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A Study of Risk Spillovers among Listed Commercial Banks in China

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Abstract: *With the accelerated pace of financial liberalization, China's banking industry has continued to introduce intersecting businesses and products, and the degree of inter-institutional linkages has exceeded any previous period. The increasingly complex network of relationships between banking institutions has also led to the rapid spread of financial risks in banking institutions, resulting in the transformation of local risks of micro-individuals into large-scale systemic financial risks. In this paper, eight listed commercial banks in China are selected as samples, and this paper is based on the Diebold & Yilmaz volatility spillover index model to carry out the study of risk spillover effects. It is found that the total risk spillover index among listed commercial banks in China is 76.19%, and there is asymmetry in the spillover effect among banks. State-owned commercial banks are net risk exporters, and joint-stock commercial banks and urban commercial banks are net risk receivers. The analysis of dynamic spillover effect shows that the total spillover index keeps changing during the observation period, and the total spillover value has been at a high level, which indicates that there is a large risk spillover among listed commercial banks in China. As a result, regulators need to realize that it is more important to incorporate interbank correlation and the resulting risk spillover effects into the research framework than bank size.*

Keywords: *commercial banks, risk spillover, Diebold & Yilmaz volatility spillover index model*

1. Introduction

In recent years, along with the accelerating pace of financial liberalization, financial institutions by virtue of a number of channels of communication so that the relationship network has become increasingly complex, and the links between institutions have become more and more close. Financial institutions in the product, business, operation and other aspects have a similar relevance, this relevance to the financial institutions to bring income, promote the development of the same time, but also become an important inter-institutional risk spillover effect of the important push. The problem of "too connected to fall" among financial institutions has become an important source of the outbreak of large-scale financial crises.

For China, banking institutions, as the dominant part of the financial system, its relevance and the risk spillover effect brought about by this relevance have become the focus of the relevant regulatory authorities. The scale of China's banking industry has risen rapidly since 2015, and the correlation behavior between banks has become more and more closely linked, and using this close correlation, banking institutions on the one hand, promote the scale of profits and economic growth, but at the same time it also increases the likelihood of the rapid spread of risk across institutions. When a bank is in trouble, its individual micro-risks can easily be spread out due to connected transactions with other banks, resulting in the so-called risk spillover effect.

2. Literature review

Lu Jing and Zhang Jia[1] (2011) conducted an empirical study using data on daily stock returns of China's listed commercial banks and proved that China's listed commercial banks have obvious correlations between institutions and that such correlations are dynamic over time. Ouyang Hong bing and Liu Xiaodong[2] (2015) take the stock prices of 13 listed commercial banks in China as sample data, and by studying the volatility of each bank's stock price, they find that there is a phenomenon of correlation within the banking system in China, and the size of the correlation shows asymmetry. The traditional measure of correlation is the Pearson correlation coefficient method, but the main drawback of this method is that it can only capture the linear correlation between the variables, while it is too weak

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in measuring the nonlinear correlation. Therefore, considering the prevalence of nonlinear correlations among financial variables, many scholars have proposed improved methods. Diebold & Yilmaz (2014) firstly sorted out the empirical methods for measuring correlations and focused on a detailed interpretation of the network topology theory, and then measured the correlations among banking institutions and between banks and the banking system, respectively, using banks' stock prices as sample data. Härdle et al.[3] (2016), based on Diebold & Yilmaz [4](2014), used topological network modeling to measure the correlation between banking institutions during the financial crisis. Ma Lin [5](2017) used the daily closing prices of the stock market of 15 commercial banks in China as a sample, constructed a quantile regression model of risk spillover effect, and the study showed that the systematic risk spillover effect occurs in China's commercial banks once they are hit by the crisis. Wenwen Duan and Jianxin Zeng[6] (2022) systematically analyze the extreme risk spillover effects of upper and lower tails of commercial banks, and the empirical results show that the risk spillover of upper and lower tails of commercial banks has significant asymmetry. Therefore, this paper adopts the Diebold & Yilmaz model, which is more scalable and better reflects the risk contagion, to quantify the risk spillover effect of banks on the basis of researching out the correlation among listed commercial banks in China.

