Proceedings of ICFTBA 2024 Workshop: Finance in the Age of Environmental Risks and Sustainability
DOI: 10.54254/2754-1169/94/2024OX0139

An Empirical Analysis of the Relationship Between Capital Regulation and Risk of Listed Commercial Banks

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Abstract: Capital regulation has caused a significant impact on the development of various business operations of listed commercial banks, while also decreasing their risk and enhancing their risk-bearing capacity. This paper uses data from 41 Chinese listed commercial banks from 2010 to 2019. To make the measured capital regulation more realistic, the author uses capital adequacy ratio and controls for 7 bank characteristic variables. The author uses fixed effect model and dynamic panel data model to empirically analyze the influence of the capital regulation on the risk of listed commercial banks. Heterogeneity study is performed by the author based on the size of commercial banks. The empirical study finds that: Firstly, the capital regulation significantly reduces the risks faced by listed commercial banks. Secondly, the influence of capital regulation on the risks of listed commercial banks shows a lag effect. Thirdly, different sized banks are affected differently by capital regulations. This study will help regulators set more effective capital requirements to ensure the stability of the entire financial system. Additionally, it will help commercial banks to establish a long-term and stable capital replenishment mechanism to ensure that capital levels continue to meet regulatory requirements and reduce risk levels.

Keywords: Capital Regulation, Chinese Listed Commercial Banks, Generalized Method of Moments, Z Score.

1. Introduction

The stability of the entire financial system is impacted by the higher risk posed by commercial banks, and it even has an impact on how the real economy grows. The banking sector has always been the most rigorously regulated financial sector globally in order to prevent enormous negative externalities. The capital regulatory system holds a pivotal role in the globally recognized framework of bank regulatory regulations. Nonetheless, it appears that the understanding of how capital regulation affects banks' risk-taking remains insufficient, both theoretically and empirically [1].

The capital regulatory policy of commercial banks in China was developed in accordance with the global trend in financial regulation as well as the country's actual banking industry development. The policy is typified by a growing number of regulatory restrictions. In 1996, China officially became a member of the Basel Accord. The official establishment of the China Banking Regulatory Commission (CBRC) took place in April 2003. The minimum capital adequacy ratio required of China's commercial banks was raised from 8 percent to 11 percent and 10 percent, and then to 11.5

DOI: 10.54254/2754-1169/94/2024OX0139

percent and 10.5 percent once more. It is evident that the period of "strong capital constraints" has arrived for China's commercial banks [2].

In summary, it is clear that tighter capital regulations are putting pressure on China's banking sector, and this development will significantly affect the commercial banks' day-to-day operations. Adopting balanced panel data from 41 listed commercial banks in China between 2010 and 2019, the paper tries to analyze the following questions: how does the capital regulation impact Chinese commercial banks' ability to take on risk? In the face of changes in regulatory requirements, is there any difference in the ability to take on risk of commercial banks of different sizes? The answers to these questions can give China's banking regulators more empirical support for improving and reforming regulations pertaining to things like capital adequacy criteria.

2. Literature Review

Capital regulation is one of the most important factors influencing banks' risk-taking, and theoretical studies on the relationship between the two have shown two competing theories: the "expected income effect" and the " capital at-risk effect".

According to research by Kim & Santomero, Koehn & Santomero, and Kahane, capital regulation has an expected income effect that increases banks' risk taking [3-5]. This means that a bank's expected income level decreases as capital requirements increase, and thus the bank will increase its allocation to assets with higher risk factors in order to balance its income. If commercial banks anticipate that capital regulatory requirements will become more stringent in the future, banks will increase their current level of risk-taking by increasing their holdings of higher-risk, higher-return assets to maintain capital adequacy levels [6]. In addition, Su et al. argued that stricter capital adequacy requirements would make banks transfer individual risks to systemic risks, leading to the aggregation and outbreak of systemic risks [7].

