Systematic Risk Measurement Based on CoVaR Model

Xiaohua Duan

***Abstract*—**With the vigorous development of China's insurance industry, it is necessary to objectively measure the systematic risk of the insurance industry. In this paper, the author selects three listed insurance companies in China as the research objects, and uses the combination of model and quantile regression model to conduct empirical analysis in order to measure the spillover effect of systemic risk in insurance companies. The measurement results show that the risk spillover value of CPIC (China Pacific Insurance Company) is the largest, followed by China Life Insurance Company (China Life), and Ping'an Insurance Company of China (China Ping'an) is the last. Finally, the author puts forward the countermeasures and suggestions to prevent the systemic risk of insurance industry by combining with the results of the empirical analysis. There should be a reasonable measurement and regulatory system, especially for risk and infection between insurance companies.

Keywords—insurance industry, systemic risk, $CoVaR$.

I. INTRODUCTION

IN recent years, the insurance industry has developed rapidly in China. By the end of 2016, the total assets of insurance industry reached 15.1 trillion yuan, up 22% over the previous year. The field of insurance asset investment has been widening, increasingly involving in banking, securities, trust and other financial markets. This undoubtedly increases the systemic risk of the insurance industry. With the rising importance of the insurance industry and the expanding of business investment continuously, the systemic risk measured objectively in the insurance industry is conductive to a more comprehensive understanding of the overall economic environment, and also to an important significance to promote the healthy development of the insurance industry and better play the role of "financial stability".

After the financial crisis, the domestic and foreign scholars have carried out a great deal of deep research on systemic risk and measured systematic risk by using the $CoVaR$, MES , CCA and other models. Adrian and Brunnermeier (2014) first proposed $CoVaR$ to measure the strength of risk spillover of a single financial institution to other financial institutions, and the contribution of financial institutions to systemic risk[1]; G Girardi and AT Ergün (2013) modified the definition of $CoVaR$, defined the systemic risk of an organization as its change of $CoVaR$ in financial distress, and estimated the links between the system risk contributions and their characteristics of the four financial industry groups[2]. Derbali and Hallara (2015) used the MES model to measure the systemic risk of European financial institutions[3]; Grieb (2015) applied the liquidity risk exposure, the model of nonlinear factors, and Logistic regression model to quantify the potential impact of hedge funds on systemic risk, and the results show that the systematic risk of hedge fund is increasing[4]; Reboredo and A Ugolini (2015) used $CoVaR$ method based on to measure the systemic risk of the European sovereign debt markets after the Greek debt crisis, and found that systemic risks are similar in all countries before the crisis, and the decoupling of the debt market and the systematic risk were reduced on the whole in the European debt market after the outbreak of the crisis[5]; C Brownlees and RF Engle (2016) introduced *SRISK* to measure the system risk contribution of financial companies, and provided a ranking of institutions in the various stages of the crisis[6]. EMH Lin et al. (2016) adopted *SRISK*, MES , $CoVaR$ and other methods to study the exposure and contribution of systemic risk in financial institutions to financial market, and used the main data of Taiwan financial institutions to make an empirical research[7]; R Ali et al. (2016) utilized network analysis method to analyze the derivative data of trade repository, and revealed the importance of the participants in derivatives market to systemic risk[8]; Karimalis and Nomikos (2017) researched the contribution of systemic risk in European large banks based on the model of *Copula* and $CoVaR$ [9]. AD Clemente (2018) used a model based on extreme value theory (EVT) to analyze the contribution of a single financial institution to system risk, described the nature of the function *Copula*, and revealed the connection between a single financial institution and the financial system [10]. Domestic scholars have also studied systemic risk of the financial industry. Some scholars use $CoVaR$ of the introduction of state variables to make an empirical analysis for the systemic risk in 14 listed banks, and the results show that there is significant systemic risk spillover in the listed commercial banks of China; some use the method $CoVaR$ to measure the systemic risk of the banking industry, and put forward the corresponding suggestions for risk supervision; some adopted the method CES to measure the systematic risk of the 14 listed Chinese banks and investigate the relationship between income of non interest and systemic risk; and the others use the quantile regression model of risk

This work was supported in part by the research projects of Shaanxi Provincial Department of Education (Program No. 17JK1024) and by Natural Science Basic Research Plan in Shaanxi Province of China (Program No. 2014JM2-7135).

