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Research on the Risk Spillover Effect Between Financial Markets in China: Based on Dynamic CoES Model

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Abstract
This paper put forward a dynamic ΔCoES model to study the time-varying risk spillover between China's stock market, exchange market and bond market from January 2007 to January 2017, based on the ΔCoVaR model proposed by Adrian and Brunnermeier (2016). The results show that the risk spillover of financial market in China is time-varying and asymmetric. During the financial crisis, the level of risk spillover between financial markets in China is higher than the average of spillover in the whole sample. During the "stock crash" of 2015, the risk spillover level of the stock market to the bond market and the foreign exchange market is higher than the average risk spillover level of the sample and the risk spillover level from the bond market to the stock market and the foreign exchange market is also higher than the average risk spillover level of the sample. After the exchange rate reform on August 11th of 2015, the risk spillover from exchange market to stock market and the bond market showed an upward trend, and in 2016, it was higher than that of the previous 8 years.

Key words: CoES model; CoVaR model; Risk spillovers; Financial markets

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INTRODUCTION

The global financial markets undertake the social redistribution of resources and risk. In the background of world economic globalization and international financial integration development, the global financial markets are more closely linked. Combined with the current situation of mixed operation of China's financial industry and the continuous innovation of financial products, the relationship between China's financial markets is becoming more and more complex. Since the international financial crisis from 2007 to 2009, the supervision authorities in different countries started to attach great importance to the macro prudential supervision. When focusing on the individual risks of financial institutions, they paid special attentions to the supervisions on the cross-institution, cross-industry, cross-market or even the cross-border financial systemic risk. While the "money shortage" event happened to Chinese banking industry in 2013 and the "stock crash" event in Chinese stock market in 2015 warned the Chinese supervision authorities, the academic circle and the industry to pay special attentions to the macro prudential supervision. On December 29, 2015, the Central Bank of China declared to upgrade the current "dynamic adjustment of differential preparation fund" and "consensual loan management mechanism" to "macro prudential assessment, briefed as MPA" from the year 2016. MPA holds that the stability of single financial institution or the financial market doesn't mean the stability of the entire financial system, so it is particularly important to study on the relationship between the financial institutions and financial markets, and this association often shown as the risk spillover, and exists not only between international the financial markets but also between the domestic financial markets such as stock market, bond market and exchange market.

1. LITERATURE REVIEW

The research on risk spillover effect in financial markets can be divided into two main categories according to the methods used to measure spillover. The first category is to measure risk the risk spillover level between two markets by examining variance fluctuation, such as GARCH model and SV model. The second category is to measure risk spillover level between financial markets based on risk metrics, such as VaR, CAViaR and CoVaR models. Kanas (2000) investigates the risk spillover level by examining variance fluctuation earlier, by establishing the EGARCH model to analyze the level of risk spillover between exchange markets and stock markets in the six industrialized countries of United States, Britain, Japan, Germany, France and Canada. Kanas (2000) finds that with the exception of Germany, the other five countries have spillover from the stock market to exchange market, and all the six countries have no risk spillover from exchange market to stock market. Caporale, Pittis and Spagnolo (2002) establish a four-element GARCH model to study the risk spillover between the East Asian stock markets and the exchange markets, and find that there is a bidirectional spillover between stock markets and the exchange markets of Indonesia and Thailand, and there is unidirectional spillover from the stock markets to exchange markets between Japan and South Korea. Morales (2008) conducts a study of Latin American countries and European economies and markets, and finds that there is only unidirectional risk spillover from the stock markets to the exchange markets. Dean and Faff (2010) establish a two-element GARCH model to study the risk spillover of the Australian stock market and bond market, and find that there exists the risk spillover from the bond market to stock market, but it is not applicable inversely.

There are many literatures on risk spillover between China's financial markets. Zhang and Zhang (2008) combine the SV model with independent component analysis (ICA) to study the spillover of multiple financial markets to a financial market. Lu and Hao (2009) set up a multivariate GARCH model to study the risk spillover level of the Chinese stock market and bond market, find that the risk spillover of the Chinese stock market and bond market is asymmetry and time-varying. Chen, Xu and Chen (2009) establish the MGARCH model, to study the risk spillover of the exchange market and the stock market in time, and find that there are bidirectional spillover effects between the fluctuation of Chinese stock market and the fluctuation of exchange market in the short term. But in the long run, there are only spillover effect from exchange market to stock market. Li, Ma and Wang (2010) establish a four-element VAR-GARCH-BEKK model to study the risk spillover of China's stock market, bond market, exchange market and currency markets, and find that there are significant bidirectional spillover between financial markets. Xiong, Wen and Xing (2015) combine the multivariate BEKK-GARCH model with the wavelet analysis to study the volatility spillover between the Chinese stock market and the exchange market, and find that the risk spillover between the stock and the exchange market is not constant and there are different risk spillover under different trading cycles. Tang (2016) use the VAR-DCC-MVGARCH-BEKK model to study the dynamic correlation between onshore and offshore RMB exchange rate market, the results show that the offshore RMB forward exchange rate market has obvious spillover effect on the onshore and forwards exchange rate market, conversely is not.

