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Research article

Risk spillover effects of international crude oil market on China's major markets

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Abstract: This paper systematically evaluates the influence of international crude oil risk on Chinese macro-financial risks, by quantifying risk spillover effects from international crude oil market to China's three major markets (stock, foreign exchange and commodity markets). Specifically, this paper initially calculates the risks of international crude oil market and China's three major markets by adopting a conditional autoregressive value at risk (CAViaR) model, then the spillover index is used to capture the risk spillovers from international crude oil market to China's major markets. The empirical results indicate that there exists significant heterogeneous risk spillover effects transmitted from international crude oil market to China's three major markets. To be more specific, the risk derived from international crude oil market is always a dominant driving force of risk in China's commodity market. However, the shocks of global oil risk do not affect much of the risks of China's stock and foreign exchange markets in general. In addition, our results further report that international oil risk has considerable effects on China's macro-financial risks during several specific periods, which can be attributed to several major events. Specifically, the risk spillovers originated from international crude oil market remarkably contribute to the risk of China's commodity market during the period of global financial crisis. International crude oil risk makes great contribution to the risks of Chinese stock and foreign exchange markets, when several global notable events occur as well as major financial reforms in China are implemented. The empirical results have significant implications for policy-makers and market participants.

Keywords: risk spillovers; crude oil market; stock market; foreign exchange market; commodity market; CAViaR; spillover index

1. Introduction

Understanding the transmission mechanism of international crude oil risk (especially the extreme risk which is always in association with major events) to market risk is of great importance to policy makers and market participants [1]. In terms of policy makers, monitoring and controlling market risk particularly the extreme market risk, is crucial to keep financial stability and economic growth. The results from a large amount of empirical studies showed that the risk spillover from international crude oil market is an unneglectable source of macro-financial risks of one country or a region (e.g., stock market risk, exchange rate risk, sovereign credit risk), especially since the global financial crisis [2–9]. In this context, the potential risk spillovers from global crude oil market, the price of which is frequently volatile with extensive amplitude in recent years, has become an important issue concerned by the authorities in the macro-financial risk management. Simultaneously, the mechanism of how risk spillover occurs across various markets is always of a great concern to the financial market participants for their hedging strategy [10,11]. In recent years, a large volume of work has examined the spillover effects of international crude oil market on financial markets.

However, the existing literature mainly focuses on the return and volatility spillovers, the research on risk spillovers between crude oil and financial markets is relatively scarce [9]. As argued by Hong et al. [11], most empirical studies in the literature use volatility to measure risk and focus on the volatility spillovers [12–15]. Whereas, volatility can only adequately reflect the small risk in practice, and it cannot satisfactorily capture the risk in scenarios of occasionally occurring extreme market movements. Additionally, volatility includes both gains and losses, however, financial risk is only related with losses but not profits. In this sense, quantifying the risk spillover effects across different markets is supposed to provide important practical implications for both policy makers and market participants in a more efficient way. Since a high level of risk always implies extreme market movements, this could result in substantial capital changes and even economic recessions [10].

On the other hand, there are several studies paying attention to examine the risk or volatility spillovers from international crude oil market to China's financial markets [4,16,17]. Nevertheless, the existing work has mostly focused on the risk transmission to Chinese stock market, less attention has been placed to understand the risk spillovers between international crude oil and other markets in China. China has become the world's largest net oil importer and the second largest oil consumer [18], its dependence on oil imports even exceeded 70% in 2018 [19]. It is naturally expected that international oil price shocks should have essential influences on its macro-financial stability. In particular, as a transition country, China is currently accelerating its pace of financial liberalization and opening (e.g., capital account liberalization, Renminbi (RMB) internationalization [20]), the role of external risk transmission in driving the risk of Chinese foreign exchange market should also not be ignored. Additionally, with the sharp increase of investment inflow into the commodity market in recent years, the commodity market is interfered with by more and more stochastic factors, which is commonly referred to as the 'financialization' [21–25]. Under the background of the financialization of commodity markets, commodities have become an important part of financial investors' portfolios, some scholars therefore believed that they should be treated as a new asset category just like stocks and bonds [26,27]. Simultaneously, several recent studies have verified the existence of a close interconnection between commodity and stock markets since the 2008 global financial crisis [25,26]. Hence, because of the increasing importance of commodity market for financial investment strategies as well as macro-financial risk management, it is necessary to identify the impact of international crude oil risk on commodity market risk.

