



Research article

Research on the impact of bank competition on stability—Empirical evidence from 4631 banks in US

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ABSTRACT

This paper systematically analyzes the impact mechanism of bank competition on stability. We select the balanced panel data of 4,631 non-failure banks from 2002 to 2017 released by FDIC to do the estimation and then make an appraisal on bank competition with Lerner index and two kinds of Z-score to measure bank stability respectively. The 2SLS with fixed effect is applied for estimation. Our results suggest that: (1) Competition is a living environment for all industries and bank competition mainly affects stability through franchise value, the cost of borrowing and operating behavior. (2) According to the overall regression, we find that there is an inverted U-shaped relationship between bank competition and stability with an inflection point where the Lerner index is about 0.35. Generally, the US banking industry has always been in a state of excessive competition during the observed period. The further analysis of 3 stages indicates that excessive bank competition, an 'invisible hand', may be one of the most important factors triggering the financial crisis. (3) According to the regression on regions, the inverted U-shaped relationship between bank competition and stability is also existing and the inflection point of Lerner index is between 0.3 and 0.37. However, there is also some regional heterogeneity in terms of the degree of competition, the level of stability and the ability to resist risks and maintain stability when facing competition. This paper may help financial regulators and commercial banks formulate differentiated regulatory policies and business strategies so that banks can control risks better and enhance stability in different competitive environments.

1. Introduction

Competition is the surviving environment and common phenomenon in various industries including the banking industry in the market economy. In recent years, the external economic environment faced by the banking industry has been complicated and changeable. At the same time, competition among banks has become increasingly fierce. Taking the US banking industry as an example, according to data released by the FDIC between 2002 and 2017, more than 3,000 banks were merged or reorganized and 546 went bankrupt, which respectively account for about 40% and 6% of the total insured banks in 2002. Obviously, we can find fierce competition and insufficient stability of the US banking industry during this period. As an important part of a country's financial system, its stability is directly related to the stability and security of the entire financial system. Therefore, it is essential to study the impact of bank competition on stability.

The impact of bank competition on stability has always been a subject of widespread concern and discussion by scholars and policy makers. It is generally believed that bank competition mainly affects stability through three ways: franchise value, the cost of borrowing and operating behavior. However, the impact of these three ways may have various directions, degrees and individuality in different periods and environment. Main views include 'competition-fragility', 'competition-stability' and a nonlinear relationship between competition and stability.

The 'competition-fragility' view believes that competition will increase the risk of banks (Aurélien and Yannick, 2017) and reduce the value of franchise (Hellmann et al., 2000), which will reduce bank income and lead to bank instability; while the 'competition-stability' view believed that fierce competition reduces the bank's liquidity risk (Jeongsim, 2017) and systemic risk (Leroy, 2016), which is conducive to improving bank stability; some believe that competition can both improve and reduce stability, thus leading to a nonlinear relationship.

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Obviously, the conclusions drawn by scholars are different or even contradictory, which makes the relationship between bank competition and stability more controversial and inconsistent.

Researches about the impact of bank competition on stability mostly focus on Europe and developing countries. Given that the United States is the largest economy entity in the world, it has a large and perfect banking system, which is critical to international financial stability. And FDIC discloses the relevant information and data of the insured banks clearly and systematically, which provides possibilities and convenience for empirical research. Therefore, based on the qualitative analysis, we select the US banking data released by FDIC to empirically study the characteristics and regularity of the impact of bank competition on stability, and hope to provide some suggestions for the healthy development of the banking industry.

The specific researches are as follows: combined with the existing literature, we firstly analyze the mechanism of how bank competition affects its stability. Secondly, based on the data of US banks from 2002 to 2017, we calculate the Lerner index and Z-score respectively to measure the level of competition and stability, then empirically examine the relationship between competition and stability. Thirdly, based on empirical results, statistical analysis of the US banking industry's competition and stability is carried out year by year to find out its changes and potential regularity during the observation period. Fourthly, according to the administrative divisions made by the US Census Bureau, we study the regional heterogeneity of the impact. Finally, we make some policy recommendations based on the research conclusions.

The main contributions are: (1) The paper systematically analyzes the mechanism of bank competition on stability, and selects 4631 banks,¹ which account for about 81% of the total existing US banking institutions, to conduct empirical research. An inverted U-shaped relationship is found between bank competition and stability and the Lerner index at the inflection point is about 0.35. (2) We find that during the observation period, the number of over-competitive banks is more than that of under-competitive banks in the US banking industry in a long-term, and the whole has been in a state of excessive competition. Moreover, in the three years (2007–2009) of the most fiercely competitive (Lerner index is the lowest), the stability has fallen sharply to a minimum, which coincides with the time of financial crisis in 2008. It supports the logical inference that 'excessive bank competition leads to a decline in stability and eventually triggered a financial crisis', indicating excessive bank competition, an 'invisible hand', may be one of the most important factors triggering the financial crisis. (3) According to the US administrative division, the banks in the nine regions are compared. The differentiation analysis suggests that banks in over-competitive states account for the majority in all regions, but there's also some regional heterogeneity in terms of the degree of competition, the level of stability and the ability to resist risks and maintain stability when facing competition. For example, under the high degree of competition, the banks of the New England show a high stability, while the banks of the southeast show a low stability.

The rest of the paper is organized as follows: The second part reviews the relevant literature. The third part analyzes the specific mechanisms of bank competition and stability. The fourth part is the model construction and the definition of the variables. The fifth part is empirical research results and analysis. The sixth part is the robustness test. The final part is the conclusion, recommendation and prospect.

2. Literature review

Existing researches have shown that there is a close relationship between bank competition and stability. The existing literature mainly contains three views:

¹ The 4631 banks refer to the banking institutions with independent ID RSSD in the Federal Reserve, which covers some branches of banks.

The first view is 'competition-fragility', which means bank competition weakens its stability. Beck et al. (2013) found that increased competition reduced bank stability, especially in countries with tighter regulations, lower systemic risks, and more developed stock and foreign exchange markets.

The second view is 'competition-stability', that is, the increase of bank competition can promote the stability. Soedarmono et al. (2013) studied the banking system in the Asia from 1994 to 2009 and found that the lower the level of competition in the market, the higher the level of capitalization, but it is not high enough to offset the impact on default risk of higher risk taking, thus leading to the lower stability.

