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A Study on the Measurement of Systemic Financial Risk and Spillover Effect of Financial Institutions

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***Abstract*—Systemic financial risk has a great impact on the financial system and the real economy. Academia and regulators pay more and more attention to it. This paper measures systemic financial risk and spillover effect of financial institutions by using the conditional value at risk model based on Quantile regression, and uses panel regression model to analyse the influencing factors of spillover effect, and then it draws conclusions and puts forward recommendations further.**

Keywords—systemic financial risk, spillover effect, conditional value at risk

I. INTRODUCTION

Due to the demand of self-development and risk management, financial institutions are more and more closely linked. The trend of financial innovation, financial liberalization and internationalization is getting obvious. In addition, spillover effect increases the systemic financial risk. How to better measure the systemic financial risk and spillover effect of financial institutions is a problem worth studying. Adrian et al. proposed a conditional value at risk (CoVaR) method to measure the systemic financial risk of a single financial institution in the face of negative shocks. Varotto et al. has studied the relationship between bank size and systemic financial risk, and found that the level of systemic financial risk increases with the size of bank growing. Li Zheng, a domestic scholar, measured the systemic financial risk of financial institutions based on the CoVaR method. The results showed that the banking and insurance sectors were stronger than the securities sector in terms of systemic importance, while the securities sector was stronger in systemic vulnerability. Zhang Zhigang et al. found that the correlation of asset positions was the main source of systemic financial risk in banking industry, and the proportion of interbank assets to total assets, macroeconomic factors (GDP growth rate, inflation rate, unemployment rate) and industry factors (competition level, development status) had significant impact on systemic financial risk. At present, there are many studies on systemic financial risk of banks, insurers and securities. Most of the research methods adopt VaR, CoVaR, MES, SES, or balance sheet-related methods, such as network analysis, index methods, etc. In this paper, the measurement of systemic financial risk includes not only banks, insurers and securities, but also diversified financial institutions. At the same time, the influencing factors of spillover effect are studied.

II. THEORETICAL BASIS

The theoretical basis of this paper is financial asset price fluctuation and information asymmetry. The theory of financial asset price fluctuation believes that excessive fluctuation in asset prices will increase systemic financial risk. Fluctuations are mainly reflected in stock prices, interest rates, exchange rates, etc. First of all, the stock price fluctuate, which is an important reason for stock market investors to enter the stock market. The public's good expectation will cause a large number of investors to buy the stock, which in turn will drive the stock price to climb. On the contrary, there will be panic selling. Secondly, if interest rates fluctuate, depositors, banks and lenders will be at risk. The rise in interest rates will benefit depositors, and lenders will have to pay more. On the contrary, it will benefit the lenders. In the deposit and loan business, the risk of banks is mainly from the deposit and loan exposure. Finally, the volatility of the exchange rate may be risky whether it is a fixed exchange rate system or a floating exchange rate system. In addition, exchange rate fluctuations are almost inevitable. The information asymmetry theory explains the causes of systemic financial risk from the perspective of micro-behavior. Banks and other financial institutions as intermediaries have reduced the problems caused by information asymmetry to some extent. Firstly, financial institutions can screen different lenders and decide whether to issue loans or price loans according to the lenders' risk, which can reduce the risk of adverse selection of lenders. In addition, compared with the decentralized lenders, financial institutions have more advantages in monitoring and restricting the behavior of lenders, thereby reducing moral hazard. However, the effect of financial institutions on solving information asymmetry will also be limited. On the one hand, the reason why it can attract deposits is because of the good expectations of depositors. Only when depositors' confidence or expectation of financial institutions remain unchanged or positive, there will be no large depositors to withdraw deposits, so financial institutions can convert this part of the deposit funds into creditors and profit from them. On another hand, the organization's supervision and influence on lenders is not always efficient and low-cost. When depositors anticipate changes or lose confidence in financial institutions such as banks, serious runs will occur. The liquidity of banks and other institutions will be

problematic, and the lack of liquidity will further spread to other financial institutions or the real economy, thus creating risks. At the same time, financial institutions' post-lending supervision of lenders cannot guarantee high efficiency and low cost, which is also the seeds for the risk of financial institutions.

