# Research on the Measurement of Spillover Effects of China's Listed Commercial Banks

**Weilong Gu**

School of Economics, Shanghai University, Shanghai, China

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**Abstract:** This paper uses CoVaR method based on quantile regression to measure the financial risks of 16 listed commercial banks in China, that is, the risk spillover effect of a single institution on the banking system. Based on the assumption of quantile, we measure the VaR value of a single institution and the CoVaR value of a single institution to the system at extreme level, and use ΔCoVaR to measure the risk contribution of a single institution to the system when a crisis occurs. There is no obvious correspondence between the VaR value of a single institution and the CoVaR value of a single institution to the system. At the same time, the VaR value based on historical data measurement may underestimate the risk in the event of crisis. Effective quantification of risk spillover intensity among listed commercial banks in China will help financial regulators capture the risk intensity among banks in time, and then monitor and manage institutions with high-risk spillover, so as to maintain the stability of the financial market.

## 1. Introduction

The research on the risk spillover effect of banks is triggered by the subprime mortgage crisis in the United States in 2008, which lead to the economic depression caused by the financial crisis in the United States. Banks and financial institutions are affected like dominoes, causing the risk of the entire banking system. This is because banks are not totally independent; they have investment exchanges with each other. When a bank is faced with insolvency, because of the economic interconnection, the risk will be transmitted to other banks and financial institutions. Then the risk can affect the whole financial industry. Therefore, a thorough study on the formation of financial risks and a precise measurement on the scale of risk impact can effectively improve China's ability to withstand financial risks and avoid us to follow the same old disastrous road of the U.S. sub-prime mortgage crisis.

## 2. Literature Review on CoVaR Method for Measuring System Importance of Financial Institutions

Scholars at home and abroad have conducted a series of studies on the contagious effect of interbank systemic risk.

Tobias Adrian and Brunnermeier (2009) innovatively put forward the method of conditional value at risk, CoVaR, on the basis of VaR (Value at Risk). That is, the original VaR is only applicable to measure the systemic risk of a single financial institution, but now CoVaR measures how much impact it will have on the financial assets of other financial institutions on the basis of VaR. Lopez-Espinosa, Moreno, Rubia and Valderrama (2012) studied a group of large international banking system risks through CoVaR and concluded that short-term wholesale funds were the key determinant of triggering systemic risk events. Girardi and Ergun (2013) tested CoVaR in reverse on the basis of Tobias Adrian and Brunnermeier (2011) and tested the more serious situation. The conclusion is that savings institutions contribute the most to systemic risk; leverage, scale and equity β are also important in explaining systemic risk. Castro and Ferrari (2014) developed a test method for CoVaR on the basis of Tobias Adrian and Brunnermeier (2011), and tested 26 samples of European banks. The results showed that only a few banks contributed significantly to the risk of the banking system.

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Pu Xiao, Yi Liu and Su-mei Yang (2012) adopted CoVaR to analyze to the risk contribution of listed banks to the whole banking system of China. The results showed that the state-owned banks contributed the most to the risk of the whole system, especially the Bank of China. With the stock return from 2006 to 2011 as research objects, Tian-yun Zhou, Kai-guo Zhou and Liang Huang (2012) also used CoVaR method to study the individual risk characteristics of financial institutions in three groups: Chinese-funded, Hong Kong-funded and foreign-funded. The conclusion is that the spillover effect of larger banks is more obvious. Xue-mei Bai and Da-long Shi (2014) also tested the systemic risk of 27 listed financial institutions in China from 2008 to 2013 based on CoVaR method. The conclusion is that banking financial institutions contribute more to systemic risk.

Generally speaking, CoVaR method is better than VaR method in testing spillover risk of banks. The study of systemic risk of banks is related to the possibility of economic crisis. CoVaR method can effectively and accurately measure the degree of risk, which is conducive to maintaining the stability of financial market and improving the ability of banks to withstand risks. Because GARCH models have different variations and extensions (such as ARMA-GARCH, TARCH and EGARCH), different scholars choose different GARCH models for empirical analysis. This paper uses several methods of GARCH model for empirical analysis through comparing the goodness of fit.

## 3. Establishment of the Quantile Regression CoVaR Model and the GARCH-CoVaR Model

The GARCH model can solve the heteroscedasticity of financial data very well. This paper attempts to use GARCH model to analyze the return series of bank stocks. According to the volatility image of the data, we use GARCH model for fitting analysis, and construct GARCH-CoVaR model to calculate the VaR and CoVaR values of stock data.