The third view is that there is a nonlinear relationship between bank competition and stability, which holds that as the competition of banks intensifies, the stability shows the trend of 'up first then go down'. Based on the Boyd and De Nicolo (2005) model, Martinez-Miera and Repullo (2010) took both risk transfer effects and profit marginal effects into consideration and found that there is an inverted U-shaped relationship between bank competition and credit risk in the loan market. Jiménez et al. (2013) further confirmed this view using data of Spanish banks. They used the indicator of concentration to measure bank competition and found the nonlinear relationship in both the loan and deposit markets. Liu et al. (2013) used data of 10 European countries from 2000 to 2008 to construct competition indicators to test the stability, which also supported the inverted U-shaped relationship between bank competition and stability.

However, some researchers pointed out that as the competition of banks intensifies, the stability decreases first and then increases. For example, Tabak et al. (2012) chose the data of 10 Latin American countries from 2003 to 2008 and used Boone index to measure bank competition. They found that the impact of bank competition on their risk-taking behavior is nonlinear and both low-level and high-level competition are conducive to improving financial stability, while the intermediate level of competition has the opposite effect, that is, there is a positive U-shaped relationship between bank competition and stability.

To sum up, the existing research on the relationship between bank competition and stability has not reached a consistent conclusion, possibly because of certain difference in the regions and sample periods. Based on the existing research, we will specifically analyze the mechanism of the impact of bank competition on stability and use the data of the US banking industry released by FDIC to conduct an empirical study.

3. Mechanism analysis

In the market economy, competition has gradually evolved into a living environment everywhere and no one is an exception. Competition has become an 'invisible hand' that profoundly affects the evolution of market supply and demand, even determines the strategic decisions and daily management of each industry and enterprise.

For the banking industry specifically, competition influences and determines each bank's strategic decisions, market positioning and selection, risk appetite and management, product development and daily operation management, and ultimately determine the bank's sustainability, stability and prospect. By combing and analyzing the existing literature, we find that bank competition mainly affects bank stability through three channels, including the franchise value, borrowing costs and operating behavior. The specific mechanism is as follows:

3.1. Franchise value

A bank's franchise value refers to its own value of the franchise license, which must be achieved through the bank's ongoing operations. To a certain extent, it reflects the present value of the bank's future earnings and represents the reputation and status of a bank.

Marcus (1984) first established the relationship between bank competition and risk through the value of franchise rights. With the

intensification of bank competition, the bank's market power declines, and its monopoly profits gradually decreases, which reduces its franchise value. For shareholders, when the value of the bank's franchise declines, the potential losses caused by the bankruptcy will be reduced, which will increase the bank's motivation to take risks in the operation, resulting in increased risks and reduced stability of the bank. And even face the risk of bankruptcy (Keeley, 1990).

3.2. The cost of borrowing

The cost of borrowing refers to the cost incurred by the bank during the credit process, including both the bank and borrower. From the perspective of banks, the cost of borrowing refers to the necessary expenses incurred by banks in order to absorb deposits, which are mainly reflected in deposit interest rates. From the borrower's perspective, the cost of borrowing refers to the expense paid by the borrower to obtain bank borrowings, that is, financing cost, which is mainly reflected in the loan interest rate.

On one hand, when bank competition in the bank deposit market declines, its market power in the deposit market rises. And it will lead to the falling of deposit interest rate, which means that the cost of capital decreases and the bank's profit rises, and the risk-taking motivation decreases accordingly, thereby increasing stability. On the contrary, the increased competition in deposit market may weaken the prudence of bank behavior (Hellman et al., 2000), which does harm to the stability of banks.

On the other hand, when competition in the bank loan market declines, the market power of banks in the loan market rises, which means the financing costs faced by borrowers will increase (Boyd and De Nicolo, 2005), and then the probability of bankruptcy will rise. Due to the risk transfer effect, the bank's credit risk will rise, and the stability will decline (Martinez-Miera and Repullo, 2010). At the same time, when the cost increases, the borrower tends to obtain high returns to cover costs by investing in high-risk projects, thereby amplifying the effect of this mechanism.

3.3. Operating behavior

A bank's operating behavior refers to activities it engages in for profits. With the intensification of competition, the bank's market power gradually declines, and the bank will adjust their operating behaviors to maintain their survival and development.

According to research by Berger and Hannan (1998), banks lack with a high market power will lack the motivation of cost control, and the intensified competition can encourage banks to reduce their operating costs or increase their income by improving their management ability, thereby increasing their benefits and enhancing bank stability. Moreover, banks on the competitive side can win more customers, which helps increase its revenue and thus enhance bank stability. However, if competition enters into a fierce and disorderly phase, the bank may reduce their business and customer's access standards in order to compete for market share or only to survive, and invest in high-risk projects to get high profits, which will lead to too much risk and reduce or even hurt its stability.

According to the above analysis, it can be known that bank competition affects its stability through the three ways: franchise value, borrowing cost and operating behavior. Among these, the decline in franchise value reduces bank stability. The decrease in borrowing cost and the adjustment of operating behavior may improve or reduce bank stability. These three ways may differently influence the directions and degrees in different competitive states. Given this, we propose the research hypotheses as follow:

There is a nonlinear relationship between bank competition and stability. In order to test it, the following will construct a model to empirically study the impact of bank competition on stability.

4. Model construction and variable description

In order to empirically study the impact of bank competition on stability, we selected relevant data of 4,631 US banks released by FDIC from 2002 to 2017 and constructed an econometric model.

4.1. Model construction

Based on the above analysis, we establish the econometric model (1).

$$\text{Ln}Z_{it} = \beta_1 + \beta_2 \text{Lerner}_{it} + \sum_{k=3}^{12} \beta_k X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (1)$$

In the model (1), i represents the bank, t represents the year. $\text{Ln}Z_{it}$ is the explained variable and it's the reverse proxy variable that measures the stability of the bank 'i' in the year t . This paper uses two indicators to measure it, namely $\text{Ln}zroa_{it}$ and $\text{Ln}zroe_{it}$. Lerner_{it} is the explanatory variable and it's the proxy variable that measures the competition of the bank i in the year t . X_{it} indicates a set of control variables. μ_i indicates individual effects. γ_t indicates unobserved time effects. ε_{it} indicates random error.