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spillover effect to calculate and compare the $CoVaR$ value of 15 commercial banks, and find that the banking industry will have a systemic risk spillover effect in the event of a crisis.

Systematic risk research is mainly from the perspective of crisis, the systemic risk is analyzed which is caused by bank run to bank operation. Before and after 1980s, a series of bank crises and high contagion during the crisis made the spillover effect of systemic risk widely concerned. In the field of research, the existing research is mainly concentrated in the field of banking and securities, and there is less research on systematic risk in the insurance field. In the aspect of measurement, the network analysis method based on the association of assets and liabilities among financial institutions only pays close attention to the static risk distribution between financial institutions, which has great limitations. At present, the simplified method of financial market data (such as stock price, CDS price difference, credit default swap, etc.) is the most commonly used method to measure systemic risk in financial institutions, in which the marginal expected loss (*MES*) and the conditional risk value (*CoVaR*) are the most popular and representative methods in the present simplified method. At present, the research on risk system of insurance industry mainly focuses on the analysis of infection mechanism and correlation. There are not various models and analysis methods for measuring the systematic risk of insurance industry. The innovation of this paper lies in applying conditional value risk (*CoVaR*) to the insurance field and combining the model *CoVaR* with quantile regression model. Taking the three listed insurance companies in China as samples, this author combines the *CoVaR* model and quantile regression model to measure the spillover effect and contribution level of systemic risk for Chinese listed insurance companies, so as to provide relevant countermeasures and suggestions for preventing systemic risk.

II. THE THEORETICAL BASIS

A. The CoVaR Method

As an indicator of the risk level in financial institutions, VaR is widely used because of its simplicity and transparency. However, this method only measures the risk level of individual financial institutions instead of the risk contagion and spillover degree between financial institutions or financial markets. On the basis of *VaR* in 2011, Adrian and Brunnermeier proposed the *CoVaR* method for condition risk value. This method can not only identify the risks of financial institutions, but also solve the problem of quantitative association between two financial institutions, so as to measure the risk spillover of financial institutions to other financial institutions.

VaR (Value at Risk) is generally known as "risk value" or "in risk value", which refers to the maximum possible loss of a certain financial asset (or portfolio) in a certain period of time under a certain confidence level. If a stochastic variable *R* represents the return rates of assets, VaR^q is defined as the quantile *q* of the yield *R*. Namely,

$$P(R \le VaR^q) = q \tag{1}$$

According to the definition by Adrian and Brunnermeier, $CoVaR_q^{j/i}$ stands for the risk level of a financial institution (or financial system) j when a financial institution i at a VaR_q^i risk level, that is to say, $CoVaR_q^{j/i}$ is for the quantile of q under conditional probability distribution. Namely,

$$\Pr\left(X^j \le CoVaR_q^{j|i} \mid X^i = VaR_q^i\right) = q \tag{2}$$

In which, q is for confidence interval and $CoVaR_q^{j/i}$ for the total risk value of financial institutions j including the value of unconditional risk and spillover risk.

In order to reflect more truthfully the risk spillover of financial institutions i to financial institutions (or financial systems) j, the value of spillover risks is defined as $CoVaR_q^{j/i}$, which can be expressed as:

$$\Delta CoVaR_q^{j|i} = CoVaR_q^{j|i} - VaR_q^j \tag{3}$$

Because the value VaR of unconditional risk is quite different in various financial institutions, $CoVaR_q^{j/i}$ cannot fully reflect the degree of risk spillover in financial institution *i* to financial institution *j*, Therefore, $CoVaR_q^{j/i}$ needs to be standardized, and the expression is:

$$\%CoVaR_q^{j|i} = (\Delta CoVaR_q^{j|i} / VaR_q^j) \times 100\% \tag{4}$$

$\%CoVaR_q^{j|i}$ removes the impact of the dimension and reflects more accurately the degree of risk spillover of financial institution j against the risk events of financial institution i.