1) Testing the ARCH effect of time series of banks. Establishment of a unitary regression equation: $r_t = \beta_0 + \beta_1 r_{mt} + u_t$. The ARCH effect of regression residuals is tested to provide the basis for the application of GARCH model.

2) Selection of GARCH model. According to the return series of each bank, different GARCH models (standard GARCH, TARCH and EGARCH) are established to fit the daily return index of each bank and the whole banking system. The fitting degree of each model is analyzed. According to the height of fitting degree of each model and the requirement of probability value p of each parameter, the best model is selected. Then the autocorrelation of residual is considered. The ARMA model is used for revision. Students' t distribution is selected randomly. The selected models are analyzed by AR (1), AR (2), AR (3) and ARMA (1, 1), so that the model with the best goodness of fit and good prediction effect can be selected to calculate the value of VaR.

3) Calculate the VaR of each bank's return series. According to the GARCH model selected above, the VaR values of individual banks and the whole banking system are calculated and recorded as $VaR_q^i$ and $VaR_q^{sys}$ . The equation of VaR calculation is as follows.

$$VaR_{it} = \hat{R}_{it} - Q(q)\hat{\sigma}_{it} \tag{1}$$

In which, $\hat{R}_{it}$ is the mean value of one-step forward prediction for the selected GARCH model; $\hat{\sigma}_{it}$ is the conditional variance of one-step forward prediction. Q (q) is a quantile at the q confidence level.

4) Calculate the CoVaR and % CoVaR of a single bank. When calculating CoVaR, it is still necessary to select the corresponding GARCH model to fit. According to the goodness of fit of each GARCH model, the most suiTable model with the highest degree of goodness-of-fit is selected to solve the CoVaR value of each bank's return series. Comparatively speaking, the mean equation of GARCH model is modified as the following form:

$$r_t^{sys} = \beta_0 + \beta_1 VaR_{q,it} + A(L)r_t + B(L)u_t \tag{2}$$

The specific formula for calculating CoVaR value of each bank's return series is as follows.

$$\mathrm{CoVaR}_{t}^{sys,i} = \hat{R}_{it} - Q\ (q)\hat{\sigma}_{it} \tag{3}$$

In which, $\hat{R}_{it}$ is the mean value of one-step forward prediction for the selected GARCH model; $\hat{\sigma}_{it}$ is the conditional variance of one-step forward prediction. Q (q) is the quantile at the level of q significance. Finally, the corresponding $\Delta CoVaR$ and % CoVaR are calculated and analyzed according to above-mentioned theory by using the calculated values of CoVaR and VaR.

## 4. Empirical Analysis

### 4.1 Selection of research objects

At present, the Basel Accord Committee, the Financial Stability Board, the International Monetary Fund and other important international institutions have introduced relevant governance measures for 28 large international financial institutions (the Bank of China is also on the list). Based on the Basel Accord, this paper uses its corresponding analysis framework to analyze the 16 large commercial banks listed in China, trying to find the relative importance of each bank, and provide the corresponding basis for the formulation of domestic macro-policy. For this reason, this paper chooses 16 domestic listed commercial banks which have available data for a long period in corresponding analysis. The data is selected from January 1, 2015 to June 30, 2017. According to the historical closing price of each stock, using the formula $R_t = 100 * \ln(P_{t+1} / P_t)$ , t = 2, 3, 4,..., 607 to solve the sequence of return of each bank, and using Excel, Eviews and other relevant software to analyze.

### 4.2 Empirical analysis

#### 4.2.1 Data descriptive analysis

Firstly, we use Eviews 6.0 software to analyze the data descriptively. The results are as follows (Table 1).