III. EMPIRICAL ANALYSIS

A. Index Selection and Data Sources

In this paper, for the measurement of systemic financial risks and spillover effect, according to the secondary industry classification of Shenyin Wanguo, 32 listed financial institutions are selected as research objects, including 14 banking institutions, 3 insurance institutions, 8 securities institutions and 7 diversified financial institutions. The 32 institutions are: 01 Pingan Bank 02 Bank of Ningbo 03 SPD Bank 04 Huaxia Bank 05 China Minsheng Bank 06 China Merchants Bank 07 Bank of Nanjing 08 Industrial Bank 09 Bank of Beijing 10 Bank of Communications 11 ICBC 12 China Construction Bank 13 Bank of China 14 China CITIC Bank 15 Pingan Insurance 16 CPIC 17 China Life Insurance 18 Pacific Securities 19 CITIC Securities 20 Southwest Securities 21 Sinolink Securities 22 Changjiang Securities 23 Guoyuan Securities 24 Northeast Securities 25 Haitong Securities 26 Bohai Leasing, 27 Minsheng Holdings, 28 Shaanxi International Trust 29 CNPC Capital 30 JD Capital 31 Aijian Group 32 Anxin Trust. The sample selection interval is from January 1, 2008 to December 31, 2018 (2677 trading days). Variables are shown in Table 1.

TABLE I. EMPIRICAL VARIABLES FOR SYSTEMIC FINANCIAL RISK

Variable types	Variable symbol	Variable name	Definition
Dependent variable	R_t^i	Return on Financial Institutions	Subtraction of logarithmic closing price of stocks
	R_t^{sys}	Financial industry overall rate of return	Financial institutions market capitalization weighted average rate of return
State variables	mr	Return on stock market	Shanghai and Shenzhen 300 Index Yield Rate
	mv	Stock market volatility	GARCH volatility of the Shanghai and Shenzhen 300 Index
	teds	Short-term liquidity spread	Shibor (1 year)-3 month government bond yield to maturity
	terms	Term spread	10 year government bond yield to maturity – 3 month government bond yield to maturity
Independent variable	R_t^i	Return on Financial Institutions	Subtraction of logarithmic closing price of stocks

This paper also empirically analyses the influencing factors of systemic financial risk spillover effects. The sample selection interval is 2008-2018, which contains panel data of 32 financial institutions. The data comes from the financial institution's annual report and the Wind database. Variables are shown in Table 2.

B. Model Set

The systemic financial risk of a financial institution is defined as VaR, the conditional value at risk of financial industry to a financial institution is CoVaR, and the systemic financial risk spillover effect of a financial institution is △ CoVaR. The following models are established for parameter estimation.

$$R_t^i = \alpha_i + \beta_i M_{t-1} + \varepsilon_t^i \tag{1}$$

$$R_t^{sys} = \alpha_{sys/i} + \beta_{sys/i} M_{t-1} + \gamma_{sys/i} R_t^i + \varepsilon_t^{sys/i} \tag{2}$$

The calculation of the systemic financial risk of financial institutions adopts the following formulas. Among them, the difference of the quantile τ represents different risk environments. In this paper, 0.01 and 0.05 indicate that the financial institutions are at risk, and the risk environment represented by 0.01 is more extreme. Taking 0.5 indicates that the financial institutions are in a normal state.

$$VaR_t^i(\tau) = \hat{\alpha}_\tau^i + \hat{\beta}_\tau^i M_{t-1} \tag{3}$$

$$CoVaR_t^{sys/i}(\tau) = \hat{\alpha}_{sys/i} + \hat{\beta}_{sys/i} M_{t-1} + \hat{\gamma}_{sys/i} VaR_t^i(\tau) \tag{4}$$

$$\Delta CoVaR_t^{sys/i}(\tau) = CoVaR_t^{sys/i}(\tau_1) - CoVaR_t^{sys/i}(\tau_2) \tag{5}$$

TABLE II. EMPIRICAL VARIABLES FOR THE IMPACT OF SPILLOVER EFFECT

Variable types	Variable symbol	Variable name	Definition
Dependent variable	$\Delta CoVaR$	Systematic financial risk spillover effects of financial institutions	Calculated in the previous paragraph
Independent variable	assets	assets of financial institutions	Logarithmic the total assets of financial institutions at the end of the year
	leverage	leverage of financial institutions	The asset-liability ratio of financial institutions at the end of the year
	mismatch	Maturity mismatch index of financial institutions	(current liabilities - cash) / non-current assets
Control variable	mr	Return on stock market	Shanghai and Shenzhen 300 Index Yield Rate
	mv	Stock market volatility	GARCH volatility of the Shanghai and Shenzhen 300 Index
	teds	Short-term liquidity spread	Shibor (1 year)-3 month government bond yield to maturity
	terms	Term spread	10 year government bond yield to maturity – 3 month government bond yield to maturity

