Systemic Risk Spillover Effect between Banking and Insurance Industry—Based on the CoVaR Method

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Abstract. Selects the July 6, 2007 - July 4, 2016, China's insurance and banking industry index. Applies the CoVaR method, which is proposed by Adrian and Brunnermeier, to measure the direction and size of systemic risk spillover between insurance and banking industries. Considering the application of AR-GARCH model to estimate the parameters of the results is better than traditional quantile regression. Then the estimation of parameters based on AR-GARCH-M model, to calculate and analyze the risk spillover effect between banking and insurance industries in our country. According to the conclusion of the empirical research, the risk spillover effect of the banking industry to the insurance industry is larger than that the insurance industry to the banking industry. Moreover, both banking industry and insurance industry are positive risk spillover effects.

Introduction

In the domestic, Gao Guohua and Pan Yingli (2011) \cite{1} based on the dynamic CoVaR method to measure the systemic risk contribution of 14 listed banks in China, and explore the impact of bank financial characteristics on its systemic risk contribution. About the CoVaR method, Adrian and Brunnermeier (2008) \cite{2} based on the value at risk (VaR) proposed a measurement method of risk spillover between financial institutions—CoVaR (Conditional value at risk). Then Adrian and Brunnermeier(2011) \cite{3}on the definition of CoVaR clearly pointed out that CoVaR is essentially VaR. Compared with the traditional risk measurement technology VaR, CoVaR can effectively capture the risk spillover effect of financial institution to other financial institutions. From the point of view of statistical technology, VaR measures the tail risk value of financial institutions from the perspective of local equilibrium; CoVaR measures the risk of tail risk from a global perspective, and it is a kind of measurement method from the perspective of systemic risk.

Considering the extensive business dealings between China's insurance industry and banking industry, and the AR-GARCH model to estimate the parameters of result is better than that of traditional quantile regression. In this paper, to explore the size and direction of risk spillovers between different financial sectors under the mixed operation mode. The AR-GARCH-M model is used to estimate the parameters, and the CoVaR between the banking industry and insurance industry is calculated, and then use it to measure the risk spillover effect between the insurance and the banking industry.

Model Theory and Method

CoVaR Model

Adrian and Brunnermeier (2011) on the definition of CoVaR clearly pointed out that CoVaR is essentially VaR, but with the assessment of a single financial institution risk VaR method is different, CoVaR indicates that at a certain probability level, when the VaR value of a financial institution is constant, the maximum possible loss of other financial institutions.

When a financial institution i falls into financial distress and its loss is VaR\textsubscript{q} i, the expression of the financial institution to the financial system’s CoVaR is shown in Eq. 1:
Pr\(r^i \leq CoVaR^i_q \mid r^i = VaR\) = \(q\). \hfill (1) 

Where, \(r^i\) represents the yield of institution \(i\). Eq. 1 means \(CoVaR^i_q\) essentially is value at risk, which represents the risk spillover of the institution \(i\) for the financial system \(s\). Define the value of the risk spillover:

\[\Delta CoVaR^i_q = CoVaR^i_q - VaR^i_q.\] \hfill (2)

Compared with the unconditional value at risk, the CoVaR method captures the transitivity and spillage of inter-agency market risk and can reflect the fact that inter-institutional correlations increase during the crisis.

**Calculation Method of CoVaR**

Kuester et al. (2006) [4] found that using AR-GARCH to estimate the parameter results is better than the traditional quantile regression. At the same time, considering the link between income and risk, the volatility is introduced into the mean equation, and the GARCH-M model is established. The method steps are as follows:

1. **ARCH effect test**
   If the yield sequence does not have ARCH effect, it cannot be modeled by the GARCH model. The ARCH model proposed by Engle (1982) [5] can describe the time variability of expected return on financial assets - revealing the profitability of financial assets, and the time variability of financial assets variance - revealing the risk characteristics of financial assets. Generally, the ARCH (q) model can be expressed as

\[R_t = X_t b + \varepsilon_t, \varepsilon_t | \Omega_{t-1} \sim N(0, \sigma_t^2).\] \hfill (3)

\[\sigma_t^2 = \omega + a_1 \varepsilon_{t-1}^2 + a_2 \varepsilon_{t-2}^2 + \cdots + a_q \varepsilon_{t-q}^2.\] \hfill (4)