In order to explore the potential non-linear relationship between bank competition and stability, we introduce the squared term of Lerner index on the basis of model (1) referring to the research method of Soedarmona et al. (2013). The other variables remain unchanged. So we get the model (2):

$$\text{Ln}Z_{it} = \beta_1 + \beta_2 \text{Lener}_{it} + \beta_3 \text{Lener}_{it}^2 + \sum_{k=4}^{13} \beta_k X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (2)$$

It should be noted that, considering that the Lerner index of some banks is negative, it is in a non-optimized operating state, but the positive number obtained by calculating its square term cannot reflect the real operating and competitive state of the bank. The negative Lerner index reveals a non-optimizing behavior of banks, so its square term which is a positive number cannot reflect the true operating and competitive status, consequently we replace negative Lerner index by zero (Soedarmona et al., 2013). Besides, in order to avoid endogenous problems, we choose the lagging period of the Lerner index as the instrumental variable for Lerner and employ the Two-Stage Least Squares (2SLS) method.

4.2. Data source and sample selection

The banking data are retrieved from FDIC, and macroeconomic data are sourced from the World Bank database. Considering the availability of data, we make the period from 2002 to 2017 as the sample period, excluding banks that were bankrupt, newly established, and with missing data during the period. Finally, 4,631 banks have been identified, accounting for 81% of the total number of US insured banks in 2017. The research sample in this paper is the balanced panel data of 4631 banks in US from 2002 to 2017.

4.3. Variables

4.3.1. Explained variable: bank stability

Z-score can be used to measure the bankruptcy risk of banks (Roy, 1952). Therefore, we use Z-score measure the bank stability. Considering that the sample size is large and the sample period is long, Z-score may fluctuate wildly, so we logarithmize the Z-score to smooth the data (Beck et al., 2013). We adopted two kinds of Z-score based on roa and roe, named zroa and zroe (Soedarmona et al., 2013) to fully measure bank bankruptcy risk. The specific calculation formula is as follows:

$$\text{zroa}_{it} = \frac{\text{roa}_{it} + (E/A)_{it}}{\text{SDroa}_{it}} \quad (3)$$

$$zroe_{it} = \frac{1 + roe_{it}}{SDroe_{it}} \quad (4)$$

In formula (3), Return on Assets(*roa*) is the ratio of net income to total assets. *E/A* is the ratio of equity to total assets. *SDroa*, the standard deviation of *roa* to test the surplus volatility, is calculated on the basis on a three-period rolling window instead of the complete sample period. This method can effectively avoid the change of Z-score over time being driven by capital and profitability completely (Schaeck and Cihak, 2010). As *roa* and *E/A* rises, the bank stability improves but it will be weakened by the increase of *SDroa*. Therefore, the bank's bankruptcy risk will decrease and its stability will increase when the *zroa* increases.

In formula (4), Return on Equity(*roe*) is the ratio of net income to total equity. *SDroe*, the standard deviation of *roe*, is also calculated on the basis of a three-period rolling window. Similarly, as *roe* rises, the bank stability improves but it will be weakened by the increase of *SDroe*. Therefore, the higher the *zroe* is, the lower the bankruptcy risk and the higher the stability the bank faces.

4.3.2. Core explanatory variable: bank competition

We use the Lerner index as a reverse proxy variable for the bank competition (Berger et al., 2009; Beck et al., 2013). The Lerner index measures the market power of a bank excluding market structure information, reflecting its pricing power above marginal cost. It is calculated as follows:

$$Lerner_{it} = \frac{P_{it} - MC_{it}}{P_{it}} \quad (5)$$

In formula (5), *i* is the bank and *t* is the year. *P*, the output price of the bank, is the ratio of the total income (interest income and non-interest income) to the total assets. *MC*, the marginal cost of the bank, derives from the translog cost function. The detailed estimation of the *MC* is in the appendix.

The Lerner index is negatively related to bank competition. Generally speaking, the Lerner index extends between 0 and 1. It will equal to 0 when it is in the condition of perfect competition, and 1 in the case of a pure monopoly. When it is lower than 0, it shows a non-optimizing behavior of banks. Maybe there is a economy downward cycle or the bank is dominated by public sector. The non-optimizing behavior makes asset prices cheaper than marginal costs. Therefore, we replace all negative Lerner index with zero when we calculate the square term of Lerner index (Soedarmono et al., 2013).

4.3.3. Control variables

In addition to bank competition, the external economic environment and self-operating behavior are also important factors. We introduce a set of control variables from the bank and macroeconomic levels, which are described specifically in Table S1.

4.3.4. Descriptive statistics

In order to eliminate the influence of some extreme variables that exhibit left-skewed or right-skewed distribution, all variables are winsorized at the 1st and 99th percentile levels. After winsorizing, the descriptive statistics of all variables are shown in Table S2. We can find that: The standard deviation of Z-score measured by both methods are very large, indicating that there are large differences in the stability of different banks. Therefore, we use the natural logarithm of Z-score to smooth the fluctuation. The mean of Lerner index is 0.316 and the range is as high as 0.653, which shows that the bank competition in US is relatively high, and the degree of competition is quite different. Besides, most of control variables fluctuate in a reasonable range.

Further, we make a correlation analysis on all variables and test whether there is collinearity between the variables. The results are listed in Table S3–S4. As it can be seen from Table S3, almost all correlation coefficients between variables are correlated at the 1% significance level. Table S4 shows that the VIF is less than 10, indicating that there is no

multicollinearity among the variables, and empirical study can be performed.

5. Empirical results

5.1. Regression on the national sample

The results of Hausman test show that the P value is 0.000. Therefore, We use fixed-effect two-stage least squares (FE2SLS) for regression. Table S5 is the regressive results of the first stage of FE2SLS. The Anderson LM-statistic the Wald F-statistic show that insufficient tool variable identification or insufficient weak tool variable identification does not exist. The final regressive results are shown in Tables 1 and 2. Table 1 is the result of regression with *Lnzroa* as the explained variable. Table 2 is the result of regression with *Lnzroe* as the explained variable. Considering the results shown in Table 2 are generally consistent with Table 1, we mainly analyze the regressive results in Table 1 below.

