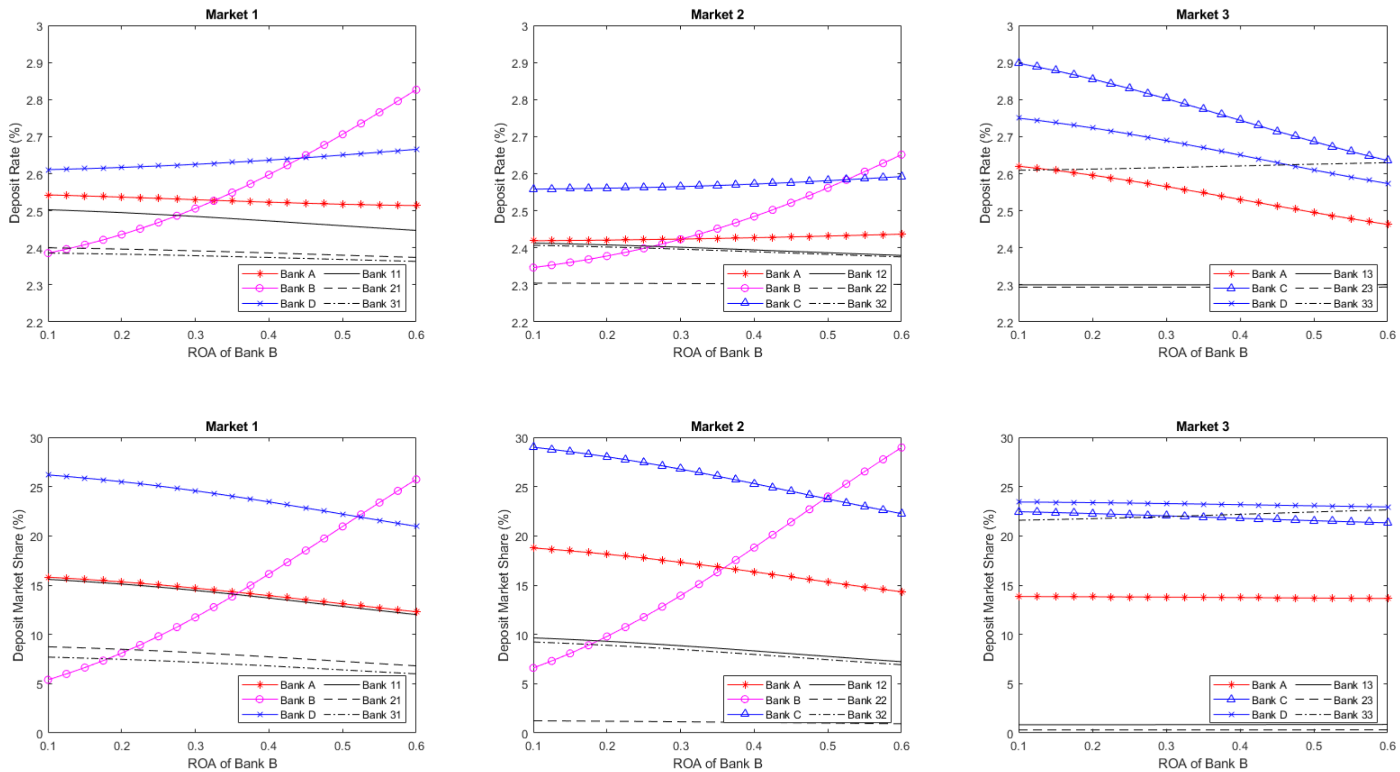


Figure 5: Simulation Example II

The upper panel shows the optimal deposit rates (%) in each regional market as the ROA of Bank B increases from 0.10 to 0.70. The lower panel shows the deposit market share (%) derived from the preferences of depositors under the simulation scenario. The values relevant to Bank A (big) are in red while the values relevant to Banks C and D (medium) are in blue. Bank B is represented with pink lines. The small banks are described with black lines.

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