In contrast, using an option pricing model, Furlong & Keeley's research in 1989 and 1990 both conclude that capital regulation has a "Capital at Risk Effect" that lowers banks' risk-taking [8, 9]. More specifically, when capital requirements rise, the option value of bank deposit insurance declines, meaning that banks' losses during a crisis must be financed by their own capital. In this instance, raising capital requirements will encourage banks to take a more conservative approach to risk and lessen their motivation to allocate their assets in a riskier strategy. Meanwhile, regulatory authorities can directly influence banks' investment asset portfolio behavior by adjusting regulatory strategies to avoid excessive accumulation of systemic risk [10]. Therefore, this paper proposes hypothesis 1(H1): The capital regulation reduces the risks faced by commercial banks.

The current risk faced by commercial banks depends not only on current factors, but may also be influenced by previous periods. Chen et al. showed that bank risk-taking is continuous and capital regulation has a long-term impact on commercial banks' risk [11]. Therefore, this paper proposes hypotheses 2(H2): The influence of capital regulation on the risks of listed commercial banks exhibits a lag effect.

Large banks typically face higher capital requirements compared to small and medium-sized banks due to their larger size and complexity of operations, which may involve more risk exposures. Regulators usually set more stringent capital requirements based on the systemic importance and risk level of large banks. In addition, large banks often face more frequent and more stringent regulatory reviews due to their systemic importance and impact on the overall economy. Regulators conduct more in-depth assessments of their capital adequacy ratios, risk management, internal controls and so on. Therefore, this paper proposes hypothesis 3(H3): The risk of commercial banks of different sizes is influenced by capital regulation in a heterogeneous way.

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3. Methodology

3.1. Data Selection

Due to the possible data bias of the novel coronavirus epidemic, the annual data for companies listed on the A-share market between 2010 and 2019 has been selected for this study. It covers a total of 10 years of observational data. The data source is CSMAR database, WIND database, annual reports of listed banks, and National Bureau of Statistics. To guarantee the data is accurate and complete, the author conducted detailed processing of the original data: (1)The author searched and matched the annual reports disclosed by listed commercial banks to supplement and correct the missing data. (2)The author removed samples with missing data. After the above processing, the author obtained a balanced panel data, including information from 41 listed commercial banks, with 410 observations.

3.2. Variable Construction

Explained Variable (Banks' Risk): Z-score is an index that can reflect the solvency and risk degree of banks. The financial situation of listed commercial banks is better if their z-score value increases, and the credit risk is decreased. Due to the large skewness of this value, the article takes the natural logarithm for the Z-score.

Explanatory Variable (Capital Regulation): Capital adequacy ratio measures the proportion of a bank's total capital to its weighted risky assets. It indicates the likelihood that a bank can use its own capital to compensate for damage to the rights and interests of its depositors or creditors, as monitored by international financial regulators. Specifically, this indicator of capital regulation mainly focuses on giving higher risk weights to the high-risk investment projects of commercial banks, thereby restricting their investment in high-risk projects and preventing banks from unreasonably expanding their risky assets, thus ensuring that the assets of depositors and creditors are not infringed upon and safeguarding the normal operation and development of commercial banks.

Control Variables: This article comprehensively considers the intrinsic factors of profitability and risk in listed commercial banks, as well as the external influencing factors. According to Chen et al.'s research, the author primarily selects 7 significant control variables [11]. They are chosen from aspects including bank size, profitability and operational capacity. Table 1 displays the definitions of the variables.

Table 1: Variable definition.

Variable	Variable description
Z	(ROAit+ROEit)/σ(ROAit)
CAR	Logarithm of (Bank capital /weighted risk assets)
LR	Current assets /current liabilities
ER	Total equity /total assets
NIM	Net interest income /total earning assets
Size	The logarithm of the total assets
TAG	(Current year total assets - previous year total assets) /previous year total assets
Ownconl1	Shares held by the largest shareholder /total share capital
PCR	Provision balance /non-performing assets balance

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3.3. Modelling

3.3.1. Fixed Effects Model

This study employs a regression analysis of the CAR as an explanatory variable and selects data from 2010-2019 to empirically test whether capital regulation has an effect on the risk faced by commercial banks. For verification of the effect of capital regulations on various commercial bank risks, the author begins with the single regressor model:

$$Z_{i,t} = \beta_0 + \beta_1 CAR_{i,t} + \varepsilon_{i,t} \quad (1)$$

To avoid potential errors caused by other factors influencing the model results, this study extends the single regressor model by incorporating corresponding variables from the bank's own level to control the model. The author constructs the following model for commercial bank risk-taking:

$$Z_{i,t} = \beta_0 + \beta_1 CAR_{i,t} + W_1 Control_{i,t} + \varepsilon_{i,t} \quad (2)$$

Where 'i' indicates banks, and 't' indicates time in years. Specifically, the variable $Z_{i,t}$ denotes the risk of each bank for each year. $CAR_{i,t}$ is the explanatory variable. $Control_{i,t}$ represents control variables. $\varepsilon_{i,t}$ is the error term.