3. Data and Models

3.1. Data selection

Compared with other financial indicators, stock prices have a natural advantage in reflecting market information and predicting market trends, in view of this, this paper selected the daily stock returns of China's listed commercial banks as the sample data for the study of bank correlation. The time period of data selection is from January 1, 2010 to June 30, 2023, and the samples of data selection are four state-owned commercial banks, three joint-stock commercial banks, and one city commercial bank. The data were obtained from the Wind database and the variables and codes are shown in Table 1.

Table 1: Selection of variables

	Variable Description	Variable Code
State-owned commercial banks	Bank of China,	BOC
	INDUSTRIAL AND COMMERCIAL BANK OF CHINA	ICBC
	Bank of Communications	BCM
	China Construction Bank	CCB
Joint-stock commercial banks	Shanghai Pudong Development Bank	SPDB
	Hua Xia Bank	HXB
	China Merchants Bank	CMB
City Commercial Banks	BANK OF NINGBO	NBCB

The data used are daily data with an interval of January 1, 2016-July 31, 2023, excluding data from non-simultaneous trading dates, and logarithmic differencing is used to obtain the return series.

3.2. Research methodology Model Setting

Diebold & Yilmaz volatility spillover index model is used for empirical analysis.

Distinguishing from the previous use of DCC and BEKK in the family of multivariate GARCH models to analyze the spillover effects between different markets, this chapter draws on the spillover index model constructed by Diebold & Yilmaz (2009, 2012, 2014) as follows:

First, construct a VAR model with a smooth covariance dimension of N and a lag period of p:

$$Y_t = \sum_{i=1}^{p} \varphi_i Y_{t-i} + \varepsilon_t \tag{1}$$

If this VAR model has smooth covariances, the moving average form of equation (1) is:

$$Y_t = \sum_{t=1}^{\infty} A_i \varepsilon_{t-i} \tag{2}$$

On the basis of the VAR model described above, the variance decomposition of the covariance matrix makes it possible to clearly identify that the variance decomposition of the fluctuations of each variable

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originates from the fluctuating portion of each variable in the system, that is, the impact of the changes in the other variables in the system on the fluctuations of that variable, i.e., the spillover effects of the changes in each variable.

Second, the definition of variance decomposition and spillover effects is used to illustrate the degree of explanation from one variable to another.

$$m_{ij}\left(H\right)=\frac{\sigma_{jj}^{-1}\sum_{h=0}^{H-1}\left(e_i'A_h\sum e_j\right)^2}{\sum_{h=0}^{H-1}\left(e_i'A_h\sum A_h'e_j\right)} \tag{3}$$

Normalization is carried out with the formula:

$$\tilde{m}_{ij}\left(H\right)=\frac{m_{ij}^H}{\sum_{j=1}^{N}m_{ij}^H} \tag{4}$$

Standardized and available: $\sum_{j=1}^{N}\tilde{m}_{ij}(H)=1,\sum_{i,j=1}^{N}\tilde{m}_{ij}(H)=N$.

Third, define the gross spillover index, the directional spillover index, the net spillover index, and the net spillover index between the two variables.

(1) The total spillover index indicates the mutual explanatory power of the variables in the whole system and is calculated as follows:

$$S\left(H\right)=\frac{\sum_{i,j=1,i\neq j}^{N}\tilde{m}_{ij}\left(H\right)}{\sum_{i,j=1}^{N}\tilde{m}_{ij}\left(H\right)}\times 100=\frac{\sum_{i,j=1,i\neq j}^{N}\tilde{m}_{ij}\left(H\right)}{N}\times 100 \tag{5}$$

