Research Articles

An Identification of Operational Risk in Commercial Banks

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Abstract

With the financial globalization, the acceleration of financial innovation, and the continuous use of new technologies, the operational risk of commercial banks has become more prominent. In recent years, an endless stream of commercial bank operational risk events has brought huge losses to many commercial banks, as a result, people tend to pay more attention to the operational risk. At present, the emphasis and difficulty of operational risk management lies in the operational risk measurement. On the basis of collecting a large number of operational risk cases, this paper empirically analyzes and measures the operational risk of domestic commercial banks using the revenue model and the stock factor model. It is of great theoretical and practical significance to enrich and improve the theory and method of the operational risk management, improve the level of operational risk management of domestic commercial banks, and strengthen the supervision of operational risk capital of commercial banks.

The first step was a review of some national and international studies on the operational risk and its measurement which helped expound the research ideas, contents, and methods in this present study. Secondly, the theoretical data related to the operational risk such as its characteristics and definitions, common risk classification, and risk measurement methods were proposed. Then, the empirical analysis and test were conducted, taking the quarterly data of nine listed commercial banks from January 1, 2009 to March 1, 2019 as samples. The operational risk of nine listed commercial banks was measured based on the income model, and the influence of fixed effect was determined by the likelihood test. The accurate setting form of the model was determined by F test in a scientific and reasonable way to establish an empirical regression model which was in line with the actual situation. Finally, this paper proposed some suggestions for the effective management of operational risk in China's banking industry.

Keywords: *Commercial Bank, Operational Risk, Revenue Model, Stock Factor Model*

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Introduction

Faced with the continuous occurrence of operational risk loss cases and the huge economic losses caused by them, the international financial community has also introduced relevant policies and regulations to guide commercial banks to standardize the development and prevent financial risks. In 2004, the Basel New Capital Accords issued by the Basel Committee on Banking Supervision explicitly proposed for the first time that operational risk should be listed as the third biggest risk after credit risk and market risk, and included in the risk management framework, requiring financial institutions to be equipped with corresponding capital to deal with operational risk. In 2010, the Basel Accord Ⅲ put forward higher requirements on the capital adequacy ratio level, which further requires commercial banks to improve operational risk control ability. At the same time, domestic policies and regulations related to operational risk have also been introduced one after another. In 2007, the China Banking Regulatory Commission issued the Operational Risk Management Guidelines for Commercial Banks, which explained the definition of operational risk, but did not define it in detail. In 2009, China formally joined the Basel Committee on Banking Supervision, which is an important step for China to actively participate in the formulation of international banking rules. It also means that China will put the operational risk management of commercial banks on the agenda. In 2010, the five largest state-owned commercial banks and China Merchants Bank were among the first to pilot the Basel II regulatory framework. From the perspective of time axis, the international community did not gradually appear the policies and regulations related to the operational risk of commercial banks until the 21st century, and China's awareness of the operational risk of commercial banks lags behind the western developed countries.

With the increasing number of operational risk cases and the increasing amount of loss, it shows that operational risk is one of the main risks faced by China's banking industry. Therefore, it is an important task for commercial banks and bank management departments to adopt scientific and appropriate measurement methods to measure the size of operational risk and equip commercial banks with appropriate operational risk capital. In view of this, this paper chooses the operational risk of commercial banks as the research object, and focuses on the assessment, measurement and control of operational risk from the perspective of commercial banks.

Objectives

After the operational risk loss events of commercial banks were constantly exposed by the media, the government and financial institutions began to rethink and understand the operational risk, and greatly strengthened their attention to it, resulting in an increasingly strong demand for improving the ability of operational risk assessment, measurement, prevention and management. Although at this stage, the domestic many Banks use index method, the standard method for rough measure operational risk, and established the operation risk management system and internal control process, can operate the risk control and management to a certain extent, but the qualitative analysis and quantitative analysis of rough enough to deal with the complex business environment faced by commercial Banks, so you need to research more precise risk assessment and measurement to correspond to the current financial system of operation risk. This article is based on the operational risk definition, characteristics, etc. On the basis of deep understanding, analysis the present situation of the current our country commercial bank operation risk, and then combining with the operational risks in commercial Banks in China at present stage of economic and applicable income model and securities factors model for quantitative analysis of operational risk, and use the historical data and compare the results, it is concluded that the results of the two methods of differences, find out the more suitable for China's current situation of operational risk measurement method, in order to provide the basis for management and regulators to make effective decisions, at the same time late for our country commercial bank operation risk of advanced measures to provide reference and reference.

Materials and Methods

3.1 Basic principles of the revenue model

The revenue model is one of the "top-down" measurement methods of operational risk. Compared with the "bottom-up" advanced measurement methods, the data needed by the revenue model to estimate operational risk are all external to it. Usually, the variable representing the bank's income is taken as the dependent variable and its influencing factors are taken as independent variables for regression analysis. The revenue model approach is from the perspective of the whole, ignoring the individual differences between risk and loss events. Under the condition that the internal loss database of operational risk is not perfect, the revenue model can measure operational risk more conveniently and accurately.