The method of variance inflation factor (VIF) is used to test for multicollinearity among variables. Table 2 shows the VIF of the variables. The values of VIF for each variable are not high and are less than 10. Therefore, there is no multicollinearity between the variables.

Table 2: Multicollinearity test.

Variable	Size	Ownconl1	NIM	TAG	CAR	ER	LR
VIF	2.02	1.64	1.32	1.17	1.17	1.14	1.04
1/ VIF	0.494	0.609	0.756	0.854	0.858	0.878	0.965
Mean VIF				1.36			

The choice of the benchmark regression model is mainly judged by the F-test and Hausman test. The results are shown in Table 3. The p value of F-test is 0, which indicates that the test results reject the null hypothesis and the mixed OLS model is inferior than fixed effect model. The p-value of Hausman test is 0.0008, indicating that the random effect model is inferior than fixed effect model.

Table 3: F test and Hausman test.

Test	P value	Conclusion
F test	0.0000	Mixed OLS model is inferior than fixed effect model.
Hausman test	0.0008	Random effect model is inferior than fixed effect model.

To mitigate the bias caused by omitted variables, the author fixes individual effect and perform regression analysis of the fixed effect model:

$$Z_{i,t} = \beta_0 + \beta_1 CAR_{i,t} + \mu_i + \varepsilon_{i,t} \quad (3)$$

Fixed effect also applies to the extended model:

$$Z_{i,t} = \beta_0 + \beta_1 CAR_{i,t} + W_1 Control_{i,t} + \mu_i + \varepsilon_{i,t} \quad (4)$$

As a precautionary measure, the study conducts a regression after introducing the quadratic term of CAR into the model and found no evidence of a nonlinear relationship.

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3.3.2. Generalized Method of Moments (GMM)

The current risk of commercial banks depends not only on current factors, but may also be influenced by previous periods. The dynamic nature of bank risk can be explained by at least four theoretical reasons. First, banks are less likely to take risks when faced with intense competition, which may lead to persistence [12, 13]. Second, the persistence of bank risk-taking can be impacted by establishing relationships with high-risk borrowers, despite repeated dealings with them can increase efficiency. Third, bank risk being linked to the business cycle stage may necessitate time for banks to minimize the impact of macroeconomic shocks. Fourth, the potential for risk to persist due to regulatory factors is a significant concern. In particular, the introduction of deposit guarantees or capital requirements could exacerbate the issue of moral hazard, leading to a prolonged period of inefficient and risky investment. In conclusion, bank risk exhibits persistence characteristics, and static models are biased, then the choice of dynamic model is well justified. In light of the aforementioned considerations, an examination of the lagged impact of capital regulations on commercial bank risk is merited. Accordingly, the lagged variable of bank risk has been introduced into the model. The expression is shown in the formula below.

$$Z_{i,t} = \beta_0 + \beta_1 Z_{i,t-1} + \beta_2 CAR_{i,t} + W_1 Control_{i,t} + \mu_i + \varepsilon_{i,t} \quad (5)$$

Specifically, the dependent variable $Z_{i,t}$ is the bank risk and $Z_{i,t-1}$ denotes the bank risk lagging one year. $CAR_{i,t}$ is the independent variable, which represents the capital regulation. $Control_{i,t}$represents control variables; μ_i represents entity fixed effect; $\varepsilon_{i,t}$ is the error term.

Then the author estimates the dynamic panel data model using the generalized method of moments put forward by Arellano & Bover's study, and Blundell & Bond'study [14, 15]. Generalized method of moments includes both Difference GMM (DGMM) and System GMM (SGMM). SGMM uses lagged values of the differenced variables as instrumental variables for the levels equation, and jointly estimates the level and difference equations to obtain new estimators. This approach addresses the problem of weak instrumental variables in DGMM. By including the "robust" option in STATA, the effects of heteroscedasticity and serial correlation can be ignored, resulting in valid parameter estimates. Thus, the author adopts the SGMM for estimation.