C. Measurement of Systemic Financial Risk and Spillover Effect

- Stationarity test. In this paper, the ADF test method is used to check the stationarity of each sequence. The lag order is chosen by the AIC criterion (Akaike Information Criterion), and the regression form is tested to contain constant terms. The test results show that the ADF test of all the yield series rejects the null hypothesis at the 1% significance level, indicating that the yield sequence is stable and the model can be established.
- Metrics for VaR and △CoVaR. Using the above formulas, this paper calculates the systemic financial risk and spillover effect of 32 financial institutions. Due to the limitation of space, this paper uses the arithmetic mean method to average the risk levels of different financial sectors. The average risk level can be found in Table 3.

TABLE III. MEASUREMENT RESULTS OF VAR AND △COVAR

institution	VaR		△CoVaR	
	0.01	0.05	0.01	0.05
Bank	-3.171	-1.942	-2.668	-1.541
Insurance	-3.736	-2.291	-2.832	-1.553
Security	-4.603	-2.744	-1.961	-1.191
Diversified Financial	-5.792	-3.569	-1.845	-1.031
Full Samples	-4.155	-2.531	-2.327	-1.343

The level of systemic financial risk varies widely among different financial institutions. From the perspective of the average risk level of the industry, the banking institutions have the lowest risk, followed by insurance institutions. The risks of securities and diversified financial institutions are greater than the average level of financial institutions. The VaR values at the quantile of 0.01 were significantly smaller than that at the quantile of 0.05. It indicates that the financial institutions were significantly more risky when they were in more extreme conditions. As banking institutions, the large-scale banks that are state-owned have less systemic financial risk, such as Bank of China, ICBC, Bank of Communications, China Construction Bank. Among securities institutions, CITIC Securities has less risk, while Sinolink Securities higher risk. Diversified financial institutions have greater systemic financial risk. The value of JD Capital 's VaR is as 2.52 times as Bank of China.

The systemic financial risk spillover effect of different financial institutions varies widely. From the perspective of the average spillover effect of the industry, insurance institutions are the largest, followed by banking institutions. Securities and diversified financial institutions are small and less than the average level of financial institutions. The △CoVaR values at the quantile of 0.01 are significantly smaller than that at the quantile of 0.05, indicating that when financial institutions in an increasingly extreme risk environment, the risk spillover effect is greater. The large-scale banks which are state-owned have less spillover effect, such as Bank of China, Bank of Communications, etc. As for insurance institutions, Pingan Insurance, CPIC, China Life Insurance, their spillover effects are successively declining. But the spillover effects of the three institutions are at the forefront of all sample financial institutions. Among securities institutions, the risk spillover effects of Southwest Securities and Guoyuan Securities are quite different. The spillover effects of Anxin Trust, Aijian Group and Shaanxi International Trust are equivalent to the level of Guoyuan Securities and CITIC Securities in securities institutions.

In addition, this paper calculates the VaR and △CoVaR of each financial institution during 2008 to 2018 at the 0.05 quantile. Because the sample data is more, the arithmetic mean is also taken. It found that the systemic financial risk and spillover effects of financial institutions in China are at a high level in 2008, while securities institutions have the largest systemic financial risks and insurance institutions the largest spillover effect. After 2008, the risk and spillover effect of financial institutions began to decline. After a slight increase in 2015, it gradually stabilized.

D. An Empirical Analysis of the Influencing Factors of Spillover Effect

According to the classification of financial institutions mentioned above, this paper conducts a stepwise regression analysis on the asset size, leverage ratio and maturity mismatch index and systemic financial risk spillover effect of banking institutions, insurance institutions, securities institutions and diversified financial institutions, and finally all three independent variables are subjected to regression analysis.

- Stationarity test. In this paper, the IPS test method without trend items is used to test whether the panel data has unit roots. The results are shown in Table 4. It can be seen from the table 4 that the P value of IPS statistic rejects the null hypothesis that there is a panel unit root, indicating that the data is stable, and regression analysis can be performed.
- Empirical analysis. This paper establishes four individual fixed effect models. The results of empirical analysis can be seen in Table 5 and Table 6.