In the revenue model, net profit is usually taken as the target variable reflecting the overall operating condition of the bank, and the regression analysis is carried out on a representative basis from the factors affecting the target variable:

$$Y = \alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k + \varepsilon$$

According to the regression results, the fluctuation of the target variable (total variance) is divided into the fluctuation explained by the explanatory variable and the fluctuation unexplained by the explanatory variable. The part that cannot be explained by the explanatory variable is called the residual. Based on the assumption that net profit conforms to the normal distribution, under certain confidence, the overall operational risk capital during the statistical period is the product of the corresponding quantile and standard deviation under certain confidence.

3.2 Selection of model estimation methods

Traditional revenue models usually adopt two estimation methods:

The first method is to use ordinary least square method (OLS), using the time series data of each bank to do regression analysis respectively, so as to estimate the operational risk capital of each bank. This approach will bring great estimation error, because the listing time of China's commercial banks is relatively late, it is difficult to obtain the historical data publicly disclosed earlier in the past, and the available financial data are usually very short. In this way, it is difficult to guarantee the validity and accuracy of measurement results when model estimation is carried out in a short time interval.

The second method is to do mixed data regression, that is, each commercial bank is regarded as the exact same, there is no individual difference between them, and the time series data of each commercial bank is simply piled together for regression analysis. Although mixed data regression solves the problem of insufficient data caused by the short sample period, it ignores the differences between different commercial banks. The defects of this estimation method usually lead to poor regression fitting effect and low goodness of fit value, and further lead to the overvaluation of commercial banks' operational risk capital.

The panel data model can overcome the shortcomings of the above two estimation methods. The use of panel data model, on the one hand, can maximize the use of sample data, on the other hand, can distinguish the differences between different samples, can construct and test more real economic phenomenon than the use of cross-section data or time series data alone, so as to carry out more practical scientific analysis. Therefore, the panel data model is adopted in this paper to study the relationship between variables, which can better overcome the shortcomings of constructing time series or cross-section data series model alone. The panel data

model is used to maximize the use of sample data, and at the same time, the differences between individuals are considered to construct a model more in line with the actual economic situation.

3.3Selection of model variables

Risks faced by commercial banks occur along with their business processes, and the impact of these risk factors on business activities is ultimately reflected in the bank's Net profit. Therefore, in this paper, Net profit is selected as the dependent variable of the revenue model, which is recorded as NP.

Due to the complexity of business environment of commercial banks, there are many factors that can affect the dependent variable net profit. Based on the importance of each influencing factor, this paper mainly selects independent variables from four aspects of profitability, market risk, credit risk and liquidity risk to conduct empirical analysis on the operational risk of commercial banks.

(1) Profitability

Commercial banks, as financial intermediaries, carry out business activities on the basis of their asset scale. In the business activities of banks, the traditional deposit and loan business, which obtains interest income from deposit and loan spreads, still plays a pivotal role in the whole business activities of commercial banks. Total assets are the basis for commercial banks to earn profits. It can be said that the scale and quality of assets determine the profitability of commercial banks. The larger the total assets, the greater the profits of commercial banks will be. Interest income is the main source of income of commercial banks. The size of net interest income directly reflects the profitability of commercial banks. The higher the net interest income is, the higher the profit level of the unit deposits and loans of commercial banks will be at a specific time. Therefore, this paper preliminarily selects Scale of Assets and Net Interest Return as the indicators to measure the profitability of banks, which are recorded as SOA and NIR respectively.

(2) Market risks

Commercial banks operate in a market-oriented environment, and their operating conditions are naturally affected by the macroeconomic environment. When the macro-economic environment is good, it will promote the investment activities of enterprises and the consumption needs of individuals, and increase the demand of enterprises for loan financing and individuals for car loans, mortgages and other loans. On the other hand, a favorable economic environment will also increase people's income level and increase the idle funds of individuals and enterprises, which will also increase the bank deposit funds relatively. Under the condition of controlling the loan scale by deposit and rapid economic development, these will inevitably promote the increase of the scale of deposit and loan business, thus increasing the profits of the bank. Real gross domestic

product can well reflect the overall economic situation of China, so we choose Real GDP as one of the indicators to measure market risks. I'll call it RG in the text.

Interest rate is a measure of the price at which money is traded. In the current our country government involvement in the market economy more, and have as lender of last resort (central bank) support conditions, the residents in the commercial bank deposit break-even value-added risks faced by small, way and when the idle funds through bank loans to enterprises from all walks of life, faces could well take the risk of loans. Therefore, we can regard the deposit rate as the risk-free rate and the loan rate as the risk rate, and the difference between the two is the market's compensation for the risk, which is called the risk premium. One-year deposit and loan spreads, as an indicator to measure market risk, are recorded as ODL in the paper.