SGMM can address partial threats to internal validity. Firstly, when the lagged term of the dependent variable is correlated with the lagged error term, endogeneity issues may arise due to the correlation between the error term and its lagged term. SGMM can resolve the endogeneity problem caused by the correlation between the lagged term of bank risk and the error term. Secondly, it is possible that there are omitted variables in the model, meaning that there are some factors that both determine the risk of commercial banks and are related to the capital regulation. SGMM can help mitigate the omitted variable bias. Thirdly, SGMM can handle errors-in-variables bias.

In addition, to ensure the estimators are consistent and efficient, two preconditions need to be tested when using SGMM. On the one hand, the premise of the SGMM is that there is no second-order or higher-order serial correlation in the error term, otherwise consistent estimator cannot be obtained. If the P-value of AR(2) in the SGMM is greater than 0.1, the null hypothesis of "no second-order serial correlation in the error term" is not rejected. On the other hand, the SGMM is subject to overfitting due to too many instrumental variables, and should be tested for overidentification constraints. Compared with the Sargan test, the Hansen test follows a chi-square distribution under heteroskedasticity, so the Hansen test is more robust. The author uses the Hansen statistic to determine the validity of the instrumental variables used in the SGMM. If the P-value of the Hansen statistic is greater than 0.1, the instrumental variables are valid.

DOI: 10.54254/2754-1169/94/2024OX0139

4. Empirical Results

4.1. Descriptive Statistics

Table 4 shows the descriptive statistics for all variables. The value of the Z-score ranges from -3.209 to 11.715 with an average of 4.706 and a standard deviation of 1.664, indicating a relatively large gap in risk of listed commercial banks. The value of the CAR ranges from 2.179 to 3.696 with an average of 2.566 and a standard deviation of 0.141, indicating a relatively small gap in the capital regulation.

From the perspective of bank characteristics, the LR has a standard deviation of 7.495, indicating widely varying liquidity statuses. The NIM has a standard deviation of 0.542, indicating relatively stable net interest margins. The Size has a standard deviation of 1.772, indicating large differences in bank sizes. The TAG ranges from -0.099 to 0.871, indicating differences in bank asset size. The Ownconl1 has a standard deviation of 17.548, indicating large differences in ownership concentration.

Table 4: Descriptive statistics.

Variable	Mean	p50	Std. Dev.	Min	Max	Observations
Z	4.706	4.673	1.664	-3.209	11.715	410
CAR	2.566	2.563	0.141	2.179	3.696	410
LR	1.546	0.522	7.495	0.305	88.560	410
ER	0.070	0.066	0.033	0.023	0.627	410
NIM	2.532	2.500	0.542	1.110	5.098	410
Size	27.390	27.205	1.772	24.412	31.036	410
TAG	0.183	0.152	0.125	-0.099	0.871	410
Ownconl1	23.005	19.660	17.548	4.310	100	410
PCR	267.574	241.230	100.450	132.440	718.680	410

4.2. Results of Fixed Effects Model

The regression results of the influence of capital regulation on the risk faced by commercial banks can be seen in Table 5. Column (1) shows the results of the single regressor model with fixed effect, and column (2) shows the results of the fixed effect model with control variables. By comparing the results of the two columns, it can be observed that model(4) has the highest R-squared value, indicating that it provides the best explanatory power. Therefore, the regression results of model(4) are chosen for explanation, which also validates the scientific extension of the model in the previous section. In column (2), the coefficient estimate of CAR is significantly positive, indicating that the larger the CAR, the smaller the risk that commercial banks bear. Thus, Hypothesis 1 is proven to be valid. The capital regulation has reduced the risk for commercial banks. This can be attributed to the fact that with stronger capital regulation, banks will be less likely to operate at risk and the level of bank risk will decline.

Table 5: Results of fixed effects model.