(2) Directional spillover index is the degree to which a variable in the system affects or is affected by other variables, and the formula for the directional spillover index of variable i on other variables is:

$$S_{.i}\left(H\right)=\frac{\sum_{j=1,i\neq j}^{N}\tilde{m}_{ji}\left(H\right)}{\sum_{i,j=1}^{N}\tilde{m}_{ji}\left(H\right)}\times 100=\frac{\sum_{j=1,i\neq j}^{N}\tilde{m}_{ji}\left(H\right)}{N}\times 100 \tag{6}$$

The directional spillover index of all other variables to the variable is given by:

$$S_{i.}\left(H\right)=\frac{\sum_{j=1,i\neq j}^{N}\tilde{m}_{ij}\left(H\right)}{\sum_{i,j=1}^{N}\tilde{m}_{ij}\left(H\right)}\times 100=\frac{\sum_{j=1,i\neq j}^{N}\tilde{m}_{ij}\left(H\right)}{N}\times 100 \tag{7}$$

(3) The Net Spillover Index (Net) is the difference between two directional spillover indices, indicating the extent of the net spillover of variable i to all other variables, and is calculated as:

$$S_i\left(H\right)=S_{\cdot i}\left(H\right)-S_{i.}\left(H\right) \tag{8}$$

4. Empirical analysis and estimation results

4.1. Descriptive statistical analysis

Table 2: Descriptive statistics of yield series

	BOC	ICBC	BCM	CCB	SPDB	HXB	CMB	NBCB
Mean	0.022417	0.024631	0.019341	0.025698	0.01284	0.01293	0.052435	0.059359
Max	9.56176	8.259292	6.099922	8.127949	9.564619	9.248254	9.519422	9.538618
Min	6.03805	-.93076	-.86393	-.93665	-.35918	-.00803	-.03393	-.76252
S.D.	0.971512	1.067092	1.001586	1.261089	1.207237	1.118749	1.800397	2.041214
Skewness	0.614673	0.51783	-0.0009	0.352819	0.418247	0.160699	0.250628	0.313571
Kurtosis	14.78981	9.668898	9.866122	8.592994	11.38946	10.03986	5.365407	4.699879
JB	10778.35	3493.819	3616.31	2437.753	5452.638	3809.56	448.4683	251.8254
Prob	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 2 gives the descriptive statistics of the return series of the bonobo listed commercial banks.

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Analyzing Table 2, it can be seen that the return of state-owned commercial banks is generally smaller than that of urban commercial banks, and the standard deviation of return of state-owned commercial banks is generally smaller than that of joint-stock commercial banks and urban commercial banks, and the return of urban commercial banks is the largest, and the standard deviation of return is also the largest. It shows that in the sample period, the average return of state-owned commercial banks is not high but the fluctuation is the smallest, while the city commercial banks have higher returns and also have larger fluctuations. According to the value of skewness and kurtosis, it can be seen that all the return series are characterized by obvious sharp peaks and thick tails, and none of them obeys normal distribution. The Jarque-Bera statistic of each return series significantly rejects the original hypothesis of normal distribution at the 1% level. It is consistent with the characteristics of financial time series, and the next step of model construction can be carried out.

4.2. Correlation analysis

Table 3: Correlation analysis

Cor	BOC	ICBC	BCM	CCB	SPDB	HXB	CMB	NBCB
BOC	---							
ICBC	0.817***							
BCM	0.820***	0.757***	---					
CCB	0.796***	0.873***	0.760***	---				
SPDB	0.605***	0.611***	0.684***	0.638***	---			
HXB	0.746***	0.693***	0.792***	0.723***	0.720***	---		
CMB	0.561***	0.609***	0.605***	0.651***	0.651***	0.639***	---	
NBCB	0.526***	0.529***	0.538***	0.585***	0.559***	0.617***	0.7172***	---

Spearman correlation coefficient (Spearman correlation coefficient) was used; *, ** and *** are 10%, 5% and 1% significance levels respectively.