In academic circle, the GARCH and SV models are often used to examine the spillover between different markets. However, Chinese scholar Zhang (2006) points out that the increase of variance can't mean the increase of risk, while the GARCH and SV models are indirect measures of variance, so the risk spillover effect is often inconsistent with reality. With the change of the economic environment, the risk spillover between different markets is changing all the time. However, two models mostly use single index to describe the whole risk cycle of the whole economic cycle, and it is difficult to accurately describe the time-varying characteristics of the financial markets.

The other method is used to measure the level of risk spillover between financial markets based on risk measures, such as VaR, CAViaR and CoVaR. Since Baumol (1963) proposed Value at Risk (VaR) model, VaR has been widely used, such as Hong, Cheng, Liu et al. (2004) combine VaR and risk-Granger causality to measure spillover effect between China securities market A shares, B shares and H shares, and between the Chinese stock market and the rest of the world's stock markets. However, since VaR itself can't measure risk spillovers between different financial markets, Engle and Manganelli (2004) propose the Conditional Autoregressive Value at Risk (CAViaR) model to study the risk spillover between different financial markets by quantile regression. Adrian and Brunnermeier (2016) put forward the ΔCoVaR to measure the extreme risk spillover between two financial markets. When there is a high risk pressure in a particular financial market, the value at risk of another financial market is $CoVaR^a$, and when the specific financial market is under normal risk pressure, the value at risk of another financial market is $CoVaR^b$, then the difference between the above two CoVaR is ΔCoVaR. Adrian and Brunnermeier (2016) also gives a dynamic ΔCoVaR model to measure the time-varying risk spillover between markets, but Tarashev (2011) thinks that the problem of method ΔCoVaR is that it does not have additive, that is, the system contribution of a single financial institution is not equal to the total measure of systemic risk. But there are still many scholars have applied the ΔCoVaR method in the study about risk spillover effect, for example, Reboredo and Ugolini (2015) establish Copula-CoVaR model by combining CoVaR with Copula function to study the systemic risk of each country before and after the euro debt crisis. Liu , Duan and Xie (2011) combine the EVT-Copula and CoVaR model to build an EVT-Copula-CoVaR model to study the risk spillover from US stock market to UK, France, Japan, Hong Kong and Chinese stock markets. Wang and Hu (2012) study the risk spillover between the stock markets among China, US and Hong Kong by the CoVaR and time-varying Copula function. The CoVaR model can not only measure the risk spillover in a single financial market, but also measure the systemic risk of financial markets or institutions. Such as Bai and Shi (2014) and Chen, Wang and Xu (2015) and so on.

Dynamic ΔCoVaR model, which compensates the defect of GRACH and SV model in measuring risk spillover. At the same confidence level, the difference in the value at risk of market B caused by the different state of market A is defined as market a risk spillover from market A to market B. Essentially, the CoVaR of market B conditional on the market A is only a percentage of the risk, regardless of the size of the loss. CoVaR is not possible to reflect the extreme losses of the market B conditional on the risk status of market A. But the huge losses is more likely to cause financial pressure than the moderate losses, such as bankruptcy, so the extreme tail characteristic of the risk is particularly important for the entire financial market.

Therefore, this paper introduces the expected loss (ES) into the direction of risk spillover effect, according on the static CoES definition proposed by Adrian and Brunnermeier (2016): When market A is in high-risk, market B's expected loss is $CoES^a$, when market A is under normal risk, market B's expected loss is $CoES^b$, the difference between the two CoES can be used to measure the risk spillover from market A to market B. The article develops and applies a dynamic CoES model to measure the Risk Spillover between financial markets and systemic risk spillover of financial institutions.

Dynamic CoES model can avoid using variance to measure risk spillover, considering the tail risk of financial market. So the paper uses this model to measure the time-varying risk spillover effect of Chinese stock market, bond market and exchange market in different financial environment and macro policy conditions from January 4, 2007 to January 17, 2017. The results show that the risk spillover from China's bond market to stock market and exchange market is much smaller than that from the stock market and the exchange market to bond market. During the financial crisis, the risk spillover level between China's financial markets was higher than the average overflow level in the sample interval. In 2015, the risk spillover level of China's bond market to stock market and foreign exchange market was higher than that in the sample. During the "stock crash" of 2015, the risk spillover level of the stock market to the bond market and the exchange rate was higher than that in the sample. After the "exchange reform" on August 11, 2015, the risk spillover level from the exchange market to the stock market and the bond market dramatically increased. After the RMB formally joined the SDR, the risk of spillover from the exchange market to the stock market and bond market increased significantly. And the mean value of the risk spillover from exchange market to stock market and bond market in 2016 has been higher than that of the previous 8 years.