Variable	(1)	(2)
	Z	Z
CAR	1.206*	1.190***
	(0.696)	(0.447)
LR		0.003
		(0.006)
ER		-1.242

DOI: 10.54254/2754-1169/94/2024OX0139

Table 5: (continued).

		(1.171)
NIM		0.390***
		(0.144)
Size		1.195***
		(0.152)
TAG		-0.066
		(0.415)
Ownconl1		0.008
		(0.007)
Constant	1.611	-32.170***
	(1.773)	(4.817)
Observation	410	410
R^2	0.663	0.742
Adjusted R^2	0.626	0.709
Entity Fixed Effects?	Yes	Yes

Note: Standard errors in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01.

4.3. Results of GMM

The author uses the SGMM to estimate the model(5). The results are shown in Table 6. Before using the SGMM estimates, the author tests the applicability of the method to ensure that the estimates are consistent and efficient. First, according to the table, the P-values of AR(1) are both less than 0.05 and the P-values of AR(2) are both greater than 0.1. In other words, first-order autocorrelation is allowed and second-order autocorrelation is not allowed, and the test passes. Second, the P-value of Hansen statistic is 0.391, which is greater than 0.1, implying that the instrumental variables used in the model are all valid. Third, for the coefficients of the lagged terms, the one-step SGMM estimation is 1.051 and the two-step SGMM estimation is 1.05, both of which are positively significant. Based on above three points, it is appropriate and reasonable to use SGMM to estimate the model.

The coefficients of the lagged term estimated by SGMM are significant at the 1% level, indicating that the bank risk has a significant lagged effect and is positively related to the lagged period. Thus, Hypothesis 2 proposed in this paper is valid. The coefficient of CAR estimated by one-step SGMM is 2.112 and is significant at 5% level and the coefficient estimated by two-step SGMM is 2.062 and is significant at 5% level. This indicates that bank risk significantly decreases with the capital regulation, which is expected to be consistent with Hypothesis 1. Thus, although the rapid development of capital regulation in the short term caused a decline in commercial bank earnings, which will cause an adverse impact on bank risk, commercial banks actively seek change and fully absorb the changes in risk management brought about by the capital regulation. Commercial banks have reduced risk while making up for adverse shocks. Therefore, capital regulation can effectively restrain the risky behavior of commercial banks and promote the stability of the entire financial system.

Table 6: Results of GMM.

Variable	SGMM(robust)	
	One step	Two step
L.Z	1.051***	1.050***
	(0.065)	(0.072)

DOI: 10.54254/2754-1169/94/2024OX0139

Table 6: (continued).

CAR	2.112**	2.062**
	(0.902)	(0.872)
LR	-0.058	-0.053
	(0.053)	(0.054)
ER	-1.449	-0.581
	(17.650)	(19.920)
NIM	0.734**	0.750**
	(0.273)	(0.287)
Size	-0.176	-0.165
	(0.210)	(0.270)
TAG	-4.949***	-4.808***
	(1.585)	(1.777)
Ownconl1	0.004	0.006
	(0.021)	(0.024)
Constant	-0.687	-1.576
	(6.656)	(7.843)
Observation	369	369
AR(1)(P-value)	(0.022)	(0.023)
AR(2)(P-value)	(0.141)	(0.125)
Hansen(P-value)	(0.391)	(0.391)

Note: Standard errors in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01.

4.4. Heterogeneity Test

The National Bureau of Statistics classifies banks into four categories according to their total assets. Banks with total assets of 4 trillion yuan and above are large banks, banks with total assets of 500 billion to 4 trillion yuan (including 500 billion yuan) are medium-sized banks, banks with total assets of 5 billion to 500 billion yuan (including 5 billion yuan) are small banks, and banks with total assets of less than 5 billion yuan are micro banks. This study employs this criterion to categorize banking institutions as either large banks or small and medium-sized banks, with the objective of investigating the influence of capital regulation on the risk faced by commercial banks with varying sizes. The regression results are shown in Table 7. For large banks, there is a non-significant negative correlation between CAR and Z. While for small and medium-sized banks, a higher capital regulation represents a higher Z, thus lower risk. This phenomenon can potentially be attributed to that the capital regulation brings more scrutiny and regulatory requirements on large banks compared to small and medium-sized banks, leading to extra governance and accountability pressures. In addition, large banks are affected by scale effect and the impact of capital regulation on them is not significant. Therefore, Hypothesis 3 proposed in this paper is supported.