(3) Credit risk

Credit risk is one of the important sources of risk faced by banks and also one of the most important risks faced by commercial banks. Credit risk usually includes the following situations: first, the borrower fails to pay the principal and interest of the loan to the commercial bank in time and in full; Second, the borrower does not perform the loan contract according to the agreed time, amount and other conditions; Third, there is the possibility that the borrower will not be able to fully perform the contract. Credit risk will bring huge losses to commercial banks. In order to reflect the size of credit risk, we choose the non-performing loan ratio as a comprehensive description index of credit risk. The higher the non-performing loan ratio, the greater the credit risk that commercial banks face. In this paper, we write the non-performing loan ratio, which is RBL in this paper.

(4) Liquidity risk

Liquidity risk refers to the risk that the bank cannot obtain sufficient funds in time to pay the due debts or obtain funds at reasonable cost to meet the needs of enterprise development. Liquidity risk is an important factor that affects the operating results of banks. Serious liquidity risk will cause people to lose their trust in banks, resulting in a run risk and further aggravating liquidity risk. As can be seen from the source of liquidity risk, liquidity risk mainly comes from the mismatch between assets and liabilities at the time point. Deposit is an important part of the liabilities of commercial banks, and loan is an important part of their assets. In order to reflect the size of liquidity risk, this paper selects the Deposit to loan ratio as an indicator to measure the size of liquidity risk, which is denoted as DR.

Based on the above analysis, the variables preliminarily selected for the revenue model are shown in Table 1

Table 1 Variable list

profitability	Asset Size (SOA)
	Net Interest Income (NIR)
Market risk	Real GDP (RG)
	One-year loan and deposit spread (ODL)
The credit risk	Non-performing loan ratio (RBL)
Liquidity risk	Loan-to-deposit ratio (DR)

3.4 Determination of data time

Firstly, this paper uses financial data and economic indicators to establish a model for empirical analysis of operational risk of commercial banks. Therefore, this paper selects quarterly data from January 1, 2009 to March 1, 2019 to conduct empirical analysis on operational risk measurement of commercial banks.

3.5 Determination of data samples

At present, there are 16 listed large commercial banks in China. Agricultural Bank of China and Everbright Bank of China were listed later, both in 2010, which did not meet the data requirements. Therefore, the other four major banks were selected from the five major banks except Agricultural Bank of China. With regard to the other 11 joint-stock commercial banks except Everbright Bank, Bank of Ningbo, Ping An Bank, Minsheng Bank, Shanghai Pudong Development Bank and China Merchants Bank are selected as samples based on their listing time and asset scale. Bank of Ningbo has the smallest asset scale among the other 11 listed joint-stock commercial banks, China Merchants Bank has the largest asset scale, Ping An Bank, China Minsheng Bank and Shanghai Pudong Development Bank have medium asset scale and have been listed earlier.

The quarterly data of commercial banks' net profit, net interest income, non-performing loan ratio, loan-to-deposit ratio, asset size, nominal GDP and monthly data of CPI are directly from Juling Financial Platform. The real GDP data is processed as follows:

RG=GDP/CPI

RG is real quarterly GDP, GDP is nominal quarterly GDP, and CPI is the quarterly consumer price index. Since GDP is a period data, quarterly CPI is averaged for each month.

The data of one-year deposit and loan interest rates are obtained from Dongfang.com. The time-weighted average of deposit and loan interest rates is used to obtain one-year deposit and loan interest rates in the

corresponding quarter. The difference between the two is the quarterly deposit and loan interest rate spread data used in this paper.

One-year deposit and loan spread $=\sum_i \frac{(\text{loan}_i - \text{deposit}_i) * s_i}{ts_i}$

The subscript I in the formula denotes the ith interest rate in the quarter, denotes the number of days corresponding to the ith interest rate in the quarter, denotes the total number of days in the quarter, denotes the ith loan rate, denotes the ith loan rate.$s_i ts_i loan_i deposit_i$Since the time for the People's Bank of China to adjust the interest rate is not fixed, in order to more accurately reflect the quarterly deposit and loan interest rate difference, the weighted average method is used to calculate the deposit and loan interest rate spread in each quarter according to the actual number of days corresponding to the interest rate in each quarter.

Based on the above analysis of model variables, this paper uses the financial data and macro data collected from various commercial banks to further analyze the relationship among variables and optimize the selection of model variables. Since quarterly data affected by seasonal factors, in order to study the real relationship between the variables, it is necessary to eliminate the influence of seasonal factors on the variable, so this paper use the seasonally adjusted for each variable to seasonal adjustment model, the second combination of stepwise regression method is used to select all alternative variable of the sub sets, finally choosing asset scale, non-performing loan ratio, spreads as a regression model of the independent variables. Taking Industrial and Commercial Bank of China as an example, the detailed regression results are shown in Table 2.