The correlation test between variables was first conducted for preliminary analysis, using Spearman's method, and the results are shown in Table 3. All variables are significantly correlated with each other at 1% water. Analysis of Table 3 shows that the correlation coefficients between the two are not less than 0.5, indicating that there is a large correlation between the commercial banks, which fully reflects the close association between the commercial banks in China. And the correlation coefficient between state-owned commercial banks is larger, the correlation coefficient between joint-stock banks is the second largest, while the correlation coefficient between urban commercial banks and other commercial banks is generally smaller compared with them.

4.3. Smoothness test, ARCH effect test

Table 4: Smoothness test, ARCH effect test

	BOC	ICBC	BCM	CCB	SPDB	HXB	CMB	NBCB
t-Statistic	-22.8644	-42.2644	-23.2266	-41.7471	-43.3315	-28.3	-42.9023	-45.1012
Prob	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
F-statistic	21.67003	5.815887	5.745742	6.185354	2.140434	4.845415	3.90034	3.974152
Obs*R	353.3008	110.52	109.2731	117.0886	21.28313	93.02623	75.63511	77.00848
Prob	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

As can be seen from Table 4, all the return series pass the ADF test and are smooth time series models. And there is an ARCH effect in the mean equation of the series, which can be used for the next step of model construction.

4.4. Spillover index model analysis

4.4.1. Static spillover index analysis

Estimate the total spillover index, directional spillover index and net spillover index of the system to get the risk spillover of the system in the whole sample period.

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Table 5: Spillover index matrix

	BOC	ICBC	BCM	CCB	SPDB	HXB	CMB	NBCB	From
BOC	22.16	14.95	15.07	14.14	8.06	12.38	7	6.24	77.84
ICBC	14.82	22.03	12.76	16.91	8.23	10.77	8.19	6.28	77.97
BCM	14.72	12.57	21.92	12.71	10.19	13.55	7.96	6.37	78.08
CCB	13.57	16.35	12.44	21.24	8.7	11.32	9.05	7.33	78.76
SPDB	9.4	9.66	12.11	10.59	25.73	13.49	10.87	8.14	74.27
HXB	12.4	10.89	13.8	11.79	11.6	22.05	9.11	8.36	77.95
CMB	8.26	9.69	9.62	11.12	11.07	10.75	26.03	13.46	73.97
NBCB	8.28	8.33	8.61	10.1	9.28	11.05	15.07	29.29	70.71
To	81.46	82.44	84.42	87.37	67.12	83.31	67.25	56.18	**76.19**
Net	3.62	4.47	6.34	8.61	-7.14	5.36	-6.72	-14.53	

As can be seen from Table 5, firstly, the total system spillover index is 76.19%, and the degree of interaction within the system is relatively high. Secondly, comparing the diagonal values with other values shows that the variables are generally more affected by their own lagged effects than by other variables. Again, urban commercial banks have the smallest impact of 70.71% on the system and the smallest contribution of 56.18% to the system, and the smallest net contribution of -14.53% to the system with a negative value, indicating that urban commercial banks are the net receivers of risk. The state-owned commercial banks all have a greater impact on the system and all have a positive net contribution to the system, making them net exporters to the system. Joint-stock commercial banks (two of them) all have a negative net contribution to the system and are net receivers of the system. Finally, the directional spillovers among variables show obvious asymmetry, and the spillovers from state-owned commercial banks to joint-stock commercial banks and urban commercial banks are significantly larger than the spillovers from joint-stock commercial banks and urban commercial banks to state-owned commercial banks.