Shown in columns (1)–(3), in the process of gradually introducing control variables, the estimated coefficient on the Lerner index is always positive, and it is significant at the level of 1%. Since the Lerner index is a reverse proxy for the bank competition, the positive coefficient indicates that bank competition has an adverse effect on its stability. The result of linear regression is consistent with the conclusion of 'competition-fragility' in the existing literature. We add the square term of the Lerner index in column (4) to study the potential nonlinear relationship between bank competition and stability. The results show that the estimated coefficient on the square term is significantly negative at the level of 1%, while the estimated coefficient on the linear term of the Lerner index remains positive and significant at the level of 1%, together suggesting that bank competition has an inverted U-shaped effect on stability.

The inflection point of the Lerner index equals to 0.35.² Further, we carry out the U-test on the basis of the above estimates to confirm that the inverted U-shaped relationship, and the result of estimation is shown in Table S6. The specific meaning of the inflection point is: bank stability increases in pace with the Lerner index when it is less than 0.35; bank stability decreases with the increase of the Lerner index when it is more than 0.35. That is: with the gradual intensification of bank competition, the stability has begun to show an increasing positive trend, supporting the theory of 'competition-stability'; when across the inflection point, competition enters in an excessive stage, bank stability will decline with the intensification of competition, which supports the theory of 'competitive-fragility'.

We also find the bank stability is proportional to total assets, the liquidity and the equity, indicating that banks with large scale and high proportion of capital have higher stability, and a higher liquidity helps banks cope with risks better, thereby improve the stability. Meanwhile, we find that the bank stability is inversely related to the deposit ratio, loan ratio, loan loss provision ratio, fixed assets ratio and non-interest income ratio. From the macroeconomic perspective, the growth of GDP is beneficial to bank stability.

5.2. Analysis of the competition and stability of the sample bank

Based on the previous findings, we use the mean of the Lerner index and Z-score to measure the average level of competition and stability in US banking industry to make a specific analysis on the 4631 banks in US. Figure 1 shows the changing trend of the Lerner Index of 4631 banks from 2002 to 2017 and Z-score of 4631 banks from 2004 to 2017.³ First, the

² We can obtain the inflection point by making the first derivative function equal to zero. The u-test can also verify it.

³ Since the Z-score is calculated through a three-year rolling, the Z-score of 4631 sample banks in 2004–2017 can be calculated during the observation period (2002–2017), which is less 2 years than the period of Lerner index (2002–2017), the same below.

average of Lerner Index was lower than the inflection point from 2002 to 2017, which shows that the US banking industry has been with an excessive competition for a long time. Compared with bank competition, its stability presents a synchronous change trend with the one period lag, which partly means it is reasonable to choose one period lag of the Lerner index as IV. Second, the US banking industry has generally gone through three stages: before the crisis (2004–2006), during the crisis (2007–2009), and after the crisis (2010–2017). The characteristics of bank competition and stability in each stage are summarized in Table S7.

Notably, the Lerner index showed a significant downward trend before the crisis, indicating that the competition of the banking industry at this stage has intensified significantly, causing the increasing of operating risks, which is likely to be one of the most important factors that induce financial crises. The Lerner index is the lowest in the whole observation period during the crisis, and reached a minimum value in 2008, which is in the most fiercely competitive state. It highly coincides with the outbreak of the financial crisis in 2008. At the same time, the stability of banks has also shown a sharp downward trend, and reached the lowest in 2009. This supports us to form such a logical inference 'excessive bank competition leads to a decline in stability and eventually triggered a financial crisis'. Excessive bank competition may be an 'invisible hand' that triggered the financial crisis. The Lerner index and Z-score both increased significantly after the crisis and gradually returned to or even exceeded the pre-crisis level. It shows that in the normal external economic, before or after crisis, bank competition and stability are in a relatively stable changing trend. It is the outbreak of the crisis that breaks the original trend. The historical low level of the Lerner index and the rapid drop in Z-score both implied the occurrence of the crisis.

We observed the distribution of the sample banks with high or low Lerner index to further investigate the competitive state of the US banking industry, which is shown in Figure 2 and Table S8. From 2002 to 2017, banks with low Lerner index accounted between 50.31%–82.38%, which was always more than that with high Lerner index. In other words,

Table 1. Empirical results of bank competition affecting stability (Lnzroa).

Variables	Lnzroa			
	(1)	(2)	(3)	(4)
<i>lerner</i>	5.32200*** (0.07670)	4.37400*** (0.08400)	3.92900*** (0.08730)	17.83000*** (0.63700)
<i>lerner</i> ²				-25.21000*** (1.01700)
<i>scale</i>		0.056400*** (0.01200)	0.15500*** (0.01360)	0.23800*** (0.01420)
<i>liquidity</i>		0.000498*** (0.00006)	0.000468*** (0.00006)	0.000770*** (0.00006)
<i>deposit</i>		-0.00903*** (0.00102)	-0.00884*** (0.00102)	-0.00583*** (0.00112)
<i>loan</i>		-0.00011 (0.00048)	0.00063 (0.00048)	-0.00351*** (0.00058)
<i>llp</i>		-0.44600*** (0.00586)	-0.42000*** (0.00594)	-0.30800*** (0.00833)
<i>equity</i>		0.05100*** (0.00229)	0.05650*** (0.00231)	0.07340*** (0.00249)
<i>fa</i>		-0.01440** (0.00649)	-0.02430*** (0.00646)	-0.01270* (0.00721)
<i>non-interest</i>		-0.01460*** (0.00071)	-0.01330*** (0.00072)	-0.01720*** (0.000823)
<i>gdp</i>			0.02820*** (0.00271)	0.06500*** (0.00305)
<i>inflation</i>			0.05160*** (0.00626)	-0.04760*** (0.00804)
Observations	64834	64834	64834	64834

Note: (1)*, **, and *** are significant at the levels of 10%, 5%, and 1%, respectively; the same below.

(2) The numbers in brackets indicate standard error, the same below.

Table 2. Empirical results of bank competition affecting stability (Lnzroe).