Table 1. Data Analysis Chart for 16 Listed Banks

| Bank | Average value | Maximum value | Minimum value | Standard deviation | skewness | kurtosis | JB statistical magnitude | P value |
|---|---|---|---|---|---|---|---|---|
| Bank of Beijing | -0.000000806 | 0.100541 | -0.190161 | 0.023769 | -1.872191 | 18.33774 | 6066.068 | 0.000000 |
| Industrial and Commercial Bank of China | 0.000268 | 0.100000 | -0.099029 | 0.016959 | -0.066017 | 12.37131 | 2221.594 | 0.000000 |
| Everbright Bank | -0.0000591 | 0.096998 | -0.099174 | 0.022314 | 0.290643 | 8.71412 | 834.3483 | 0.000000 |
| Huaxia Bank | -0.000329 | 0.099739 | -0.230347 | 0.023749 | -2.286185 | 24.41107 | 12123.32 | 0.000000 |
| Bank for economic construction | 0.0000456 | 0.100147 | -0.100365 | 0.019661 | -0.316428 | 10.27809 | 1349.845 | 0.000000 |
| Bank of Communications | 0.0000725 | 0.100271 | -0.100575 | 0.021668 | -0.110935 | 11.05304 | 1641.448 | 0.000000 |
| Minsheng Bank | -0.000284 | 0.099228 | -0.099902 | 0.018855 | 0.034025 | 8.801617 | 851.4032 | 0.000000 |
| Bank of Nanjing | 0.000116 | 0.100241 | -0.455257 | 0.030867 | -5.400596 | 81.34204 | 158177.7 | 0.000000 |
| Bank of Ningbo | 0.000714 | 0.100353 | -0.238417 | 0.027157 | -1.02948 | 15.1305 | 3828.862 | 0.000000 |
| Agricultural Bank | 0.0000575 | 0.099715 | -0.098985 | 0.016941 | -0.358789 | 11.92534 | 2027.800 | 0.000000 |
| Ping An Bank | -0.00061 | 0.100000 | -0.179119 | 0.022114 | -1.637443 | 18.48978 | 6339.562 | 0.000000 |
| Pudong Development Bank | -0.000138 | 0.085066 | -0.164189 | 0.020607 | -1.269096 | 14.78491 | 3675.548 | 0.000000 |
| Industrial Bank | 0.000236 | 0.099807 | -0.10006 | 0.020079 | 0.231553 | 9.83243 | 1186.092 | 0.000000 |
| China Merchants Bank | 0.000801 | 0.100255 | -0.099138 | 0.020010 | 0.397061 | 8.843124 | 879.4604 | 0.000000 |
| Bank of China | 0.0000132 | 0.100000 | -0.10978 | 0.020123 | 0.105209 | 10.75709 | 1522.982 | 0.000000 |
| CITIC Bank | -0.000137 | 0.100885 | -0.100254 | 0.024047 | 0.238645 | 7.634574 | 549.0082 | 0.000000 |

According to above analysis results, we can see that the skewness of each bank's return rate is

not 0, and the kurtosis value is greater than 3, so we reject the assumption of normal distribution. Further analysis based on JB statistics shows that the JB statistic values of each bank's return series are very large, and their probability value is 0.0000. From these properties, we can see that above data does not satisfy the assumption of normal distribution, and the return data show the characteristics of "the tail after the peak". Therefore, in following analysis, we use t distribution to replace the corresponding normal distribution.

### 4.2.2 Empirical analysis of GARCH Model

(1) The first step is the test of ARCH effect. This paper uses Eviews software to test the correlation of ARCH effect, and takes the daily return series of ICBC as an example to analyze. According to test results, the probability value P=0.0000. It is far less than 0.05, which indicates that the time series has ARCH effect. Because of the limited space, the ARCH tests of other earning efficiencies are not listed. The analysis results of each bank show that ARCH effect exists in each bank's time series. Therefore, GARCH model can be applied in corresponding analysis.

(2) The second step is the GARCH model fitting. Taking ICBC as an example, this paper uses GARCH, TARCH and EGARCH models to analyze the return series of each bank. The three test results with higher fitting powers are 2.911988, 2.997630 and 3.189778. From this, we can see that the fitting degree of EGARCH model is the best. The probability of asymmetry is 0.0094; the figure is less than 0.05, which meets the requirements. So we can use EGARCH model to analyze ICBC. Because of the limited space, this paper does not list the fitting results of other banks. The best fitting models of each time series are shown in the following VaR solution results.

(3) The third step is taking ICBC as an example to estimate the ARMA-EGARCH model. In order to verify the order of the autoregressive moving average term of each bank's earnings sequence, this paper estimates the ARMA-EGARCH model, and uses Eviews software to analyze the AR(1) -EGARCH, AR(2) -EGARCH, AR(3) -EGARCH, ARMA(1,1) -EGARCH models respectively. According to the fitting results, except for EGARCH (1, 1), the corresponding probability values in the models are greater than 0.05; the original hypothesis is rejected.