4.4.2. Dynamic spillover index analysis

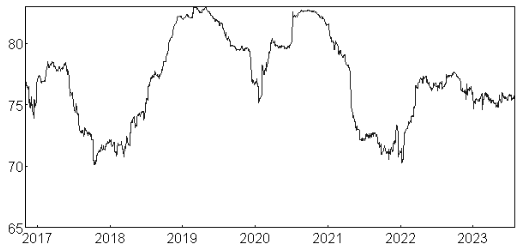

Figure 1: Total spillover index

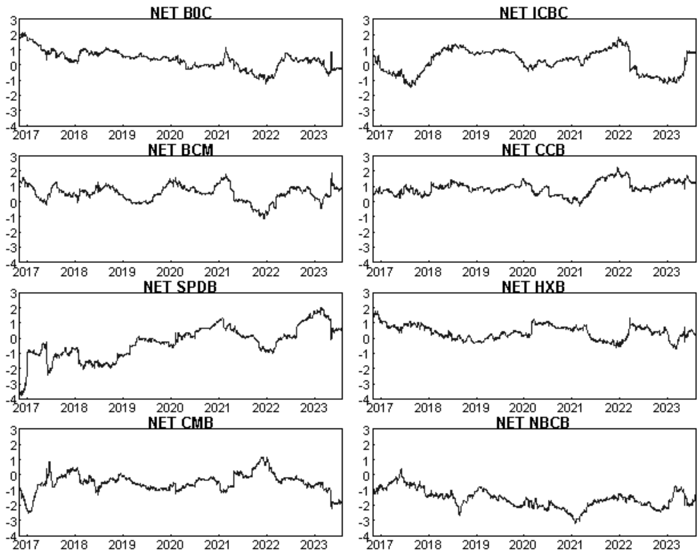

Figure 2: Net spillover index

In order to further the dynamic change of spillover effect (the total spillover effect of the whole system) among listed banks in China, the rolling time window technique is introduced to test the time-varying characteristics of the total spillover index over the whole sample period, with a window period of 200.

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From Figure 1, it can be seen that the fluctuation range of the total spillover index ranges from 70% to 90%, and the spillover effect exhibits a dynamic change and a large value, which suggests that, during the sample period, there is a large risk spillover among the selected commercial banks. There is a large risk spillover.

As can be seen from Figure 2, the net spillover indices of the four state-owned commercial banks as well as Hua xia Bank among the joint-stock banks are positive in most of the periods, indicating that the state-owned commercial banks are net exporters in most of the observation periods. While the net spillover index of the remaining two joint-stock commercial banks as well as urban commercial banks is negative in most periods, which is more inclined to be net receivers.

5. Conclusions

By using Diebold and Yilmaz volatility spillover index model, the study of spillover effect among listed commercial banks in China was carried out, and the following conclusions were drawn based on the analysis of the empirical results: the static system total spillover index is 76.19%, and there is an obvious asymmetry in the spillover effect among commercial banks. State-owned commercial banks are net risk exporters, joint-stock commercial banks and urban commercial banks are net risk receivers, and the directional spillover effect between variables shows obvious asymmetry, and the spillover effect of state-owned commercial banks on joint-stock commercial banks and urban commercial banks is significantly larger than the spillover effect of joint-stock commercial banks and urban commercial banks on state-owned commercial banks. The analysis of dynamic spillover effect shows that the total spillover index keeps changing in the observation period, and the total spillover value has been at a high level, indicating that the risk spillover effect among listed commercial banks in China is larger.

Based on the above empirical test results and in combination with the display, the following suggestions are made:

Firstly, moderately limit the bank-associated business. As the core institutions of China's financial industry, inter-bank business transactions involve a wide range of high relevance and complexity, which brings considerable benefits to the banking institutions at the same time, but also leads to mutual contagion of bank risks due to the existence of high inter-institutional correlation. Relevant departments should appropriately limit the related business transactions between banking institutions and accelerate the construction of early warning mechanisms for the relatedness of banking business.

Secondly, accelerate the establishment of risk management mechanisms. Banking institutions should change the “wind control concept” in time, pay attention to the risk spillover effect on affiliated banks, and pay close attention to their own risk transmission channels and paths while monitoring their own risks in real time. For banks with large risk spillover effects, they need to effectively control their business operation level in financial innovation, appropriately increase their risk monitoring efforts, and curb their risk exposure in market risk and credit risk.

Finally, dynamic adjustment of the list of systemically important banks and effective identification and key supervision of systemically important banks in China are key measures to curb systemic financial risks and promote the stable development of the banking industry.

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