Variables	Lnzroe			
	(1)	(2)	(3)	(4)
<i>lerner</i>	5.32600*** (0.07700)	4.54100*** (0.08490)	4.12800*** (0.08840)	18.67000*** (0.64800)
<i>lerner</i> ²				-26.38*** (1.034)
<i>scale</i>		0.04720*** (0.01210)	0.14300*** (0.01370)	0.23000*** (0.01440)
<i>liquidity</i>		0.00059*** (0.00006)	0.00057*** (0.00006)	0.00089*** (0.00007)
<i>deposit</i>		-0.00813*** (0.00103)	-0.00779*** (0.00103)	-0.00464*** (0.00114)
<i>loan</i>		-0.00142*** (0.00049)	-0.00076 (0.00049)	-0.00510*** (0.00059)
<i>llp</i>		-0.44800*** (0.00592)	-0.42400*** (0.00602)	-0.30800*** (0.00848)
<i>equity</i>		0.02200*** (0.00232)	0.02740*** (0.00233)	0.04510*** (0.00254)
<i>fa</i>		-0.00988 (0.00656)	-0.01950*** (0.00654)	-0.00734 (0.00733)
<i>non-interest</i>		-0.01340*** (0.00072)	-0.01210*** (0.00073)	-0.01620*** (0.00084)
<i>gdp</i>			0.02360*** (0.00274)	0.06210*** (0.00310)
<i>inflation</i>			0.05410*** (0.00634)	-0.04960*** (0.00818)
Observations	64834	64834	64834	64834

there were more banks with excessive competition than those with insufficient competition. It revealed that the US banking industry has been in a state of excessive competition for a long time. But in 2017, the proportion of under-competitive banks (50.49%) exceeded that of over-competitive banks (48.28%) for the first time, indicating that although there is excessive competition in the US banking industry as a whole, it is also necessary to beware of instability caused by insufficient competition. The number of banks after the crisis with low Lerner index is less than that before the crisis, indicating that the overall competition in the US banking industry tended to ease. The changing trend of the bank's overall stability (Figure 2) is opposite to the changing trend of the proportion of banks with low Lerner index, and similar to the changing trend of the proportion of banks with high Lerner index, indicating that too much more excessively competitive banks are unfavorable to bank stability.

Significantly, the number of banks with low Lerner index rose sharply before the crisis, and rose to 3815 in 2007, accounting for 82.38% of total sample banks, which indicates that the number of over-competitive banks continued to increase and reached the highest peak during this period. The risks faced by the banking industry have risen sharply so the stability has fallen sharply. It is likely to be the trigger of the global financial crisis in 2008, which further implies that excessive competition may be one of the important factors that triggered the 2008 financial crisis.

5.3. Further: regional studies

In order to investigate whether there is regional heterogeneity in the impact of bank competition on stability, we divided 4631 sample banks according to nine administrative regions which The United States Census Bureau divides and conducted statistical analysis on each region (Figure S1). The statistical results of bank competition and stability in the nine regions are shown in Figures 3 and 4.

It can be found from Figure 3 that the lowest points of Lerner index in nine region all appeared in 2007 or 2009, indicating that most regions behaves intense bank competition during the crisis (2007–2009). After the crisis (2010–2017), bank competition continued to ease, even

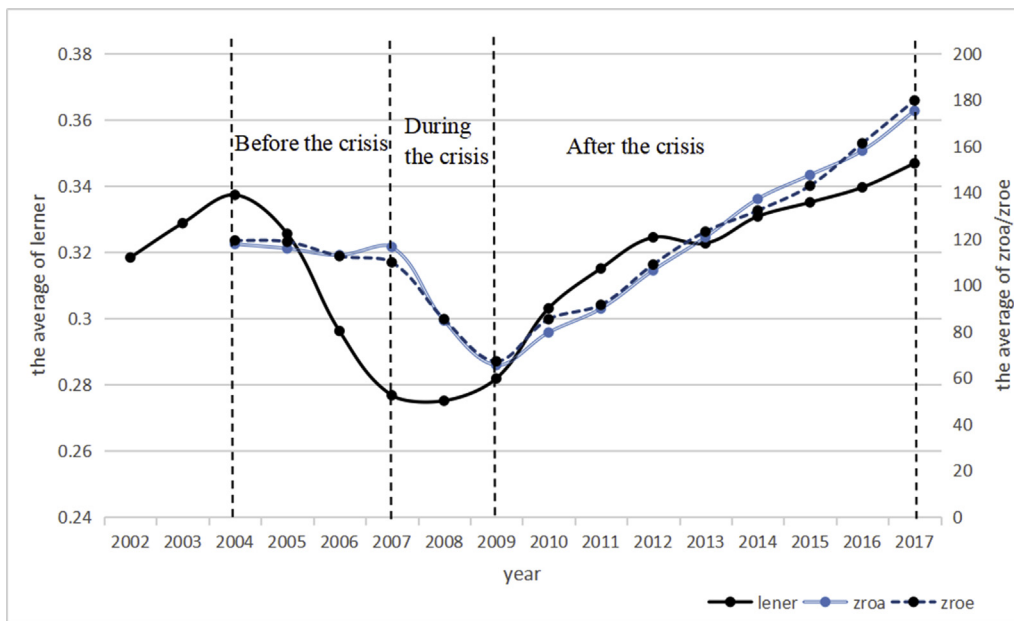


Figure 1. The changing trend of Lerner index and Z-score.

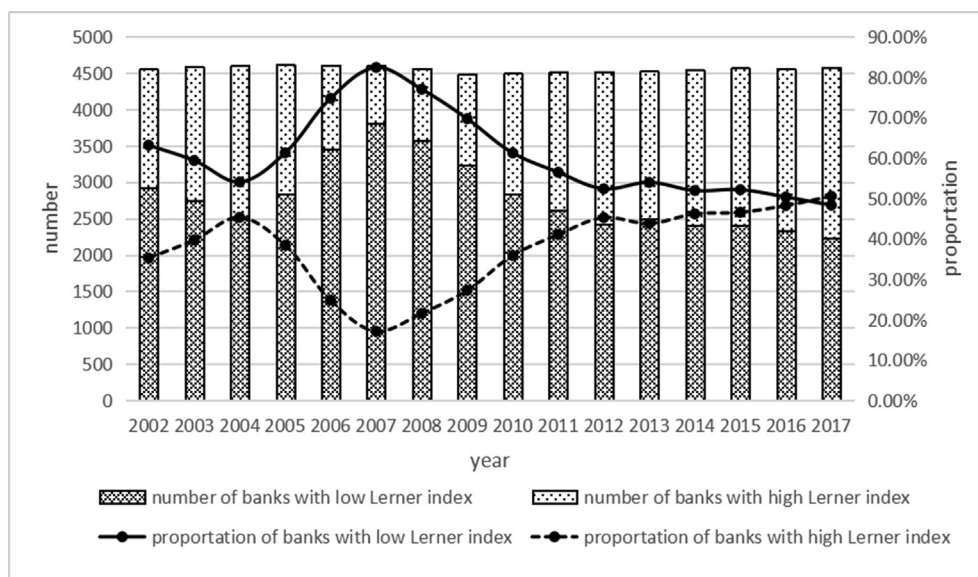


Figure 2. Distribution of 4631 banks around the inflection point.