B. The Quantile Regression Method

CoVaR can be measured in a variety of ways mentioned by Adrian and Brunnermeier (2011) in their article. The real financial data are usually not distributed normally, but they are distributed in "peak tail thickness". The traditional linear regression method is based on the mean value estimation, so it is invalid when the financial econometric model is estimated. The quantile regression is based on the regression of the different quantiles of the variable. The model based on the mean correlation is extended to the correlation of the tail. All the quantile regression models can be obtained, which effectively compensates the defects of the traditional linear regression and is widely used in the measurement of financial risk. Compared with the *CoVaR* of *EVT* and other estimation methods, quantile regression can reflect the level of systemic risk under different quantiles. It is simple and easy to operate, commonly used to measure *CoVaR*. The method is applied to measure *CoVaR* in this paper.

Quantile regression (Quantile Regression) was first proposed by Koenker and Bassett in 1978. It regresses the independent variable according to the conditional quantile of the dependent variable, and gets the quantile regression model. Therefore, quantile regression can fully reflect the influence of dependent variables on independent variables.

When a random variable X is established, its distribution function can be expressed as,

$$F(x) = P(X \le x) \tag{5}$$

Then, the quantile q of a random variable Y is Q(q) which is defined as a minimum value y meeting with $F(x) \ge q$. Namely,

$$Q(q) = \inf\{x : F(x) \ge q\}, 0 < q < 1 \tag{6}$$

In which, the median can be expressed as q (0.5), and the mean square error of the sample mean is the smallest for a set of random samples Y(y_1, y_2, L, y_n). That is,

$$\min \sum_{i=1}^{n} (y_i - \varepsilon)^2 \tag{7}$$

The median regression in the samples is the minimum sum of absolute errors. Namely,

$$\min \sum_{i=1}^{n} | y_i - \varepsilon | \tag{8}$$

The general sample quantile regression is to minimize the sum of the absolute value of the weighted error. That is,

$$\min \left\{ \sum_{i:y \ge \varepsilon} q | y_i - \varepsilon | + \sum_{i:y \ge \varepsilon} (1-q) | y_i - \varepsilon | \right\} \tag{9}$$

In order to investigate the risk spillover of financial institutions i to financial institutions j in case of risk, the following regression model of quantile q is established.

$$R_q^{j|i} = \alpha_q^i + \beta_q^i R_q^i \tag{10}$$

Among them, $R_q^{j|i}$ stands for the yield rate of j under the quantile q risk for financial institution i in case of risk, and R_q^i is for the yield rate of financial institutions i.

According to the definition of the risk value *VaR*, it can be obtained:

$$VaR_q^{j|i} = R_q^{j|i} \tag{11}$$

In the framework of quantile regression, *CoVaR* value can be estimated by using the coefficient evaluation value α_q^i and β_q^i:

$$CoVaR_q^{j|i} = \alpha_q^i + \beta_q^i \times VaR_q^i \tag{12}$$

III. THE EMPIRICAL ANALYSIS

A. The Selection of Samples

As an important part of the capital market, the stock price volatility of listed insurance companies has an important impact on the financial market of a country. At present, there are six A shares listed insurance companies in China (mainland). According to the listed sequence, they are: China Life (601628), China Ping'an (601318), CPIC (601601), Xinhua Insurance (601336), West Water Shares (600291) and Tianmao Group (000627). Among them, Xinhua Insurance was launched in December 16, 2011, and the West Water Shares was held by Tian'an Property Insurance in February 2016. Tianmao Group changed into an insurance industry in July 2016. The three companies had short listing time and less data, so they should be excluded. Therefore, this author selects the three longest listed and most representatives, China Life, China Ping'an and CPIC. The three insurance companies are regarded as the overall insurance system to measure the risk contribution of a single insurance company to the insurance system. Because the number of listed insurance companies is relatively small, the scope of the research is limited. In the further research, the scope of the research will be expanded, the listed data of foreign insurance companies will be introduced and the limitations of insurance market in China will be compared, so that the results of the research will be more reliable. The *CoVaR* method and quantile regression are applied to measure the risk contribution of a single insurance company to the insurance system. The specific steps are as follows.