The article is arranged as follows: The first part, the literature review; the second part, the method and the model; the third part, the empirical study of the time-varying risk spillover between Chinese stock market, bond market and exchange market; the fourth part, the basic conclusion of the article.

2. MODEL INTRODUCTION

ΔCoES is an improvement based on ΔCoVaR. CoVaR: (a) System-ΔCoVaR is able to measure systemic risk contribution of single financial institution i to financial system s through calculating $\Delta CoVaR^{s|i}$; (b) exposure-ΔCoVaR similar to pressure test used to measure the assets exposed of single financial institution i when financial system s is under risk pressure; (c) Network-ΔCoVaR can be applied to research on risk spillover effect of the entire network by calculating $\Delta CoVaR^{j|i}$, for instance, when institution i at risk pressure, the changed CoVaR of institution j conditional on institution i's risk pressure; (d) the ΔCoVaR can be further promoted in other methods with excellent properties, such as conditional expected loss (CoES). However, there are no papers have been adopted ΔCoES to measure the risk spillover and systemic risk. Based on the static ΔCoES model, this paper proposes a dynamic ΔCoES model that can be used to measure the dynamic risk spillover between financial markets, and capture the impact on expected losses of financial market when the entire financial system is under risk pressure or the impact on expected losses of financial system when the special financial market is under risk pressure.

2.1 Static CoES Model

CoES is the expected loss (ES) of the financial market j when the financial market s is under extreme risk pressures:

$$\mathrm{CoES}_q^{j|s} = E(X^j \le \mathrm{CoVaR}_q^{j|C(X^s)} \mid C(X^s)) \cdot \tag{1}$$

ΔCoES is the difference between the CoES of financial market *j* conditional on the financial market *s* is under extreme risk pressure and the CoES of financial market *j* conditional on the financial market *s* is under the normal risk pressure.

$$\begin{aligned}\Delta \mathrm{CoES}_q^{j|s} &= \mathrm{CoES}_q^{j|x^s=\mathrm{VaR}_q^s} - \mathrm{CoES}_q^{j|x^s=\mathrm{VaR}_{0.5}^s} \\ &= E(X^j \le \mathrm{CoVaR}_q^{j|C(X^s)} \mid C(X^s)) - E(X^j \le \mathrm{CoVaR}_{0.5}^{j|C(X^s)} \mid C(X^s))\end{aligned} \tag{2}$$

Where, the CoVaR is defined as

$$Pr(X^j \le \mathrm{CoVaR}_q^{j|C(X^i)} \mid C(X^i)) = q \ . \tag{3}$$

In detail, the CoVaR refers to VaR of market *j* when the financial market *s* is under risk pressure; $C(X^i)$ refers to state of financial market *s* under extreme risk *X*. The risk spillover from financial market *s* to market *j* is:

$$\Delta \mathrm{CoVaR}_q^{j|s} = \mathrm{CoVaR}_q^{j|x^s=\mathrm{VaR}_q^s} - \mathrm{CoVaR}_q^{j|x^s=\mathrm{VaR}_{0.}^s}. \tag{4}$$

It means the risk spillover from financial market *s* to market *j* refers to VaR difference of market *j* conditional on that the financial market *s* is under *q* quantile and 0.5 quantile. Since we focus on the loss which is corresponding to the left-tail distribution of random variables, the value of *q* is generally small, and it is 0.1, 0.05, or 0.01 in literatures. However, one needs to notice that CoVaR is not the consistent risk measurement as a result of its failure to meet subadditivity. But subadditivity is a property which must be met by any risk measure. It describes the risk diversification principle in modern investment portfolio theory and which is a basic condition for portfolio decision making.

2.2 Dynamic CoES Model

Considering the time dimension and spatial dimension of risk, this paper further builds dynamic CoES model based on dynamic VaR model where the data generation process of X^s and X^j is set as follows:

$$X_t^s = \alpha^s + \gamma^s M_{t-1} + \varepsilon_t^s \ , \tag{5}$$

$$X_t^j = \alpha^{j|s} + \beta^{j|s} X_t^s + \gamma^{j|s} M_{t-1} + \varepsilon_t^{j|s}. \tag{6}$$

Here, the M_{t-1} refers to the lagged state variable vector. The quantile regression coefficients of (5) and (6) are obtained by quantile regression, and then the time-varying VaR and CoVaR are obtained:

$$\mathrm{VaR}_{q,t}^s = \hat{\alpha}_q^s + \hat{\gamma}_q^s M_t , \tag{7}$$

$$\mathrm{CoVaR}_{q,t}^{j|s} = \hat{\alpha}_q^{j|s} + \hat{\beta}_q^{j|s} \mathrm{VaR}_{q,t}^s + \hat{\gamma}_q^{j|s} M_t. \tag{8}$$