Where, \(X_t\) is the vector of the explanatory variables, \(R_t\) can be composed by Lag items or other exogenous variables, \(\varepsilon_t\) is the t-period perturbation term, which is the independent distribution of the white noise process, that is, the sequence \(\{\varepsilon_t\}\) satisfies

\[\varepsilon_t = \sigma \nu_t.\] \hfill (5)

Indicating the role of accidental factors; \(\omega > 0, a_i \geq 0 (i = 1, \cdots, q)\) is to ensure that the conditional variance strictly positive, and \(\sum_{i=1}^{q} a_i < 1\) is to ensure the ARCH process is stable. In the ARCH (q) model, the first equation is the mean equation, the change of the conditional mean of the yield sequence is described by \(E(R_t | \Omega_{t-1}) = X_t b\), and the second equation is the variance equation, and the change of the condition variance is described by \(\text{var}(\varepsilon_t | \Omega_{t-1}) = \sigma_t^2\).

In this paper, the most classical Lagrange Multiplier (LM) test, which proposed by Engle (1982), is used to test the ARCH effect. For the mean equation in the ARCH model, if the random variable \(\varepsilon_t\) is a white noise process and \(\varepsilon_t | \Omega_{t-1} \sim N(0, \sigma_t^2)\), then the variance equation (4) has \(a_1 = a_2 = \cdots = a_q = 0\) and \(\sigma_t^2 = \omega\) is a constant. If the random variable follows the ARCH procedure, then at least one of \(a_1, a_2, \cdots, a_q\) is not 0.

2. **The establishment of GARCH-M model**
   In general, the GARCH-M model can be expressed as

\[R_t = X_t b + \gamma \sigma_t^2 + \varepsilon_t, \varepsilon_t = \sigma \nu_t.\] \hfill (6)
\[ \sigma_i^2 = \omega + \sum_{t=1}^{q} \alpha_t e_{t-1}^2 + \sum_{t=1}^{h} \beta_t \sigma_{t-1}^2. \]  
(7)

Where, the coefficient \( \gamma \) is called the risk premium parameter, it means the reward paid by the risk.

(3) Calculate CoVaR

First, under the condition of a given GARCH-M model, the maximum possible loss of the banking industry \( b \)

\[ \text{VaR}_{q, b} = \hat{R}_i^b + Q(q) \hat{\sigma}_i. \]  
(8)

Where, \( \hat{R}_i^b \) and \( \hat{\sigma}_i \) are the estimation values of the yield and variance, respectively; \( Q(q) \) is the quantile corresponding to the probability level \( q \) in the standard normal distribution or standard t distribution.

Secondly, the AR-GARCH-M model is used to model the return between the insurance industry \( i \) and the banking industry \( b \). The model is shown below:

\[ R_i^t = \mu^t + a_i R_{i-1}^t + \theta R_{i}^b + b_i \varepsilon_i, \]  
(9)

\[ h_i^2 = \omega^t + \alpha_i e_{t-1}^2 + \beta_i \sigma_{t-1}^2. \]  
(10)

Where, \( R_i^t \) and \( h_i^2 \) represent the yield and variance of the insurance index, respectively.

Again, \( R_i^b \) is substituted into Eq. 8, and based on the estimation of the parameters, the mean equation becomes:

\[ \hat{R}_i = \hat{\mu}^t + \hat{a}_i R_{i-1}^t + \hat{\theta} R_{i}^b + \hat{b}_i \varepsilon_i. \]  
(11)

\[ \hat{h}_i^2 = \hat{\omega}^t + \hat{\alpha}_i e_{t-1}^2 + \hat{\beta}_i h_{t-1}^2. \]  
(12)