B. The Data Selection and Process

The daily closing price data of three listed insurance companies and the insurance industry index are selected to measure the systemic risk of China's insurance industry from January 2, 2008 to December 31, 2015. The sample period covers the whole period of subprime crisis and the macroeconomic regulation and control of Chinese government. It can effectively measure the systemic risk spillover of insurance companies before and after the crisis. The data comes from the Wind Information Client. Due to the different time of the insurance stock year and the quarterly report, the Occurrence time of the major events is different, and the time of the stop is different. Based on the stepwise method, the samples are pretreated with the time of all the transaction data of the insurance shares. All analytical calculations were performed by using Eviews8.0.

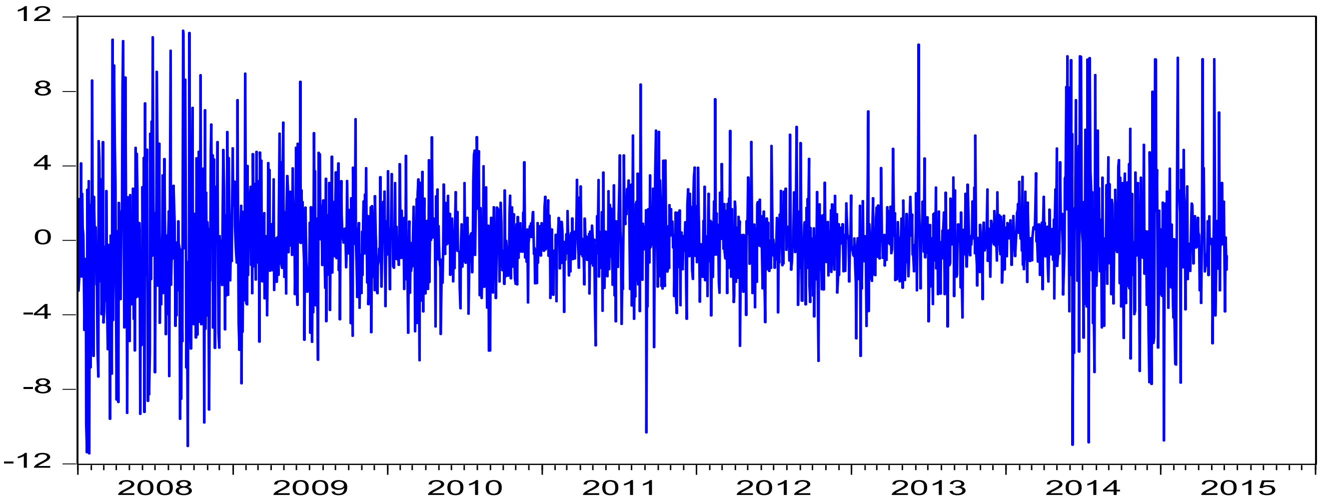

Figure 1. Time Series of Stock Return of China Life

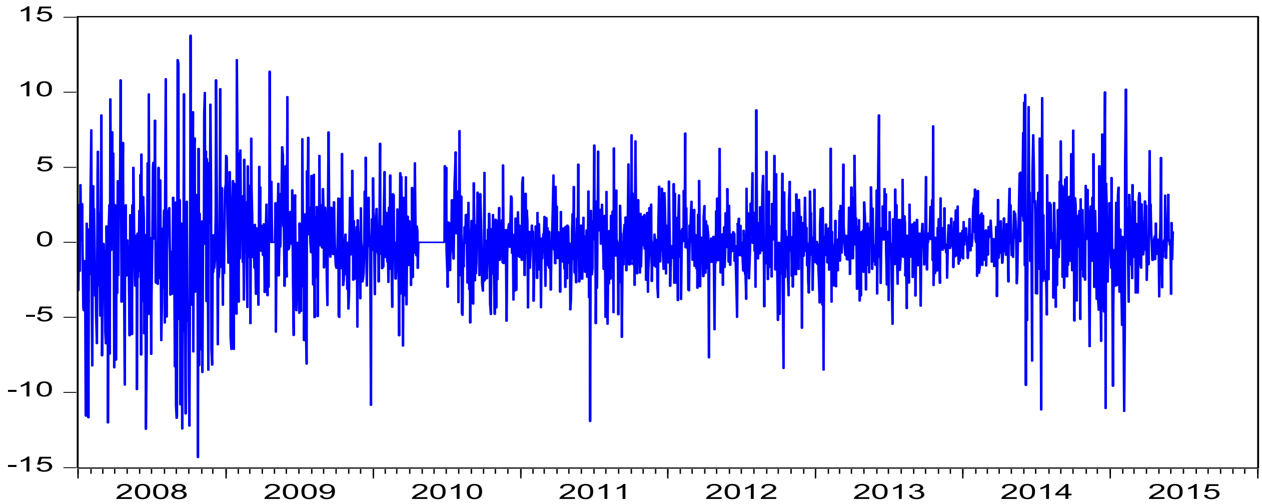

Figure 2. Time Series of Stock Return of China Ping'an

The closing price of each insurance company is converted to the form of logarithmic yield. In order to reduce the error, the calculation results are multiplied by 100. The formula is:

$$R_t = 100 \times Ln(P_t / P_{t-1}) \tag{13}$$

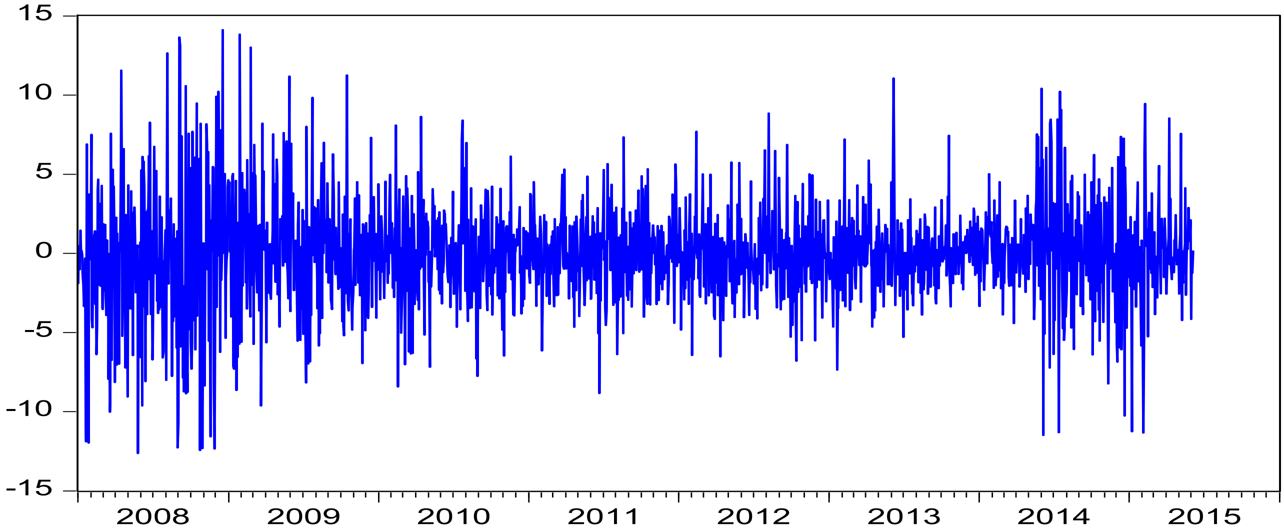

Figure 3. Time Series of Stock Return of CPIC

Among them, R_t is the stock returns for the day *t;* and P_{t-1} is the closing price of the day *t* and day *t-1* respectively.

The daily yield series of the three insurance companies and the insurance industry index are respectively descriptive

According to the above formula, the time series diagram of the yield is calculated for the three listed insurance companies in the sample interval as follows:

statistics to observe the morphology of the yield distribution and test its normality. The results are shown in Table 1.

Table 1. The Statistical Description of the Daily Yield Rate for the Three Insurance Companies

Name	Mean Value	Standard Deviation	Skewness	Kurtosis	JB Statistics
China Life	-0.0350	2.8537	0.1971	5.6045	560.2981
China Ping'an	-0.0186	3.0627	-0.1318	5.9908	727.9321
CPIC	-0.0259	3.2766	0.0604	5.1828	385.9217
Insurance Industry Index	-0.0270	2.5323	0.0524	5.5006	505.8135

From the above table, it can be seen that the skewness of yield series in insurance companies and insurance industry index is not zero, and the kurtosis is greater than 3, taking a form of "peak kurtosis and tail thickness", which is consistent with the asymmetric distribution of most financial events sequence. The statistics JB are not zero, indicating that the yield rate of insurance companies and the insurance industry index does not obey the normal distribution.