surpassing the pre-crisis (2004–2006) level. Figure 4 shows: during the crisis (2007–2009), the Z-score of 9 regions declined rapidly, and 2009 witnessed the lowest point of the stability in all regions except New England. After the crisis, the stability of various regions in 2010–2016 significantly increased and exceeded the level of the pre-crisis period. However, a downward trend began to appear after 2016. On the whole, the trend of the banking industry in nine regions is similar over time in terms of both the competition and the stability, consistent with the overall changing trend in national level. The direction of competition's impact on stability in different periods is nearly the same in nine regions, but there are regional differences in the level of bank competition and stability. Therefore we rank the nine regions according to the degree of bank competition and stability respectively for further analysis. The statistical results are shown in Table S9.⁴

⁴ The statistical method of regional score is shown in Supplementary material B.

It can be found from Table S9: on one hand, there are differences in the degree of competition and stability in various regions. On the other hand, the ability of the regions to resist risks and maintain stability when facing competition is also different. We try to use a matrix diagram to reflect these differences much more intuitively in Figure S2. The relationship between bank competition and stability in nine regions is roughly divided into the four situations. The banking industry in different regions has different ability to resist risks and maintain stability in the face of market competition, showing obvious regional heterogeneity. Taking New England and the Southeast as an example, it is not difficult to find that in a high degree of competition, banks in New England show high stability, while the Southeast show low stability. The stability of banks in the Rocky Mountain, the Pacific Coast and the Southeast is the lowest, especially the Southeast shows low stability under a high degree of competition, which deserves the attention of regulators and investors. The analysis above shows banking industry in different regions has differences in the three aspects: the degree of

competition, the level of stability, the ability to resist risks and maintain stability in the face of market competition.

Considering that there are certain differences in the degree of bank competition and stability among regions, we further make an empirical estimation to verify the impact of bank competition on stability. The results are shown in Table 3. It shows that although the degree of bank competition and stability as well as the risk resistance is different in various regions, the inverted U-shaped relationship between competition and stability is proved in all regions. On this basis, we calculate the inflection point of each region during the observation period in Table 4, which shows that there are some differences in the inflection point of various regions, which are generally in the range of 0.30–0.37.

In order to better observe the current competition status of the nine regional banks, we counted the number of banks with low of high Lerner index in 2017 according to the inflection point of the regions listed in Table 4, and the results are shown in Table 5. It is not difficult to find from Table 5 that the number of banks distributed around the inflection point was equivalent in most regions in 2017, maintaining a relatively reasonable level of competition. However, the number of banks on the left of the inflection point in New England is as high as 63.69%, which is in excessive competition, while the Rocky Mountain and the Pacific Coast are relatively under-competitive.

6. Robustness test

We use three robustness test methods to test whether our conclusion is robust. Method 1 is to recalculate the explained variables, specifically, the calculation of SD_{roa} and SD_{roe} in Z-score is changed from a three-year rolling window to a two-year rolling window (Table S10). Method 2 is the re-division of the regressive sample period. We divides the entire sample regression period into two sub-sample periods of 2002–2008 and 2009–2017 (Table S11), additionally, we eliminate the data during the global financial crisis (2007–2009) for robustness test (Table S12). In view of Z_{roa} is highly similar to Z_{roe} , we only use Ln_{roa} as the explained

variable for regression. Method 3 is to redivide banks according to their total assets. We divide the banks into three groups (the top 10%, above the median and below the median) for regression analysis (Table S13).

The empirical results show that the direction and significance of the estimated coefficients of the core explanatory variables and the main control variables did not change substantially, meanwhile the inverted U-shaped relationship between the bank competition and stability still keep valid so that we believe that our conclusion is robust.

7. Conclusion, recommendation and prospect

7.1. Conclusion

Our analysis indicates that bank competition mainly affects its stability through franchise value, borrowing cost and operating behavior. The decline in franchise value reduces bank stability while decreasing in borrowing cost and the adjustment of operating behavior may improve or reduce bank stability. There is an inverted U-shaped relationship between bank competition and stability, which the inflection point is 0.35. This shows that moderate competition is beneficial to bank stability but excessive competition will cause bank instability and even trigger systematic risks. On the whole, the US banking industry has been in a highly competitive operating environment for a long time, and there has always been excessive competition. However, it is also necessary to be aware of instability caused by insufficient competition.

Specifically, the Lerner index before the crisis showed a clear downward trend. The Lerner index was at the lowest level and the Z-score dropped rapidly to the lowest during the crisis. After the crisis, both the Lerner index and the Z-score increased significantly and gradually returned to or even exceeded the pre-crisis level. On one hand, it supports the logical inference that 'excessive bank competition leads to a decline in stability and eventually triggered a financial crisis', indicating excessive bank competition, an 'invisible hand', may be one of the most important factors triggering the financial crisis'. On the other hand, it shows that in