Therefore, when the banking industry \( b \) has the greatest possible loss of VaR, the condition value at risk \( \text{CoVaR}_{q, b} \) and the risk added value \( \Delta \text{CoVaR}_{q, b} \) of the insurance industry \( i \) can be expressed as:

\[ \text{CoVaR}_{q, b} = \hat{R}_i + Q(q) \hat{h}_i. \]  
(13)

\[ \Delta \text{CoVaR}_{q, b} = \text{CoVaR}_{q, b} - \text{VaR}_{q, i}. \]  
(14)

Finally, CoVaR and VaR as the main risk measure, calculate the banking industry on the insurance industry risk spillover rate

\[ I_{q, b} = \frac{\Delta \text{CoVaR}_{q, b}}{\text{VaR}_{q, i}} \times 100 = \frac{\text{CoVaR}_{q, b} - \text{VaR}_{q, i}}{\text{VaR}_{q, i}} \times 100. \]  
(15)

Data

In this paper, we select the banking index and insurance index of our country to conduct empirical research. Take weekly closing price of each index, and there are 508 observations for each index. The sample time span is July 6, 2007 - July 4, 2016. The above data comes from the RESSET financial database, data processing using R software (R version 3.2.3).

Use \( \frac{R_i^t}{P_{t-1}^i} = 100 \times \ln \left( \frac{P_t^i}{P_{t-1}^i} \right) \) to calculate the percentage yield of each industry index, \( P_t^i \) is the weekly closing price. Table 1 is the descriptive statistic of the yield sequence
Table 1 The descriptive statistic of the yield sequence

<table>
<thead>
<tr>
<th>Industry</th>
<th>Mean</th>
<th>Maximum</th>
<th>Maximum</th>
<th>Std.Dev</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>J-B(p)</th>
<th>ADF(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banking</td>
<td>0.023426</td>
<td>16.962787</td>
<td>-18.020045</td>
<td>4.398328</td>
<td>-0.014245</td>
<td>4.865822</td>
<td>74.94(0)</td>
<td>-16.8562(0)</td>
</tr>
<tr>
<td>Insurance</td>
<td>-0.044560</td>
<td>21.176520</td>
<td>-20.034833</td>
<td>5.165738</td>
<td>-0.050600</td>
<td>4.332660</td>
<td>38.632(0)</td>
<td>-15.7693(0)</td>
</tr>
</tbody>
</table>

It can be seen from Table 1 that the skewness coefficient of each index yields is less than 0, which shows that there is a certain left partial state, and the kurtosis coefficients are larger than 3, which shows that there is a "thick tail" feature. At the same time, the probabilities of J-B test results are 0, and the hypothesis that each yield is normal is rejected, and the probability of ADF test results of each yield series is 0, which indicates that the stock returns of each sub-market are basically stable. Figure 1 depicts the time variation of the two yield series. As can be seen from Figure 1, the two yield sequence changes are basically stable, and there may be autocorrelation between the two sequences.

![Figure 1 The time variability of yield series](image)

**Empirical**

First, the ARCH effect test, the results shown in Figure 2. The p-value of test results is less than 0.05, which shows the existence of ARCH effect.

![Figure 2 The ARCH effect test](image)

Secondly, the ARMA process is used to eliminate autocorrelation and partial autocorrelation. According to the comparison of AIC and BIC, the fitting effect of ARMA (1, 1) is the best.

Again, we do Ljung-Box test for the residual sequence, and the test result rejects the original hypothesis, that is, the conditional heteroskedasticity exists. Therefore, the GARCH-M (1, 1) model is used to overcome the conditional heteroskedasticity, so that $p = q = 1$ in Eq. 7.

Finally, the distribution of sequence $\{v_t\}$ is fitted and the results are shown in Table 2. From Table 2, the t-distribution has the best fitting effect; it is consistent with the KS test results of the fitting distribution.