C. The Stability Test of Sample Sequence

Before the model is fitted, the stationarity test of the stock return time series of the sample insurance company is carried out. The ADF method in unit root test is used to test the stationarity of sample insurance company's stock return series. The unit root test of stock returns of all sample insurance companies is conducted. The results are shown in the table 2.

Table 2. ADF Test Results for Stock Returns Series of China Life

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-43.56003	0.0001
Test critical values:	1% level	-3.433526	
	5% level	-2.862829	
	10% level	-2.567503	

*MacKinnon (1996) one-sided p-values.

Table 3. ADF Test Results of Stock Return Series of the Three Insurance Companies

Name	ADF Test Result	Value P	Test Result
China Life	-43.5600	0.0001	Stable
China Ping'an	-43.3873	0.0000	Stable
CPIC	-44.1523	0.0001	Stable

The ADF test results from all the sample insurance companies show that the mean value of the ADF statistics of the stock return sequence of all sample insurance companies is less than the critical value under each set of confidence level.

D. The Systematic Risk Measurement of Insurance Companies

The systematic risk of insurance companies is estimated by using the method *CoVaR* and the method of quantile regression, that is, the spillover effect on the insurance industry. $q = 0.05$ is taken, namely, the risk spillover effect when the confidence is 95%. Taking China Life (abbreviated as *rs*) as an example, the quantile regression model was established at $q = 0.05$. Among them, sys means the insurance industry index, and *rs* for China life.

$$R_{0.05}^{sys|rs} = \alpha_{0.05}^{rs} + \beta_{0.05}^{rs} R_{0.05}^{rs} \tag{14}$$

$$CoVaR_{0.05}^{sys|rs} = a_{0.05}^{rs} + \beta_{0.05}^{rs} \times VaR_{0.05}^{rs} \tag{15}$$

$$\Delta CoVaR_{0.05}^{sys|rs} = CoVaR_{0.05}^{sys|rs} - VaR_{0.05}^{sys} \tag{16}$$

The quantile regression of formula (14) can be obtained $\alpha_{0.05}^{rs} = -1.2768$, $\beta_{0.05}^{rs} = 0.8227$ and the obtained parameters pass the saliency test.

The results are subdivided into quantile regression models (15), it can be obtained:

$$CoVaR_{0.05}^{sys|rs} = -1.2768 + 0.8227 VaR_{0.05}^{rs} \tag{17}$$

In order to get value $CoVaR_{0.05}^{sys|rs}$ and value $\Delta CoVaR_{0.05}^{sys|rs}$, value $VaR_{0.05}^{rs}$ and $VaR_{0.05}^{sys}$ need to be obtained, that is, 0.05 digits of the yield sequence of China Life and the insurance industry. The yield rate is descended in sequence, and value $VaR_{0.05}^{rs}$ and value $VaR_{0.05}^{zs}$ can be obtained, that is $VaR_{0.05}^{rs} = -4.5688$ and $VaR_{0.05}^{sys} = -3.9642$.

$VaR_{0.05}^{rs} = -4.5688$ is replaced into (16), $CoVaR_{0.05}^{sys|rs} = -5.0356$ can be obtained; the result is replaced into (15), $\Delta CoVaR_{0.05}^{sys|rs} = -1.0714$ can be obtained; into (3), $\%CoVaR_{q}^{sys|rs} = 27.03\%$ can be obtained.

In the same way, the Risk Spillover value of China Ping'an and CPIC at the confidence level of 95% can be obtained, as shown in Table 2, that is, the stock return sequence of each sample insurance company does not exist in the unit root. Therefore, the stock return series of sample insurance companies are stable.