The time-varying ΔCoES can be obtained according to Formulas (7) and (8):

$$\begin{aligned}\Delta \mathrm{CoES}_{q,t}^{j|s} &= \mathrm{CoES}_{q,t}^{j|x^s=\mathrm{VaR}_q^s} - \mathrm{CoES}_{0.5,t}^{j|x^s=\mathrm{VaR}_{0.5}^s} \\ &= E(\hat{X}^j \le \hat{\alpha}_q^{j|s} + \hat{\beta}_q^{j|s} \mathrm{VaR}_{q,t}^s + \hat{\gamma}_q^{j|s} M_{t-1}) - E(\hat{X}^j \le \hat{\alpha}_q^{j|s} + \hat{\beta}_q^{j|s} \mathrm{VaR}_{0.5,t}^s + \hat{\gamma}_q^{j|s} M_{t-1}) .\end{aligned} \tag{9}$$

2.3 ΔCoES Model Expansion

Firstly, Exposure-$\Delta \mathrm{CoES}^{j|s}$ is able to measure the risk spillover of the financial system s to the single financial institution *j* or the assets exposed of single financial institution *j* when financial system *s* is under risk pressure; secondly, System-$\Delta \mathrm{CoES}^{s|i}$ is able to measure the risk spillover or the contribution of a single financial institution *i* to its financial system *s*.

3. EMPIRICAL ANALYSIS

3.1 Data Selection and Description

This paper selects the Shanghai Composite Index, the Chinese bond index and the nominal exchange rate of US dollar against RMB from 4 to 17 January 2007 to represent the stock market, the bond market and the exchange market respectively. Excluding the data of inconsistent business dates, 2,337 sets of valid data are obtained by adopting formula $r_t = 100 \times \ln(p_t / p_{t-1})$, which includes price series p_t of the stock market, the bond market and the exchange market; r_t refers to the corresponding yield data. Data in this article are derived from the Wind database.

Before modeling, we first consider whether the yield data satisfies the stability hypothesis test. Table 1 describes the basic characteristics of the daily yield sequence of the bond market, the stock market and the exchange market. From Table 1, we know that the standard deviation of the stock market in the sample interval is 1.8516, higher than the standard deviation between the bond market and the exchange market, which indicates that the fluctuation of the stock market in the sample interval is relatively large, and the bond and exchange markets are relatively stable and similar. The average yield of the bond market is 0.0162 in the sample range, which is greater than the average yield of the stock market, and the average yield of the exchange rate is negative. From the range of yield change, the range of the stock market is the biggest, and the range in the bond market and the exchange rate is smaller than that of the stock market. The kurtosis of each yield is greater than the kurtosis of the normal distribution of 3, showing a "peak thick tail" characteristics. Exchange and bond market yields are right biased, the yield of stock market is left biased, and the *P* value corresponding to the Jarque-Bera test is close to 0, rejecting the original hypothesis, that is, the yield sequence does not obey the normal distribution. In this paper, quantile regression is used to solve the model parameters, so the sequence is not required to obey normal distribution. The stability hypothesis test of the stock market, bond market and exchange market yield data shows that the *P* value of the statistic is close to 0, and the original hypothesis of the unit root is rejected, so the yield series are all stationary sequences.

Referring to the studies of Adrian and Brunnermeier (2016), the state variables and their calculations are as follows: Shanghai-Shenzhen 300 index volatility, the standard deviation obtained from the 22-day rolling yield represents the market volatility; Trend variables of interest rate can be represented by changes in intreasury bond rate of 3 months; the short-term liquidity trend variables indicate short-term liquidity tightening degree of the financial market, which is represented by the difference of the interbank interest rate of 3 months and treasury bond rate of 3 months; the CSI 300 index yield represents market returns; US yield curve represents changes in world business cycle is expressed by the difference of US treasury bond interest of 10 years and 3 months; the Chinese yield curve represents the changes in the Chinese business cycle is expressed by the difference of Chinese treasury bond interest of 10 years and 3 months.

Table 1
Descriptive Statistics of Financial Market Yield

Ffinancial market	Mean	Max	Min	Std	Skewness	Kurtosis	JB-test	ADF-test
Bond market	0.0162	1.3766	-0.9559	0.1284	0.9339	20.4299	0.0000	0.0000
Stock market	0.0064	9.0345	-12.7636	1.8516	-0.6025	7.3780	0.0000	0.0001
Exchange market	-0.0053	1.8403	-0.9263	0.1282	2.5629	39.0334	0.0000	0.0000

3.2 Empirical Results

According to (1)-(2), we use the method of regression and historical simulation to calculate the static risk spillover between financial markets. For example, when the bond market is in distress, the expected loss of the stock market or the exchange market is different from the expected loss of the stock market or the exchange market when the bond market is in normal condition, that is, the risk spillover effect from the bond market to the stock market and the exchange market. Similarly, models are set up to study the risk spillover of any market to other markets. Because, the value of the ΔCoVaR, ΔCoES is negative generally, we take its absolute value to indicate the size of the risk, the greater the absolute value indicates the greater the risk spillover. Table 2 outlines the risk spillover between the three markets, it can be seen that the static ΔCoVaR and ΔCoES of financial markets are close to each other, and the order of risk spillover between the three markets is basically the same.