<table>
<thead>
<tr>
<th>Industry</th>
<th>Normal AIC</th>
<th>std std</th>
<th>sstd</th>
<th>GED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banking</td>
<td>5.264367</td>
<td>5.214663</td>
<td>5.223557</td>
<td>5.231046</td>
</tr>
<tr>
<td>Insurance</td>
<td>5.176456</td>
<td>5.114457</td>
<td>5.125652</td>
<td>5.133244</td>
</tr>
</tbody>
</table>

Table 3 The KS test result of fit distribution

<table>
<thead>
<tr>
<th>Industry</th>
<th>std(p-value)</th>
<th>sstd(p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banking</td>
<td>0.7146</td>
<td>0.6913</td>
</tr>
<tr>
<td>Insurance</td>
<td>0.8012</td>
<td>0.7735</td>
</tr>
</tbody>
</table>
Based on the above analysis, the AR-GARCH-M model can be determined. Table 4 is the parameter estimation result. In this table, the values in parentheses are the standard deviations of the corresponding parameter estimates.

Table 4 Estimation of the parameters of the AR-GARCH-M model

<table>
<thead>
<tr>
<th>parameters</th>
<th>Banking</th>
<th>Insurance</th>
</tr>
</thead>
<tbody>
<tr>
<td>mu</td>
<td>0.321611 (0.633829)</td>
<td>0.046758 (0.356586)</td>
</tr>
<tr>
<td>ma1</td>
<td>-0.078511 (0.193431)</td>
<td>-0.298708 (0.468365)</td>
</tr>
<tr>
<td>ar1</td>
<td>0.050699 (0.197191)</td>
<td>0.256674 (0.466189)</td>
</tr>
<tr>
<td>omega</td>
<td>0.486673 (0.401157)</td>
<td>0.164356 (0.142331)</td>
</tr>
<tr>
<td>archm</td>
<td>-0.085300 (0.156459)</td>
<td>-0.041461 (0.107351)</td>
</tr>
<tr>
<td>alpha1</td>
<td>0.111178 (0.041042)</td>
<td>0.110884 (0.036972)</td>
</tr>
<tr>
<td>beta1</td>
<td>0.871944 (0.044966)</td>
<td>0.885479 (0.033068)</td>
</tr>
<tr>
<td>eta</td>
<td>9.678817 (3.401638)</td>
<td>6.031837 (1.661954)</td>
</tr>
</tbody>
</table>

According to the above parameter estimation results, combined with Eq.10-14, calculate the risk spillover effect between banking and insurance industry results in Table 5.

Table 5 Calculation result

<table>
<thead>
<tr>
<th>quantile</th>
<th>VaR\textsubscript{b}{q}</th>
<th>VaR\textsubscript{i}{q}</th>
<th>CoVaR\textsubscript{b}{q}</th>
<th>CoVaR\textsubscript{i}{q}</th>
<th>I\textsubscript{b}{q}</th>
<th>I\textsubscript{i}{q}</th>
</tr>
</thead>
<tbody>
<tr>
<td>q=0.01</td>
<td>-4.36</td>
<td>-3.31</td>
<td>-5.21</td>
<td>-5.85</td>
<td>19.5</td>
<td>76.7</td>
</tr>
<tr>
<td>q=0.05</td>
<td>-5.58</td>
<td>-4.77</td>
<td>-6.32</td>
<td>-6.73</td>
<td>13.3</td>
<td>41.1</td>
</tr>
</tbody>
</table>

Conclusion

First, from Table 5, no matter given the VaR\textsubscript{b}{q} or VaR\textsubscript{i}{q}, the smaller the quantile value, the higher the risk spillover rate. Why is there such a result? We think that there is a large risk spillover effect between the industries because of extreme risk. The range chosen in this paper includes the global financial crisis and the debt crisis in Europe.

Secondly, when the banking industry happens extreme situation, the risk spillover effect of banking on the insurance industry is significantly greater than when the insurance industry happens extreme situation, the risk spillover effect of insurance on the banking industry. When the banking sector is in crisis, its risk spillover rate for the insurance industry is as high as 76.7% at q = 0.01 and 41.1% at q = 0.05. It is the status of these two industries in China's financial industry is consistent.

Finally, there is a two-way risk spillover effect between banking and insurance. In the direction of risk spillovers, the risk spillover effect between the two industries is positive.

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References