Table 4. The Risk Spillover Effect of The Three Listed Insurance Companies

Name	VaR	$CoVaR$	$\Delta CoVaR$	$\%CoVaR$
China Life	-4.5688	-5.0356	-1.0714	27.03%
China Ping'an	-4.8361	-5.0057	-1.0415	26.27%
CPIC	-5.4093	-5.4527	-1.4885	37.55%

E. The Result Analysis

With comparison and calculation value VaR and value $CoVaR$ of the three insurance companies, the true risk spillover effect of the insurance company may be seriously underestimated when the risk of single insurance company is measured by using value VaR ,but $CoVaR$ is an effective and comprehensive risk measure method, which can measure the risk spillover of individual insurance company.

If value $\Delta CoVaR$ is negative, that indicates the loss in extreme circumstances when the crisis comes. In order to make the result more intuitive, $\Delta CoVaR$ is turned into absolute value, and the greater the value is, the greater the systemic risk spillover in crisis, and the greater the impact on the whole insurance market. As shown in Table 2, systemic risk spillover value $\Delta CoVaR$ of CPIC is the largest, 1.4885, followed by China Life, 1.0714, and the smallest is China Ping'an, 1.0415. The difference of systematic risk spillover is little among the three insurance companies, that is, the influence is roughly the same in economic situation, market environment and regulatory policies, but because of the scope of business, premium income growth and other factors, there is a difference in the systemic risk spillover of the three companies.

From $\%CoVaR$, the risk spillover effect can be seen directly in insurance companies to insurance industry.

IV. THE COUNTERMEASURES AND SUGGESTIONS

Based on the model $CoVaR$ and quantile regression method, this author conducts an empirical analysis of the systemic risk of the three listed insurance companies, and measures the risk spillover effect of insurance companies on the insurance system. From the results of the empirical analysis, the systemic risk spillover value of CPIC is the largest, China Life is the second, and China Ping'an is the smallest.

With the deepening of risk management, it has become an important task to strengthen the control of various risks for the safe operation of insurance companies. However, at present, there has not yet formed a unified risk monitoring measurement technology and system framework in China. There is no reasonable measurement and regulatory system, especially for risk and infection between insurance companies. The regulatory authorities not only lack the effective risk control measures for single insurance companies, but also fail to form an effective regulatory framework for the overall risk spillover effect of the insurance industry. The systemic risk and spillover of insurance companies have impacted on the stability of the insurance industry in the country. It is a must to prevent systemic risk for regulatory agencies to strictly supervise insurance companies in the aspect of microcosmic and macro system design.

Firstly, the method of optimization for risk measurement. After identifying the risks that need to be managed, the risk factors are quantified, such as monitoring VaR , and improving the foresight and scientific nature of risk assessment at the same time.

Secondly, the improvement of the risk warning system. From the two sectors of the insurance industry and non-insurance industry, potential risks need to be sorted out, information collection and analysis should be strengthened in insurance institutions, and daily monitoring and analysis system should be established. The index system and analysis framework of risk warning with internal relations are established, and risk prevention measures are formulated to prevent the occurrence of financial crisis. The supervision department should continuously improve the regulatory system, timely and effectively carry out the risk assessment of the insurance companies, and put forward the corresponding improvement measures.

Thirdly, the prevention from the risk of financial system. There is a systemic risk spillover effect in insurance company of China, which has an important impact on the safe operation of the insurance industry. It is necessary to monitor risks and prevent financial risks from a micro and macro perspective. Macro prudential supervision should be strengthened and the systemic financial crisis caused by the increase of risk spillover effect should be avoided. Differentiated management should be done according to the spillover effects of insurance companies, and more stringent supervision should be imposed on insurance companies with high risk spillovers to ensure the stability of the entire insurance industry, thereby inhibiting the spread of financial risks when there is a crisis.

Finally, speeding up the management of daily risk. Regulators should pay close attention to the systemic risk spillover effect of insurance industry, focus on tracking the operational risk of systemically important insurance companies, and strictly guard against the extreme risks of insurance companies, and then transmit to other financial sub markets. For individuals of insurance companies, they should not only focus on their own internal risks, but also concern about their spillover risks to other financial institutions, and constantly improve their risk control capabilities. Listed insurance companies should improve the way of premium investment, and optimize portfolios and minimize systemic risk spillovers under the condition of scientific judgement of macroeconomic situation.

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