Table 2 Output results of regression data series of ICBC

The coefficient of	Standard error of	t-statistic	Concomitant probability	
0.003809	0.00018	21.21824	0	
-64.09328	13.58286	-4.71869	0.0001	
177.9455	38.36489	4.638238	0.0001	
0.983607	Adjustment coefficient of determination	0.98164		
21.29499	Sum of squares of residuals	11336.92		
0.0000	D.W.statistic	1.971956		

As can be seen from the regression results, the optimal model takes asset size, non-performing loan ratio and deposit and loan interest rate as independent variables. Each variable passes the t-test and the R value reaches 0.98, indicating a high degree of model fitting. A DW value close to 2 indicates that there

is no autocorrelation problem in the variable. The coefficients of each variable are also in line with economic significance. Net profit is positively correlated with asset size and interest rate spread between deposits and loans, and negatively correlated with non-performing loan ratio. For other commercial banks, the regression results of asset size, non-performing loan ratio and deposit and loan spread are shown in Table 3:

Table 3 Regression output results of sample data series

		SOA	RBL	ODL	Decision	The coefficient of	
Bank of China	coefficient	0.003388	-36.01531	182.2429	0.9670	0.9630	1.5439
	T - statistic	15.38101	-3.183054	5.113152			
China Construc	coefficient	0.003837	-64.77022	164.9537	0.9557	0.9504	2.1748
	T - statistic	13.01683	-2.849431	3.119621			
BOCOM	coefficient	0.00268	-22.43512	39.30308	0.9612	0.9565	1.5681
	T - statistic	15.1202	-3.384022	2.856756			
CMB	coefficient	0.004058	-32.46669	90.71666	0.9277	0.9191	2.1139
	T - statistic	15.11163	-3.108428	4.197591			
Ping An Bank	coefficient	0.002595	-1.835155	19.74399	0.8624	0.8458	1.9954
	T - statistic	8.775328	-0.684849	0.801817			
CMBC	coefficient	0.003879	-35.90099	27.76347	0.9512	0.9453	1.7524
	T - statistic	17.47693	-3.969773	1.861218			
BANK OF	coefficient	0.002558	-3.825207	-3.106969	0.9327	0.9246	1.4232
	T - statistic	14.20238	-1.342047	-1.186201			
SPDB	coefficient	0.003509	-0.553487	34.46403	0.9842	0.9823	2.0143
	T - statistic	31.768	-0.164871	4.361288			

From the above table, we can see that most independent variables pass the t-test, and only a very few fail the t-test. R of a very few banks is lower than 90%, indicating a poor degree of model fitting. More than 90% of the net profits of most banks can be explained by bank asset scale, non-performing loan ratio, deposit and loan spread. DW values to measure the autocorrelation of the independent variables are also between 1.42 and 2.2. At the significance level of 1%, they all pass the DW test, indicating that the independent variable overcomes the autocorrelation. Based on the above analysis, this paper selects three variables of asset size, non-performing loan ratio and deposit and loan interest rate from the alternative variables to establish a panel data model for net income.

Results and Discussion

4.1 Unit root test

If the traditional causality model is directly used to build a regression model for non-stationary economic variables, the determination coefficient of the regression results may be very high, which indicates that the model of the model fits well. However, there may be no causal relationship between the actual variables, so

the simulation results have no practical significance.R^2The data used in the empirical analysis in this paper are all time series, while most of the time series in real economic life are non-stationary. Therefore, it is necessary to conduct stationarity test on the selected variables before conducting empirical research in this paper.

The specific inspection process is taken DR variable as an example. The unit root test results of the original sequence of DR are shown in Table 4:

Table 4 Unit root test results of DR

test method	LLC	Breitung	IPS	ADF - Fisher	PP - Fisher
statistical	-2.82615	-1.34504	-3.05242	44.5402	172.248
Prob.**	0.0024	0.0893	0.0011	0.0005	0.0000

As can be seen from Figure 1, the unit root test of the net profit variable was conducted directly, and at a high significance level of 5%, the null hypothesis was rejected by the Breitung t-Stat method, that is, DR was a non-stationary series. Unit root test was continued for the first-order difference variable of DR, and the test results were shown in Table 5:

Table 5 Unit root test of first order difference of DR series

test method	LLC	Breitung	IPS	ADF - Fisher	PP - Fisher
statistic	-9.61856	-2.27816	-13.588	157.9	690.107
Prob.**	0.0000	0.0114	0.0000	0.0000	0.0000

As can be seen from Figure 2, at the significance level of 1%, the associated probability of the first-order difference statistics calculated by Breitung t-Stat is also around 1%, and the p-value of the other methods is zero. Therefore, it can be considered that the first-order difference of DR is a stationary series without unit root. According to the above analysis, we can conduct unit root test for SOA, RBL and ODL variables in turn. The summary of unit root test results for first-order difference variables is shown in Table 6:

Table 6 Unit root test results of first-order difference of independent variable

variable	test method	LLC	Breitung	IPS	ADF - Fisher	PP - Fisher
SOA	statistic	-8.62909	-5.24987	-9.32149	104.239	127.38
	Prob.**	0.0000	0.0000	0.0000	0.0000	0.0000
RBL	statistic	-10.6741	-2.57309	-10.5171	116.992	362.051
	Prob.**	0.0000	0.0050	0.0000	0.0000	0.0000
ODL	statistic	-5.55211	-4.09622	-3.4402	38.2337	44.6809
	Prob.**	0.0000	0.0000	0.0003	0.0036	0.0005

As can be seen from the table, at the significance level of 1%, the first-order difference variables of SOA, RBL and ODL all reject the null hypothesis under the above method, that is, the variables are all first-order non-stationary, and the single-order degree is 1.

4.2. Co-integration test

Definition of cointegration: for random variables = (...)$\mathbf{X_t X_{1t} X_{2t} X_{Nt}}$', if it is known that (1) ~ I(d) (that is, each of the components of is nonstationary of order d), (2) there exists a column vector β of order N * 1, ($\beta \neq 0$), such that β' ~ I(d-b) is called a variable...$\mathbf{X_t X_t X_t X_{1t} X_{2t} X_{Nt}}$The existence of order (d,b) co-integration relationship is expressed by ~ Ci (d-b).$\mathbf{X_t}\beta$ is called the co-integration vector, and the elements of β are called the co-integration parameters.1

According to the definition of co-integration, before testing the co-integration of a set of time variables or the long-term equilibrium relationship, the single product number of time series should be tested first, and the co-integration test can be conducted directly if the single product number of variables is the same. When The Times of the single product of the variable are different, it should be transformed into the same single product by difference or other model transformation, and then the co-integration relation test should be carried out.

According to the analysis results of the unit root test above, the first-order difference of the variables selected in the paper is all stable, that is, the variable ~ I(1). The existence of co-integration relationship can be directly tested, and the test results are shown in Table 7.

Table 7 Pedroni test results

statistic	Panel v	Panel rho	Panel PP	Panel ADF	Group rho	Group PP	Group ADF
Statistical quantity (P value)	1.8386 (0.033)	-1.3790 (0.0839)	-13.4807 (0.0000)	-8.3445 (0.0000)	-0.3568 (0.3606)	-15.9672 (0.0000)	-6.8838 (0.0000)
Weighted statistical value	0.0396 (0.4842)	-1.1859 (0.1178)	-14.0113 (0.0000)	-6.9327 (0.0000)			

As can be seen from the above table, the P values corresponding to Panel Rho statistics and Panel V statistics are 8.39% and 3.3% respectively. Under the significance level of 1%, the null hypothesis without co-integration cannot be rejected. The P values of Panel PP statistics and Panel ADF statistics are both 0. Under the significance level of 1%, the null hypothesis will be rejected and all sections will be considered to have a

common AR coefficient, and the value of this coefficient is less than 1. It is easy to know that Panel Rho statistics and Panel V statistics are considered to have no co-integration relationship, while other statistics are considered to have co-integration relationship. The P value of Group Rho statistic is 0.3606, and at the significance level of 1%, it is considered that there is no co-integration relationship. The P values of Group PP and Group ADF statistics were both 0, which were significant, indicating the existence of a heterogeneous co-integration relationship. Taken together, it can be concluded that there is a co-integration relationship between DR, SOA, RBL and ODL.

In the income model, the independent variable of deposit and loan spread is used as a measure of market risk, the non-performing loan ratio is used as a measure of credit risk, and the asset scale is used as a measure of the profitability of commercial banks. The part of the model that cannot be explained by deposit and loan spreads, non-performing loan ratio and asset size is regarded as operational risk.

4.3. Mixed regression analysis

Considering the small number of sample data selected, the differences among commercial banks were firstly ignored and mixed regression analysis was conducted using the data of sample banks. The regression results are shown in Table 8:

Table 8 Measurement results of mixed regression

variable	coefficient	T - statistic	Concomitant
ODL	0.003878	54.65446	0.0000
SOA	-10.24664	-3.790725	0.0002
RBL	71.25058	7.234377	0.0000
coefficient of	0.990345	residual sum of	90457.28
ient of determination of	0.989919	D.W. statistics	1.127149
F - statistics	2321.982		

It can be seen from the table that the adjoint probability of the independent variable t-test is zero, indicating that the independent variable has a significant influence on the dependent variable. Using ordinary least squares (OLS) to estimate the model parameters are got by fitting the model, the decision coefficient reached close to 0.99, the asset scale, the non-performing loan ratio changes, explained the net profit margin of 99%, the residual sum of squares of 9.045728 trillion yuan, according to the confidence level of 99.9% of normal distribution quantile of 3.09, can draw statistical sample Banks during the period of the venture capital operation as follows:

OpRisk = 3.09 * = 929.35$\sqrt{90457.28}$

The above formula shows that during the period from 2008 to the first quarter of 2015, capital provisions of 92.935 billion yuan should be set aside for operational risks for 9 sample individuals, with an average annual capital provision of 12.82 billion yuan.