Static ΔCoES estimation results show that the risk spillover between the three markets is obviously asymmetric. And the risk spillover from the stock market to the bond market is bigger than that from the bond market to stock market; the risk spillover from exchange market to stock market is bigger than that from the stock market to exchange market; the risk spillover from exchange market to bond market is bigger than that from the bond market to exchange market. In view of the spillover from the single market to the other two markets, the risk spillover from the stock market to the bond market is much greater than the risk spillover from the stock market to the exchange market; the risk spillover from the exchange market to the bond market is much greater than the risk spillover from the exchange market to stock market; the risk spillover from bond market to stock market is larger than that from bond market to exchange market. In the whole financial market, the biggest spillover between three markets is that from exchange market to bond market, the appreciation and depreciation of the RMB, has the greatest impact on the Chinese bond market.

Table 2
Static ΔCoES and static ΔCoVaR

1%	GZ	GH	ZG	ZH	HZ	HG
ΔCoVaR	0.2327	0.0243	0.0553	0.0325	1.1963	0.0105
ΔCoES	0.2294	0.0198	0.0775	0.0308	0.9240	0.0277

Note. GZ, GH, ZG, ZH, HZ and HG respectively indicates that the risk spillover from stock market to bond market, the spillover from stock market to exchange market, the spillover from bond market to stock market, the spillover from bond market to exchange market, the spillover from exchange market to bond market, and the spillover from exchange market to stock market.

The static value is difficult to accurately reflect the risk spillover between financial markets for a period of time, so this paper calculates the dynamic risk spillover between financial markets based on (5)-(9). Table 3 gives a descriptive statistic of ΔCoES sequence and ΔCoVaR sequence.

Table 3 shows that in terms of averages the using dynamic ΔCoES to measure the risk spillover between financial markets is slightly greater than the value obtained by static ΔCoES. But the size sorting of spillover lever between markets obtained by two methods is similar. Table 3 shows the asymmetric characteristics of risk spillover in China's financial markets, for example, the risk spillover from exchange market to bond market is 1.6672 greater than the risk spillover from bond market to exchange market 0.1772. Mainly because the bond market is the most responsive to a country's interest rate market, when the currency is expected to rise, the extreme risk of the exchange market can easily affect the interest rate markets and thus affect the bond market, but China's bond market due to the long-term market segmentation led to the liquidity and effectiveness is still relatively limited, so the spillover effect from bond market to exchange market is the relatively small. The risk spillover from stock market to bond market is 1.4411 greater than the spillover from bond market to stock market, which is 0.0906. The segmentation of China's bond market (mainly divided into inter-bank bond market and exchange bond market) leads to the lack of uniformity and efficiency, make the information of bond market can't be transferred to the stock market effectively, shows that China's stock market is more effective than bond market. The risk spillover from the stock market to the exchange market is slightly greater than the spillover from exchange market to stock market, which can't be separated from the increase of the liquidity of the stock split reform in China's stock market.

Table 3
Description Statistics of Sequence ΔCoES

ΔCoES	GZ	GH	ZG	ZH	HZ	HG
Mean	1.4411	0.2172	0.0906	0.1772	1.6672	0.0784
Max	1.7239	0.4903	0.1281	0.3638	2.0059	0.0824
Min	1.3581	0.1079	0.0788	0.1039	1.3396	0.0752
Std	0.0369	0.0372	0.0064	0.0352	0.1019	0.0011

Note. The same as Table 2.

Table 4
Annual Average of Sequences ΔCoES

Year	GZ	GH	ZG	ZH	HZ	HG
2007	1.4153	0.1901	0.0944	0.1985	1.8575	0.0808
2008	1.4786	0.2540	0.1009	0.2319	1.6273	0.0779
2009	1.4921	0.2678	0.0877	0.1618	1.7040	0.0787
2010	1.4691	0.2444	0.0867	0.1551	1.6568	0.0782
2011	1.4353	0.2128	0.0873	0.1603	1.5482	0.0772
2012	1.4118	0.1874	0.0874	0.1617	1.6738	0.0783
2013	1.4255	0.2039	0.0894	0.1766	1.6138	0.0777
2014	1.4240	0.2024	0.0864	0.1528	1.6012	0.0776
2015	1.4515	0.2283	0.0962	0.2087	1.6577	0.0782
2016	1.4096	0.1830	0.0884	0.1652	1.7218	0.0789
Sample size	1.4411	0.2172	0.0906	0.1772	1.6672	0.0784

Note. The same as Table 2.