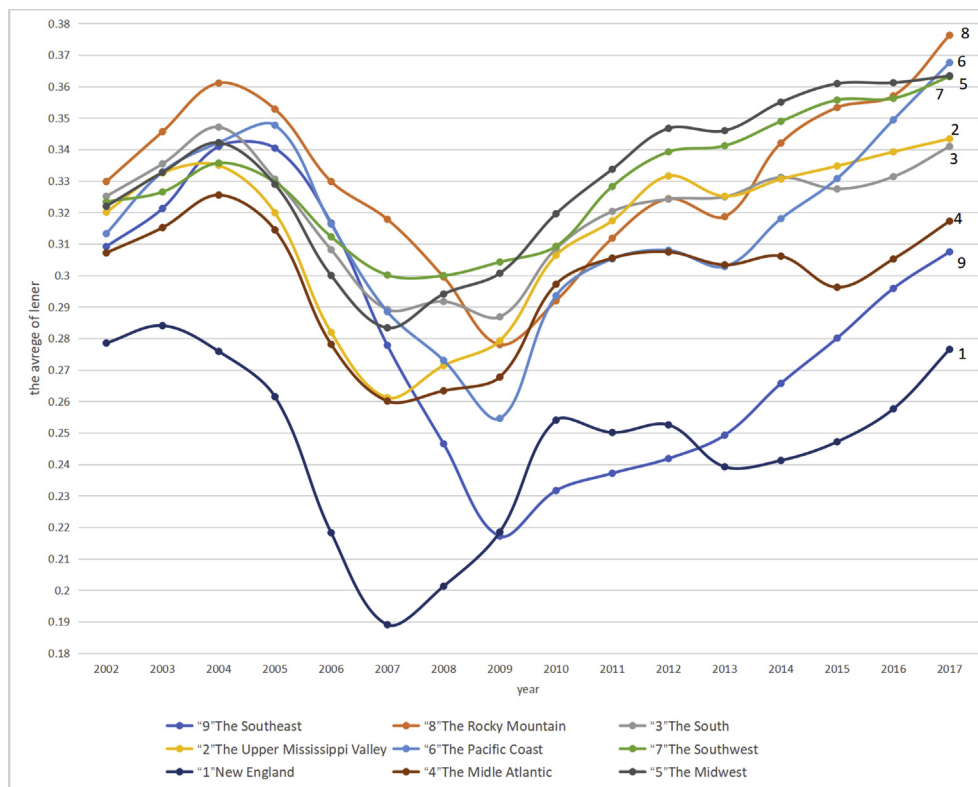


Figure 3. Changing trends of bank competition in the nine regions from 2002 to 2017.

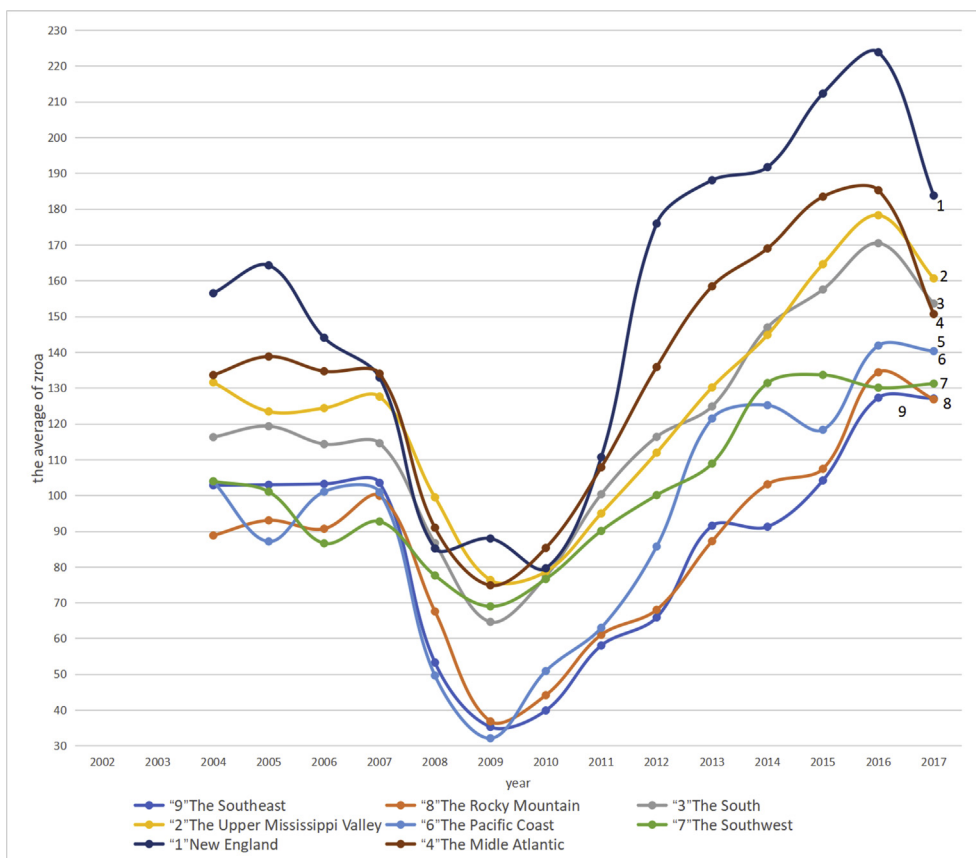


Figure 4. Changing trends of bank stability in the nine regions from 2004 to 2017.

Table 3. Regional empirical results.