Since mixed regression regards all commercial banks as the same and ignores the differences among banks, such neglect will inevitably increase the variance of the estimation equation and thus increase the sum of squares of residuals that we regard as operational risks. In view of this, the following panel regression analysis will be carried out taking into account the differences between individuals.

4.4 Determination of model influence forms

Firstly, the likelihood ratio test was used to test the individual fixation effect, and the F statistic tested was 16.9063, and the corresponding associated probability was 0.0000. At the significance level of 1%, the null hypothesis of the random effects model was rejected. Therefore, the individual fixed effect model should be established.

4.5 Determine F test of model form

(1) Three forms of the model

CheckedListBox Label：Variable coefficient model $y_i = \alpha_i + x_i\beta_i + u_i$

CheckBox LinkLabel：Variable intercept model $y_i = m + \alpha_i^* + x_i\beta + u_i$

TreeView Button：Invariant parameter model $y_i = \alpha + x_i\beta + u_i$

(2) Based on assumptions

H_1:$\beta_1 = \beta_2 = \cdots = \beta_N$

H_2:$\alpha_1 = \alpha_2 = \cdots = \alpha_N$

$\beta_1 = \beta_2 = \cdots = \beta_N$

Through regression estimation of the above variable coefficient regression model, variable intercept regression model and constant intercept constant coefficient regression model, the following results can be obtained:

S_1= = 90457.28 50764.46 = 191376.1 S_2 S_3

And N = 9 T = 29 K = 3

F_1= = = 7.33$\frac{(S_2-S_1)/[(N-1)K]}{S_1/[(NT-N(K+1)]}$ $\frac{(90427.89-50723.19)/24}{50723.19/225}$

F_2= = = 19.48$\frac{(S_3-S_1)/[(N-1)(+1)]}{S_1/[(NT-N(K+1)]}$ $\frac{(101234.2-50723.19)/32}{50723.19/225}$

$F_{0.05}$(24225) = 1.52 (32225) = 1.46$F_1$$F_{0.05}$$F_2$

Therefore, the rejection, assumption and variable coefficient model are in line with the sample situation. Combined with the analysis of the influence form of the model, this paper adopts the variable coefficient model of individual fixed effect for empirical analysis and research.$H_1$$H_2$

4.6 Panel regression analysis

Based on the analysis of the above model form, ordinary least square method (OLS) was used to estimate the variable coefficient model of the individual fixed effect. The results are shown in Table 9.

Table 9 Panel regression results

bank name	C	SOA	RBL	ODL
ICBC	-434.4321	0.00361 (0.0000)	-68.58 (0.0000)	155.679 (0.0000)
Bank of China	-578.5923	0.00348 (0.0000)	-29.4928 (0.0007)	176.4658 (0.0000)
CCB	-322.6159	0.00347 (0.0000)	-77.1243 (0.0000)	135.9886 (0.0038)
Bank of Communications	-64.5644	0.00252 (0.0000)	-25.401 (0.0000)	33.8359 (0.0072)
CMBC	-222.13878	0.00376 (0.0000)	-29.1593 (0.0005)	74.4245 (0.0001)
Ping An Bank	-96.3363	0.00267 (0.0000)	-3.1777 (0.1481)	30.6063 (0.1389)
China Minsheng Bank	-32.0889	0.00361 (0.0000)	-30.9437 (0.0000)	14.8532 (0.2658)
ANK OF NINGB	15.5867	0.00244 (0.0000)	-3.6783 (0.0292)	-3.7761 (0.0565)
Shanghai Pudong Development Bank	-136.36885	0.00358 (0.0000)	-0.8623 (0.7734)	37.7775 (0.0000)
Weighted Statistics	coefficient of determination	0.996557	residual sum of squares	254.0943
	The coefficient of determination of adjustment	0.996022	D.W. statistics	1.935892
Unweighted statistics	determination coefficient	0.994313	residual sum of squares	53281.95
	D.W. statistics	1.906716		

Regression analysis results: the coefficient of asset size are all positive, and change in the same direction with net profit, in line with economic conditions; The coefficient of non-performing loan ratio is all negative, which changes negatively with net profit and is also consistent with the actual situation. Most of the coefficients of one-year deposit and loan spreads are positive, only the Bank of Ningbo is negative, which is not consistent with the actual situation. Most of the coefficients of cross-section individuals also pass the t-value or p-value test, but only a few fail. The sample determination coefficients are all above 99%, indicating that the model has a good goodness of fit. DW values are between 1.9 and 2.0, and the null hypothesis H0 is rejected and considered to be non-autocorrelation.$\mathbf{u_t}$At the 1% confidence level, the operational risk capital of the sample banks during the calculation period is:

OPRISK = 3.09* = 71.3 billion$\sqrt{53281.95}$

According to the calculation results of the panel regression model, capital provision of 71.3 billion yuan should be set aside for the nine samples during the sample data period, with an average annual set aside of 9.83 billion yuan.