Table 4 calculates the average value of the annual ΔCoES series, and indirectly reflects the impact of the financial crisis on China's bond market, stock market and foreign exchange market, which has a higher risk spillover from 2008 to 2010 from stock market to exchange market and bond market. Compared with the initial time when the stock market was affected by the crisis, China's exchange market and bond market were affected by the financial crisis earlier, and the risk spillover from the Chinese exchange market to bond market in 2007 was higher than the average level in the sample. In the 2007 and 2008, the level of Chinese bond market spillover to stock market and exchange market was also significantly higher than the risk spillover average. It also shows that the financial crisis has the longest impact on the stock market among China's finance markets. In 2015, China's exchange rate reform, stock market supervision technology reform and product innovation of bond market enhance the liquidity and integration degree of China's financial market, and the risk spillover of China's bond market and stock market to other financial markets in 2015 is obviously strengthened. In 2015, the risk spillover level of the bond market to the stock market and the exchange market were higher than the average of the total sample. During the stock market crash in 2015, the risk spillover level of the stock market to the bond market and the exchange market were higher than the average of that in the sample. After August 11, 2015 "Exchange reform", the risk spillover level from the exchange market to bond market rose until October 1, 2016, when the RMB formally joined the SDR. The risk spillover from exchange market to stock market and bond market has increased significantly, and the average value of foreign exchange market in 2016 has been higher than that of the previous 8 years.

In order to see more clearly the characteristics of the risk spillover between China's financial markets, the mean value of the dynamic ΔCoES is labeled in Figure 1, and the value in the figure represents the size of risk spillover from the starting point of the line to the direction of the arrow, and the high asymmetry of risk spillover between financial markets in China can be clearly seen from Figure 1. The risk spillover of the stock market to other markets is greater than that of other markets, which show the high liquidity of the Chinese stock market. The risk spillover of the exchange market to the bond market is the biggest, followed by the risk spillover of the stock market to the bond market, the risk spillover from China's bond market to other markets is relatively small, which means that the bond market is vulnerable to risk spillover from other financial markets, but it is difficult to transfer its own risk to other financial markets, thus increasing the risk of China's bond market. The significant asymmetry of the bond market is mainly because of the long-term market of China's bond market segmentation, including the development of inter-bank bond market and stock exchange bond market is not harmonious, the market size and the trading volume of two markets is disparity, and the regulation is not unified, the exchange bond market's supervision is the China Securities Regulatory Commission to be responsible, but the inter-bank market, mainly to self-discipline supervision. The risk spillover from the exchange market to other markets shows that the spillover from exchange market to bond market is significantly greater than that of the stock market, that is, the stability of the Chinese bond market is related to the stability of the exchange rate.

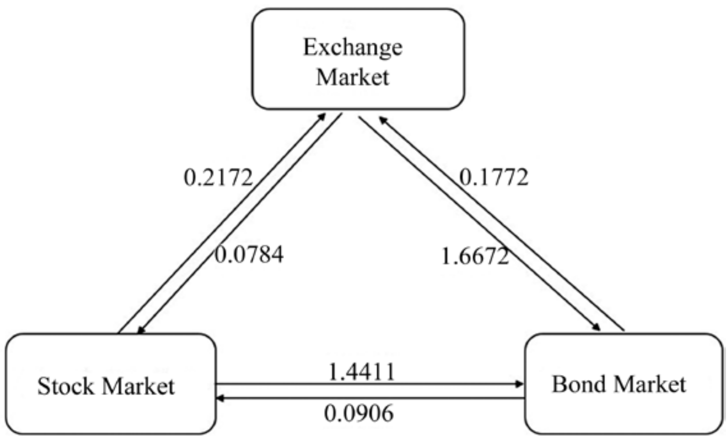

Figure 1
Network od Risk Spillover Between China's Financial Markets

Figures 2-4 show the time-varying risk spillover between the Chinese financial markets. Figure 2 depicts the dynamic spillover from stock market to exchange market and bond market, it can be seen that the risk spillover of financial market in the sample interval has obvious time-varying characteristics, and the trend the spillover from stock market to exchange market is similar to that from the stock market to the bond market, which is consistent with our definition and understanding, that is, when the stock market is at risk, the change trend of its spillover to exchange and bond market mainly comes from the trend of the stock market's own risk, but the sizes are different. Because the stock market and the bond market are affected by some of the same factors, the risk spillover from the stock market to the bond market is much larger than that from the stock market to the exchange market. During the financial crisis, the risk of stock market became bigger, and the risk spillover from the stock market to the bond market and the exchange was significantly higher than the average overflow level in the sample.

On June 20, 2013, China's inter-bank overnight repo rate reached 30%, 7 days repo rate reached 28%, the industry will be compared to the phenomenon of "interbank mutual usury", known as the "money shortage". As showed in Figure 2, during the period of "money shortage", the risk spillover from stock market to bond market and the exchange market is unusually large. June 2015, under the influence of the China Securities Regulatory Commission's (CSRC) strong inventory allocation of capital, China's stock market began to slump, and A shares lost 15 trillion of its value, the stock market continued to slump by external events called "stock crash". Figure 2 shows that the risk spillover from the stock market to the bond market and exchange market increased significantly during the 2015 "stock crash", the lever of risk spillover is even close to that of the financial crisis period, indicating that when the stock market faces the increasing risk pressure, the risk spillover of the stock market and the bond market will increase and reflecting the reform of China's exchange rate system, the reform of the split share structure and the bond market, have strengthened the integration of financial markets. But the risk spillover from the stock market to exchange market is much smaller than that of the stock market to bond market. This is mainly because the weak wealth effect of the Chinese stock market and the common factors of stock market and bond market are affected. During the financial crisis, the spillover from the exchange market to stock market and bond market is greater than the average value of the corresponding risk spillover sequence. After the "8.11 exchange reform" in 2015, the impact of China's exchange market on the stock market and the bond market has shown an upward trend.