Table 7: Heterogeneity test based on bank size.

Variable	Large bank	Small and medium-sized bank
	(N=12)	(N=29)
CAR	-0.299	1.064*
	(0.995)	(0.560)
LR	0.408	0.003
	(0.778)	(0.006)

DOI: 10.54254/2754-1169/94/2024OX0139

Table 7: (continued).

ER	61.530***	-1.695
	(14.280)	(1.069)
NIM	-0.026	0.448***
	(0.212)	(0.170)
Size	0.235	1.220***
	(0.258)	(0.190)
TAG	0.967	-0.043
	(0.681)	(0.490)
Ownconl1	-0.003	0.017
	(0.006)	(0.010)
Constant	-5.421	-31.880***
	(7.415)	(6.162)
Observation	120	290
R^2	0.679	0.749
Adjusted R^2	0.622	0.715

Note: Standard errors in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01.

4.5. Robustness Test

To ensure that the above empirical results are robust, the author considered to verify the reliability of the results by replacing the explained variables. PCR will be used here as alternative indicators of Z. PCR can be used as measurements for the risk of banks because a higher PCR indicates that a bank has set aside a greater proportion of funds to cover potential loan losses. As a result, the bank is better positioned to withstand any adverse impact from loan defaults.

Holding explaining variable and other control variables constant, re-estimate the regression model(4). Table 8 shows a significant positive CAR coefficient for PCR. This indicates that the capital regulation can increase PCR, thereby lowering the risk for commercial banks, which is consistent with the results of empirical analysis.

Table 8: Substitution of variables.

Variable	PCR
CAR	99.48**
	(40.32)
LR	0.64
	(0.42)
ER	78.36
	(71.46)
NIM	39.99***
	(11.81)
Size	-52.55***
	(14.75)
TAG	-7.30
	(47.21)
Ownconl1	0.73
	(0.49)

DOI: 10.54254/2754-1169/94/2024OX0139

Table 8: (continued).

Constant	1328.40***
	(411.0)
Observation	410
R^2	0.501
Adjusted R^2	0.437

Note: Standard errors in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01.

5. Conclusion

The dataset utilized in this study comprises data from 41 listed commercial banks in China, spanning the period from 2010 to 2019. In this study, the author employs two statistical techniques—a fixed-effects and a dynamic panel data model—to investigate the influence of capital regulation on the risk profile of listed commercial banks. Based on the size of commercial banks, this paper conducts heterogeneity analysis. Finally, the following conclusions are reached: Firstly, the capital regulation will significantly reduce the risks faced by listed commercial banks. Secondly, the influence of capital regulation on the risks faced by listed commercial banks shows a lag effect. Thirdly, the influence of capital regulation on different sized banks is heterogeneous. For large banks, there is a non-significant negative correlation between CAR and Z. While for small and medium-sized banks, a higher capital regulation represents a higher Z, thus lower risk.

The 41 sample banks adopted in this paper are all listed commercial banks. These banks have been established for a long time, have had a long history of development, are relatively stable, and are the mainstay of banks in the financial market. However, the banking industry covers a wide range of banks, with a small number of banks with small assets or unlisted, and a large number of foreign banks. Due to the limitation of data sources, this paper does not obtain the data of unlisted small and medium-sized banks and foreign-funded banks and fails to analyze them. As the development of China's financial industry continues to grow and formalize, the information disclosure of commercial banks will become more and more perfect, which will be more conducive for researchers to study the impact of the risk faced by commercial banks through capital regulation.

The results of the aforementioned study have yielded three recommendations for the formulation of policy. First, commercial banks should establish a long-term and stable capital replenishment mechanism to ensure that capital levels continue to meet regulatory requirements. Second, for supervisory authorities, it is necessary to implement categorized supervision and organically combine macro and micro prudential supervision. Differentiated regulatory measures should be adopted for different types of banks to enhance the effectiveness of capital regulation. Thirdly, commercial banks should be encouraged and guided to innovate risk management models and tools, so as to provide strong support and protection against market volatility and unexpected risks by improving their own "hard power".

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