4.7 Comparative analysis of state-owned commercial banks and joint-stock commercial banks

In the above analysis, the 9 sample banks were regarded as a whole, and the sum of squares of residuals was used to estimate the size of the overall operational risk, so the respective risks could not be understood. In order to better understand the operational risk difference between state-owned commercial banks and joint-stock commercial banks, this part divides the 9 sample data into two groups. The first group is the remaining five joint-stock commercial banks. First of all, each bank is analyzed to estimate the operational risk of each commercial bank, and then the comparative analysis is carried out on this basis.

(1) Operational risk analysis of state-owned commercial banks

Table 4.10 reflects the empirical analysis and operational risk status of state-owned commercial banks. It can be seen from the table that the coefficients of independent variables all pass the t-value test, and the signs are consistent with the actual economic meaning. At the significance level of 1%, the DW values of the four banks all passed the test, that is, there was no autocorrelation among independent variables. For ICBC, the coefficient of determination of the regression equation reached 0.983607, and the goodness-fitting degree of the model was good. The sum of squares of residuals was 11336.92, and the operational risk capital requirement was 32.901 billion yuan. For Bank of China, the coefficient of determination of the regression equation is 0.966976, the sum of squares of residuals is 9555.21, and the operational risk capital requirement is 30.205 billion yuan. For China Construction Bank, the coefficient of determination of the regression equation is 0.955773, the sum of squares of residuals is 21581.52, and the operation risk capital is required to be 45.394 billion yuan. For Bank of Communications, the coefficient of determination of the regression equation is 0.961189, the sum of squares of residuals is 1558.01, and the operational risk capital requirement is 12.197 billion yuan.

Table 10. Operational risk assessment of the four rows in the sample

	ICBC	Bank of China	CCB	Bank of
	Coefficient (T-	Coefficient (T-	Coefficient (T-	Coefficient (T-
SOA	0.003809 (21.2182)	0.0034 （15.3810）	0.003837 （13.0168）	0.00268 (15.1202)
RBL	-64.0933 (-4.71869)	-36.0153 （-3.1830）	-64.77022 （-2.8494）	-22.4351 (-3.3840)
ODL	177.9455 (4.6382)	182.2429 （5.1132）	164.9537 （3.1196）	39.3031 (2.8568)
coefficient of	0.983607	0.966976	0.955733	0.961189
The coefficient	0.98164	0.963013	0.950421	0.956531
D.W. statistics	1.971956	1.543897	2.17483	1.568121
residual sum of	11336.92	9555.21	21581.52	1558.01
operational risk （OpRisk）	329.01	302.05	453.94	121.97

(2) Operation risk analysis of joint-stock commercial banks

See Table 4.11 for the regression results and operational risk status of joint-stock commercial banks. Most of the coefficients of independent variables passed the t-value test. Except that the coefficient of one-year deposit and loan spread LC of Bank of Ningbo was inconsistent with the actual economy, the coefficients of independent variables in the empirical model of other commercial banks were consistent with the actual economic situation. At the significance level of 1%, DW values passed the test. For China Merchants Bank, the coefficient of determination of the regression equation is 0.927731, the sum of squares of residuals is 3072.445, and the corresponding operational risk is 17.323 billion. For Ping An Bank, the coefficient of determination of the regression equation is 0.862354, the sum of squares of residuals is 1142.46, and the corresponding operational risk is 10.444 billion. For Minsheng Bank, the coefficient of determination of the regression equation is 0.951179, the sum of squares of residuals is 1993.102, and the corresponding operational risk is 13.795 billion. For Bank of Ningbo, the coefficient of determination of the regression equation is 0.932713, and the sum of squares of residuals is about 34.34. The calculated operational risk is only 1.812 billion; For SPD Bank, the goodness of fit of the regression model is very high, reaching 0.984157, the sum of squares of residuals is about 490.42, and the corresponding operational risk is 6.843 billion.

Table 11. Operational risk estimation of joint-stock commercial banks in the sample

	CMBC	Ping An	CMBC	China	SPDB
	The coefficient	The coefficient	The coefficien	The coefficien	The coefficien
SOA	0.004058 (15.1116)	0.0026 (68.7753)	0.0039 (17.4769)	0.0026 (14.2024)	0.0035 (31.7680)
RBL	-32.4667 (-3.1084)	-1.8352 (-0.6848)	-35.9010 (-3.9698)	-3.8252 (-1.3421)	-0.5535 (-0.1649)
ODL	90.7167 (4.1976)	19.7440 (0.8018)	27.7635 (1.8612)	-3.1070 (-1.1862)	34.4640 (4.3613)
coefficient of	0.927731	0.862354	0.951179	0.932713	0.984157
The coefficient of	0.919059	0.845837	0.94532	0.924639	0.982256
D.W. statistics	2.113919	1.995369	1.752408	1.423215	2.01426
residual sum of	3072.445	1142.46	1993.102	34.37719	490.4172
Operational Risk	171.23	104.44	137.95	18.12	68.43
	55.42964009	33.80029586	44.64417095	5.863206461	22.1453652
	171.2775879	104.4429142	137.9504882	18.11730796	68.42917848