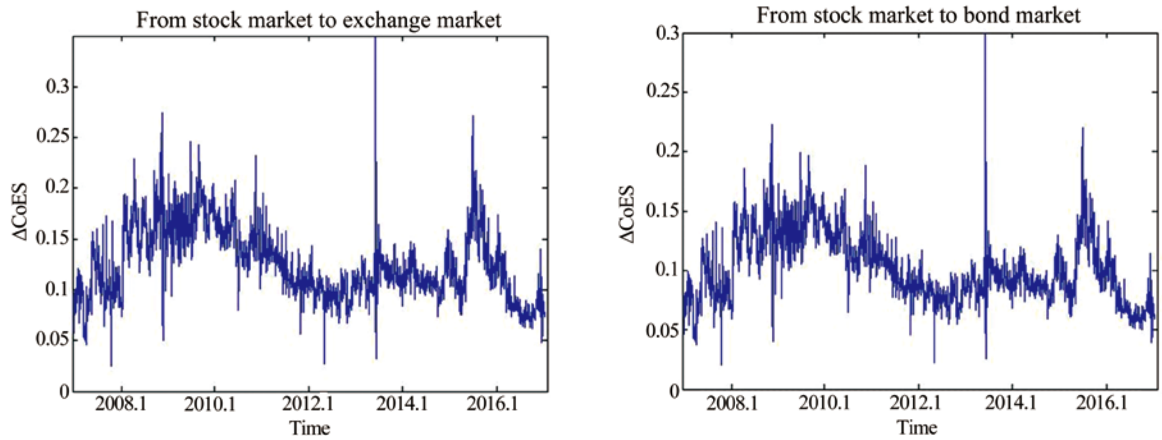

Figure 2
Sequence of Risk Spillover From Stock Market to Exchange Market and Bond Market

Figure 3 depicts the time-varying spillover from exchange market to stock market and bond market, it can be seen that the exchange market has obvious time-varying effect on the risk spillover from the sample interval, and the trend of the spillover from the exchange market to the stock market and the bond market is consistent, which reflects the change of the risk of exchange market.

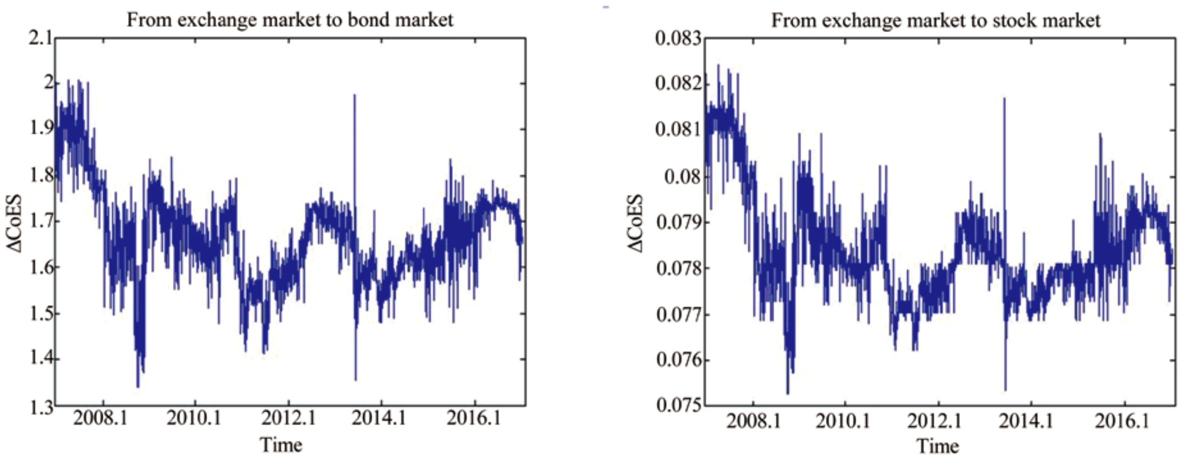

Figure 3
Sequence of Risk Spillover From Exchange Market to Stock Market and Bond Market

August 11, 2015, the People's Bank of China announced that the RMB's exchange rate is no longer pegged to the single dollar, but with reference to a basket of currencies. This adjustment makes the RMB exchange rate mechanism further marketization. During this period, the spillover from exchange market to the domestic stock and bond market is on the upward trend, and that of foreign exchange market to the bond market is far bigger than that of exchange market to stock market, shows that when the currency is appreciated or devalued, the risk to the bond market is greater. October 1, 2016 the RMB was formally added to the SDR basket, then the weight of dollar fell from 41.9% to 41.73%, the weight of euro fell from 37.4% to 30.93%, the weight of yen fell from 9.4% to 8.33% and weight of the pound fell from 11.3% reduced to 8.09%. The RMB became the third-largest currency in the basket, which increases the links between the RMB and domestic and foreign financial markets, thus in 2016, the risk spillover of the exchange market to the stock market and the bond market has been greater than that in 2008-2015.