TABLE IV. IPS TEST RESULTS

Variable	IPS	P	Variable	IPS	P
△CoVaR	-10.7639	0.0000	mr	-6.7212	0.0000
assets	-10.2530	0.0000	mv	-8.8009	0.0000
leverage	-5.5251	0.0000	teds	-7.5502	0.0000
mismatch	-7.9071	0.0000	terms	-3.1666	0.0008

TABLE V. EMPIRICAL RESULTS OF SPILLOVER EFFECT (1)

△CoVaR	Bank			
	(1)	(2)	(3)	(4)
assets	0.298***			0.322***
leverage		-0.071***		-0.083***
mismatch			0.181	-0.495**
adjusted R^2	0.800	0.772	0.739	0.842
△CoVaR	**Insurance**			
	(1)	(2)	(3)	(4)
assets	0.347***			0.334***
leverage		-0.024		-0.0246
mismatch			-0.020	-0.0151*
adjusted R^2	0.897	0.797	0.810	0.915

TABLE VI. EMPIRICAL RESULTS OF SPILLOVER EFFECT (2)

△CoVaR	Security			
	(1)	(2)	(3)	(4)
assets	0.040***			0.036**
leverage		0.0018		0.0004
mismatch			0.0003*	0.0002
adjusted R^2	0.751	0.725	0.730	0.761
△CoVaR	**Diversified financial**			
	(1)	(2)	(3)	(4)
assets	0.0420***			0.0458***
leverage		-0.002*		-0.0007
mismatch			-1.43e-05	7.95e-05
adjusted R^2	0.743	0.681	0.679	0.754

According to the empirical results, asset size is an important factor affecting spillover effect of financial institutions. It has a significant impact on the risk spillover of all financial institutions, including banks, insurance, securities, and diversified financial institutions, and the coefficient are positive values, indicating that the larger the asset size of a financial institution, the larger the ΔCoVaR is, that is, the less risk spillover. At the same time, the asset size of banks and insurance institutions has a greater impact on risk spillover than securities and diversified financial institutions. In addition, for banking institutions, leverage ratio and maturity mismatch also have a significant impact on their risk spillover. As the coefficient value is negative, it shows that the higher the leverage ratio of the bank, the greater the risk spillover effect. It is the same as the maturity mismatch. For insurance institutions, the coefficient of leverage ratio is not significant, but the coefficient of maturity mismatch is significant at the level of 0.1. What's more, the coefficient is negative, it indicates that the insurance institution's maturity mismatch will increase its risk spillover effect. Similarly, for securities institutions, when the independent variable of regression analysis only has a maturity mismatch index, it has a significant impact on the systemic financial risk spillover effect, but when the asset size and leverage ratio added to the model, only the impact of asset size is significant. The leverage ratio of diversified financial institutions is similar. When the independent variable has only leverage ratio, it has a significant impact on the systemic financial risk spillover effect. However, when the asset size and maturity mismatch index added to the model, the influence coefficient of the leverage ratio decreases and changes no significant.

IV. CONCLUSION AND RECOMMENDATION

This paper empirically analyses the systemic financial risk of financial institutions and their spillover effect, furthermore the influencing factors of spillover effect. The conclusion is drawn that the overall risk of the financial industry is in a relatively stable range, and the possibility of systemic financial risk is small. Bank institutions have the least risk, but their spillover effect is large. Securities and diversified financial institutions have greater risk which is greater than the industry average, but their risk spillover are smaller than insurance and banking institutions. The larger the asset size of a financial institution, the smaller its spillover effect, and the impact of the asset size of banks and insurance institutions on risk spillover is greater than that of securities and diversified financial institutions. In addition, leverage ratio and maturity mismatch have a significant impact. The maturity mismatch of insurance and securities institutions will increase their risk spillover to a certain extent. The leverage ratio of diversified financial institutions will also have an impact on their systemic financial risk spillover.

At this stage, although the possibility of a financial crisis in China is very small, it can be seen that with the continuous transformation of China's economic structure and increasing uncertainty of the external economic environment, many risk points are gradually exposed. On the one hand, speed up the improvement of China's macro-prudential management framework, supervise systemic financial risks from a macro perspective, not only for individual institutions, but also for the complex links between the real economy and financial institutions, and gradually explore a system suitable for China's actual situation. The financial risk supervision system is of great significance for effectively monitoring and preventing China's systemic financial risk. On the other hand, strengthen the supervision and management of systemically important financial institutions, especially for large insurance and banking institutions, while continuing to pay attention to the risk of securities institutions and diversified financial institutions. Although securities and diversified financial institutions have less risk spillover effects than banking and insurance institutions, they are growing at a faster rate and their impact on financial markets is also increasing.

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