(4) The fourth step is using GARCH model to find CoVaR and% CoVaR of banks respectively. According to the fitting results of the GARCH model, the VaR of the risk value and the CoVaR value of the conditional risk value of each bank are calculated; the contribution rate of each bank system is obtained. The results are as follows.

Table 2. Median Results of VaR, CoVaR and % CoVaR Sequences of Banks

| bank | VaR | VaR estimation model | CoVaR | CoVaR estimation model | Risk spillover % CoVaR |
|---|---|---|---|---|---|
| Bank of Beijing | -3.91 | EGARCH(1,1) | -3.04 | GARCH(1,1) | 22.92 |
| Industrial and Commercial Bank of China | -2.33 | EGARCH(1,1) | -3.41 | GARCH(1,1) | 37.83 |
| Everbright Bank | -2.50 | GARCH(1,1) | -2.62 | MA(1)- GARCH(1,1) | 15.09 |
| Huaxia Bank | -2.62 | EGARCH(1,1) | -2.82 | GARCH(1,1) | 23.93 |
| Bank for economic construction | -2.55 | EGARCH(1,1) | -2.91 | MA(2)- GARCH(1,1) | 33.40 |
| Bank of Communications | -2.36 | GARCH(1,1) | -2.78 | MA(1)- GARCH(1,1) | 21.09 |
| Minsheng Bank | -3.23 | GARCH(1,1) | -3.16 | GARCH(1,1) | 30.58 |
| Bank of Nanjing | -3.37 | AR(1)-TARCH(1,1) | -3.35 | GARCH(1,1) | 1.94 |
| Bank of Ningbo | -3.51 | TARCH(1,1) | -2.50 | MA(1)- GARCH(1,1) | 7.62 |
| Agricultural Bank | -1.92 | EGARCH(1,1) | -3.00 | MA(1)- GARCH(1,1) | 25.64 |
| Ping An Bank | -1.98 | AR(1)-TARCH(1,1) | -3.16 | GARCH(1,1) | 42.87 |
| Pudong Development Bank | -3.72 | EGARCH(1,1) | -3.44 | GARCH(1,1) | 30.88 |
| Industrial Bank | -2.48 | GARCH(1,1) | -2.56 | MA(2)- GARCH(1,1) | 16.88 |
| China Merchants Bank | -3.05 | GARCH(1,1) | -2.56 | MA(1)- GARCH(1,1) | 10.03 |
| Bank of China | -2.11 | EGARCH(1,1) | -2.80 | MA(2)- GARCH(1,1) | 25.22 |
| CITIC Bank | -3.63 | GARCH(1,1) | -2.47 | MA(1)- GARCH(1,1) | 7.19 |

From the above information (Table 2), it can be clearly seen that banks with the system contribution rates greater than 30% include Ping An Bank with 42.87%, ICBC with 37.83%,

Construction Bank with 33.40%, Minsheng Bank with 30.58% and Pudong Development Bank with 30.88%; banks with the system contribution rates greater than 20% and less than 30% include Bank of Beijing with 22.92%, Huaxia Bank with 23.93%, Bank of Communications with 21.09%, Agricultural Bank with 25.64% and Bank of China with 25.22%. The contribution rates of the five big state-owned banks are very high. Therefore, in macro-supervision, we should strengthen the control of large state-owned banks. In addition, there are five large joint-stock banks whose contribution rate is very high. The effective macro-supervision and control of the corresponding large joint-stock commercial banks are also needed, so as to ensure the stability of the whole financial system.

## 5. Conclusion

Through in-depth and meticulous research in this paper, it is found that we need to measure the systemic risk of banks; our regulatory agencies should strengthen supervision to limit the impact in an accepTable range. Firstly, we should establish scientific and reasonable criteria to distinguish the importance of the banking system, and give priority to more important banks, especially for the Bank of China, which is an important financial institution in the world. For other state-owned banks and large commercial banks, we can gradually implement the supervision and improve the regulatory system step by step. Secondly, we need to standardize the risk warning system. Indicators such as capital adequacy as well as leverage and return rates should be included in the system. Pressure tests should be carried out for banks, so as to find more sensitive indicators, gradually improve the early warning system, and provide data support for supervision. Finally, while supervising, we also need to find out ways to deal with the crisis. While constantly improving our financial market, we should learn from foreign countries and learn their advanced financial systems and solutions. We can get national and international support when the bank is in crisis, so as to avoid herding effect and limit the crisis in an accepTable range. Through effective supervision measures and solutions to crisis, we can control the financial market and guarantee its sTable development.

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