Figure 4 depicts the time-varying risk spillover from the bond market to the stock and exchange market. It can be found that, the spillover from bond market to the financial markets is significantly higher than the average value of the sample in the periods of financial crisis and "money shortage". It is also worth noting, Chinese bond market reform and product innovation have made great breakthroughs in 2015. And a series of market-oriented policies, audit process greatly simplified, enhance the bond market efficiency and flexibility and promote the China's bond market growth in the overall development of the situation, thus increase the risk spillover of China's bond market to the other financial markets. So, the average lever of spillover from the bond market to the stock market and exchange market is larger in 2015.

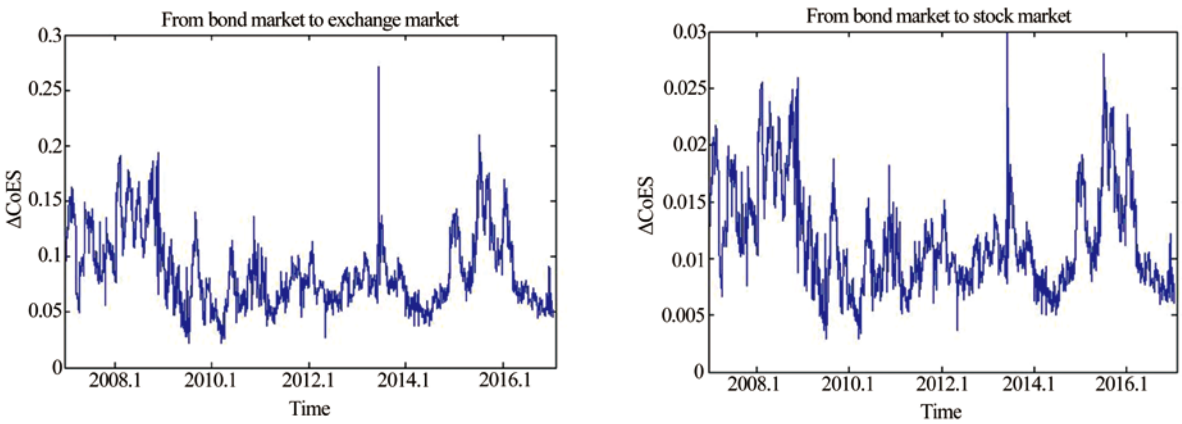

Figure 4
Sequence of Risk Spillover From Bond Market to Exchange Market and Stock Market

CONCLUSION

The CoVaR model proposed in Adrian and Brunnermeier (2016) is essentially the difference of conditional quantiles, which represent the value at risk of another market conditional on the specific market is in the normal risk condition and the value at risk of another market conditional on the specific market is in the extreme risk, while the value at risk does not take into account the tail risk. Therefore, based on the model CoVaR proposed by Adrian and Brunnermeier (2016), this paper developes a dynamic CoES method, and promotes the CoES model to System-ΔCoES, Exposure-ΔCoESand Network-ΔCoES.

Based on the data of China's Shanghai Composite Index, the total Chinese bond index and the nominal exchange rate of US dollar against the RMB from January 2007 to January 2017, the paper uses dynamic ΔCoES model to study the risk spillover between Chinese stock market, exchange market and bond market, and finds that there is obvious time-varying and asymmetric risk spillover between China's financial markets. The risk spillover level between Chinese financial markets during the financial crisis is higher than the average spillover level in the sample interval. The "money shortage" phenomenon in mid-June 2013 had a significant impact on China's financial market spillover, but the impact lasted a short time, and a series of market reforms in the stock market, bond market and exchange market in the second half of 2015 enhanced the level of risk spillover between financial markets in China and increased the level of spillover from bond market to other financial markets. China's stock market and exchange market have higher risk spillover lever to bond market, and the risk spillover of the bond market to the stock market and exchange market is relatively small, which is unfavorable to the risk transfer and share of the Chinese bond market. August 11, 2015, after the "exchange reform", the risk spillover from China's exchange market to the bond market and stock market is increased significantly, October 1, 2016, the RMB formally joined the SDR, enhanced the links with domestic and international financial markets, the spillover from exchange market to the stock market and bond market continue to strengthen. In 2016, the level of China's exchange market spillover to the stock market and bond market has been higher than that of the previous 8 years, just slightly lower than that during the financial crisis.

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