(3) Comparison of operational risks between state-owned and joint-stock commercial banks

According to the state-owned commercial Banks and joint-stock commercial Banks operational risk measurement result shows that most of the operation of the state-owned commercial bank risk is higher, in addition to the bank of communications in 12 billion, the rest of the three operation risk is bigger, the industrial and commercial bank and the bank of China close to, in 30 billion, China construction bank, the largest reached $45.4 billion, risk size is about 3.7 times of bank of communications. Relatively speaking, the operating risk of joint-stock commercial banks is relatively low, the highest is China Merchants Bank, reached 17.123 billion yuan, the lowest Bank of Ningbo, only 1.812 billion yuan.

Conclusion

First, the empirical model to measure the samples of individual operation risk comparing with the results the statistical analysis shows that income model to calculate the various operational risks in commercial bank individual size statistical result is not consistent with the history, the operational risks in each individual sample size together, calculate the sample average annual operating risk capital is about 23.5 billion, is the maximum annual average historical figures 120.8 to 2 times, but compared with the results securities factors model, income

model to measure the operational risk capital compared with actual loss, about reference can be used as a measure of operational risk. The above results may be caused by the following reasons: due to the small sample data available during the period, the sample individuals are regarded as independent and the simple regression analysis is applied to each individual to calculate the operational risk capital, which ignores the relationship between each individual, thus affecting the accuracy and effectiveness of the operational demeanor.

Second, when from the overall Angle to deal with the operational risk, we find that: if the object is just a sample bank individual statistics, and does not include cannot separate the collection to a single sample bank losses events, samples of the overall loss events for 1139, the loss amount is 128.63 billion yuan, nine samples of individual loss amount is RMB 9.895 billion per year on average; If all the state-owned and joint-stock commercial banks involved in the sample are collected and counted, the total number of loss events of the sample individuals is 1,182, with a total loss amount of about 157.08 billion yuan, and the average annual loss amount of the sample individuals is about 12.08 billion yuan. Therefore, the average annual loss of the sample should be between RMB 9.895 billion and RMB 12.08 billion based on the historical statistical data.

Thirdly, combined with the empirical analysis results of the model, it can be seen that the annual operational risk provision calculated by the mixed income model should be 12.82 billion yuan, and the annual operational risk provision calculated by the income panel regression model should be 9.83 billion yuan. It can be concluded that: within the allowable error range of 1 unit, the capital provision calculated by the analysis of income panel regression model is the closest to the actual loss amount; The mixed regression results of the income model are greater than the maximum loss data of the historical statistics. The reason for this result is that the mixed income regression model ignores the differences among the sample individuals, so it may overestimate the operational risk capital of commercial banks.

Fourth, by the stock factor model, the empirical result shows that annual stock panel regression model calculation of operation risk set aside capital should be $497 billion, with the actual loss data differs very big, 40 to 50 times that of the latter, suggesting that the current phase of securities factor model in calculating the capital operation risk in commercial bank may exist some defects. First of all, China's securities market can only meet the standard of weak and efficient market at present, and the market operation mechanism and relevant legal system and norms of securities market are not perfect, which may result in that the price of China's securities market can not really reflect the intrinsic value of securities, and the market value of tradable stocks may distort the intrinsic value of securities. Second, in addition to stock market prices are influenced by supply and demand, may also be factors including politics, economy, culture and so on various aspects of influence,

and some data may involve the secrets of commercial Banks, the availability of this part of the data is restricted, regression model fitting in this paper chose three factors that affect the securities market price as the independent variables, the selection of variables may not be comprehensive and accurate enough. Therefore, the securities factor model may not be suitable to measure the operational risk of commercial banks in China under the situation that the current securities market and information disclosure mechanism are not perfect.

Fifthly, in view of the current situation in China, the operational risk loss database was established late, and the data were few and incomplete. A large number of historical loss event data is an important basis for the use of advanced measurement methods to measure operational risk. The imperfect development of securities market restricts its effective play as a barometer of real economy, thus affecting the accuracy of operational risk measurement of securities factor model. The basic index method and standard method proposed in the Basel Accord are also affected by the subjective β coefficient, which cannot objectively calculate the operational risk capital requirements. The financial data of each listed company is audited by an independent professional third party organization - accounting firm every year, so the accuracy of the data is relatively guaranteed, and the publicly disclosed financial data is also easy to obtain.Therefore, from the perspective of economy and feasibility, revenue model is a more appropriate and accurate method to measure operational risk at the present stage.

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