Variables	The Southeast	the Rocky Mountain	The South	The Upper Mississippi Valley	The Pacific Coast	The Southwest	New England	The Mid Atlantic	The Midwest
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
<i>lerner</i>	16.86*** (1.70400)	12.36*** (1.76700)	21.60*** (2.08500)	23.24*** (2.35600)	21.14*** (3.54100)	12.70*** (1.69600)	7.554*** (2.76000)	18.86*** (1.72000)	20.23*** (1.76300)
<i>lerner</i> ²	-26.12*** (3.12200)	-17.62*** (2.95300)	-30.90*** (3.34400)	-33.08*** (3.70100)	-30.94*** (5.73900)	-17.23*** (2.66000)	-12.39** (5.23700)	-27.37*** (2.95900)	-27.82*** (2.63700)
<i>scale</i>	0.156** (0.06710)	0.496** (0.05850)	0.287*** (0.04250)	0.289*** (0.04140)	0.236** (0.09640)	0.144*** (0.03630)	0.530*** (0.08210)	0.0955* (0.04900)	0.189*** (0.02540)
<i>liquidity</i>	0.00111*** (0.00030)	0.000111 (0.00022)	0.00118*** (0.00027)	0.000804*** (0.00016)	0.000439 (0.00031)	0.00100*** (0.00017)	0.000264 (0.00051)	0.000704*** (0.00024)	0.000966*** (0.00011)
<i>deposite</i>	-0.0063 (0.00527)	-0.0105* (0.00569)	-0.00975*** (0.00339)	-0.00431 (0.00310)	-0.0112* (0.00674)	-0.00755** (0.00367)	0.00915** (0.00454)	-0.00472 (0.00354)	-0.00509*** (0.00194)
<i>loan</i>	-0.00391 (0.00256)	-0.00107 (0.00251)	-0.0105*** (0.00185)	-0.00517*** (0.00155)	-0.0137*** (0.00413)	-0.00702*** (0.00179)	0.00419 (0.00294)	-0.00187 (0.00188)	-0.000198 (0.00107)
<i>llp</i>	-0.274*** (0.02380)	-0.208*** (0.03180)	-0.271*** (0.02760)	-0.311*** (0.02490)	-0.300*** (0.04020)	-0.272*** (0.02590)	-0.442*** (0.07670)	-0.285*** (0.02860)	-0.348*** (0.01720)
<i>equity</i>	0.0564*** (0.01070)	0.0534*** (0.01110)	0.0980*** (0.00774)	0.0695*** (0.00683)	0.0407*** (0.01360)	0.0801*** (0.00784)	0.127*** (0.01590)	0.0673*** (0.00792)	0.0715*** (0.00452)
<i>fa</i>	0.0333 (0.03110)	0.0315 (0.02860)	0.0163 (0.01960)	0.00297 (0.02020)	0.167*** (0.06190)	-0.00915 (0.01930)	-0.134*** (0.04070)	-0.0521* (0.03150)	-0.0302** (0.01280)
<i>non-interest</i>	-0.0216*** (0.00317)	-0.00965*** (0.00274)	-0.0170*** (0.00258)	-0.0206*** (0.00215)	-0.0141*** (0.00411)	-0.00981*** (0.00245)	-0.00901** (0.00433)	-0.0158*** (0.00255)	-0.0191*** (0.00164)
<i>gdp</i>	0.0698*** (0.01370)	0.0895*** (0.01580)	0.0744*** (0.00859)	0.0448*** (0.00786)	0.0592*** (0.02240)	0.0707*** (0.00885)	0.0955*** (0.01410)	0.0882*** (0.01060)	0.0545*** (0.00535)
<i>inflation</i>	0.0207 (0.03560)	0.0496 (0.03700)	-0.0720*** (0.02240)	-0.0360* (0.02060)	-0.042 (0.05650)	-0.119*** (0.02490)	0.0545 (0.03380)	-0.0503* (0.02640)	-0.0539*** (0.01480)
Observations	3,906	2,450	8,526	12,166	1,876	6,104	2,506	5,838	21,210

Note: In view of the high correlation between Lnroa and Lnroe, we only use Lnroa as the explanatory variable in the regional regression.

Table 4. The inflection point of nine regions.

Region	The inflection point
The Southeast	0.32
The Rocky Mountain	0.35
The South	0.35
The Upper Mississippi Valley	0.35
The Pacific Coast	0.34
The Southwest	0.37
New England	0.30
The Middle Atlantic	0.34
The Midwest	0.36

the normal external economic environment before or after crises, bank competition and stability are in a relatively stable changing trend. It is the outbreak of the crisis that breaks the original trend.

The inverted U-shaped relationship between bank competition and stability is also valid in nine regions, but these regions have differences in the three aspects which are the degree of competition, the level of stability and the ability to resist risks and maintain stability in the face of market competition. The Rocky Mountain, the Pacific Coast and the South are the most unstable regions, while New England and the Middle Atlantic show high stability. In addition, under the high degree of competition, New England showed high stability while the southeast showed low stability. However, the Rocky Mountain showed low stability under low competition.

7.2. Policy recommendation

The research in this paper shows that bank competition has a certain predictive effect on stability: a certain degree of competition can promote bank stability, but when the competition exceeds the inflection point, further intensification will hurt bank stability. In addition, banks in different regions differ in competition, stability and risk resistance. Based on this, we put forward policy recommendations from three aspects.

Financial regulatory authorities should try to build a 'competition-stability' monitoring system for the banking industry. When bank competition is below the inflection point, the regulatory authorities should encourage the banking industry to increase the effective supply of financial products and service through market competition and support economic development. When bank competition exceeds the inflection point, the regulatory authorities should strengthen the regulation of the bank's disorder competition and improve its stability. In addition, the

Table 5. The distribution of banks around the inflection point in the nine regions in 2017.

Region	Non-optimized operating bank	Banks with low Lerner index		Banks with high Lerner index	
		Quantity	Proportion (%)	Quantity	Proportion (%)
The Southeast	7	140	50.18%	132	47.31%
The Rocky Mountain	4	69	39.43%	102	58.29%
The South	7	322	52.87%	280	45.98%
The Upper Mississippi Valley	8	425	48.91%	436	50.17%
The Pacific Coast	1	53	39.55%	80	59.70%
The Southwest	5	228	52.29%	203	46.56%
New England	4	114	63.69%	61	34.08%
The Middle Atlantic	9	223	53.48%	185	44.36%
The Midwest	11	678	44.75%	826	54.52%

banking industry in the Rocky Mountain, Pacific Coast and Southeast regions is highly unstable and should be highly watched.

Banks should also establish their own stability management system, pay more attention to their own competition and adjust their operating behavior timely in the course of operation. In addition, banks should also focus on liquidity, loan ratio, loan loss provision ratio, fixed assets ratio and non-interest income ratio and keep them within a reasonable range to promote their own stability.

Since bank stability shows too much difference and the results of different competition's impact on stability are also different among different regions, so investors should avoid entering the 'investment minefield'. In addition, investors should also pay attention to the competitive status of banks in different regions and judge their stability timely to avoid the risks caused by bankruptcy.

7.3. Prospects

In this paper, sample banks are statistically divided by the distribution on the left and right sides of the inflection point, which, to a certain extent, can reflect the overall state of competition of the national or regional banks, but it is relatively rough. In the future, a reasonable interval can be further constructed according to the inflection point. The bank competition will be divided into various levels and categories, such as 'excessive competition', 'moderate competition' and 'insufficient competition', which can provide reference for the regulatory authorities to implement classified management of banks.

This paper only studies the general relationship between competition and stability, without in-depth research into whether or how competition will lead to bank bankruptcy. Subsequently, samples of bankrupt banks can be specially selected for research.

Declarations

Author contribution statement

Xiaoan Gu: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Tingting Yuan: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Yamin Yuan: Conceived and designed the experiments; Wrote the paper.

Jiajun Lu & Baiping Ni: Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data associated with this study has been deposited at <https://www.fdic.gov/> and <https://www.ffiec.gov/>.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

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