This study attempts to present a comprehensive assessment of the influence of international crude oil risk on Chinese macro-financial risks, by evaluating risk spillover effects from international crude oil market to China's three major markets, namely stock market, foreign exchange market and commodity market. The contributions of this paper to the ongoing empirical literature are as below: First, different from most studies which used volatility to measure risk and concentrated on the volatility spillover effects, this paper applies a conditional autoregressive value at risk (CAViaR) model to calculate risk and employs the spillover index developed by Diebold and Yilmaz [28] to quantify the risk spillovers transmitted from international crude oil to three major markets in China, this is supposed to be able to measure the risk spillover effects in a more efficient way, which can also provide a better understanding of the impact of global oil risk on Chinese macro-financial stability. Second, this paper adds to the existing empirical literature by investigating the risk spillovers emanating from international crude oil to China's macro-financial risks in a more comprehensive manner. As described above, the existing literature mainly focused on addressing the oil-stock risk spillovers. However, in order to thoroughly evaluate the impact of international crude oil risk on the macro-financial risks, particularly in the context of China's financial liberalization and opening as well as financialization of the commodity market, the risk spillovers between international crude oil and Chinese foreign exchange, commodity markets should also be taken into account. This paper thus systematically analyzes the influence of international crude oil risk on the risks of China's three major markets.

The estimation results of this paper indicate that there exists significant heterogeneous risk spillover effects transmitted from international crude oil to China's three major markets. More specifically, the international oil risk is a leading driving force of China's commodity market risk. By contrast, the global oil risk shocks do not affect much of the risks of China's stock and foreign exchange markets in general. Additionally, our results further report that international oil risk has considerable effects on China's macro-financial risks during several specific periods, which is caused by major events. Specifically, the risk spillovers originated from international crude oil market remarkably contribute to the risk of China's commodity market during the global financial crisis. International crude oil risk makes great contribution to China's stock and foreign exchange markets, when several global notable events occur as well as major financial reforms in China are implemented.

The remainder of this paper is organized as follows. In the next section, we present a brief review of the literature. Section 3 outlines the methodology and variable calculation method. The data source and data preprocessing results are provided in Section 4. Results regarding the risk spillovers from international crude oil to stock, foreign exchange and commodity markets in China are reported and discussed in section 5. Section 6 provides the concluding remarks.

2. Literature review

Since the seminal work of Hamilton [29], the connection between global crude oil price and macroeconomy, crude oil market and financial markets have been extensively investigated. In the empirical literature, many research articles have documented the relationship between crude oil and stock, foreign exchange and commodity markets from different perspectives including the examinations of cointegration relationships, causality behavior, co-movements, information transmission through return or volatility spillovers [30–39]. However, only a few papers in the literature have examined the risk spillovers between crude oil and one specific financial market. The research which provides a thorough investigation of the impact of international crude oil risk on macro-financial risks is even scarcer.

There are several studies examining the risk spillover effects between crude oil and stock market in the context of different countries and regions, and most of the studies indicate that the risk spillover is significant and becomes stronger since the 2008 global financial crisis. Du and He [10] used Value at Risk (VaR) to measure market risk, and applied kernel-based tests to examine the spillovers of extreme risks between West Texas Intermediate (WTI) crude oil and S&P 500 stock markets in the US. Their results confirmed that there exists significant risk spillovers between these two markets, and the bidirectional positive risk spillovers increase remarkably after the financial crisis. Balcilar et al. [1] employed the volatility impulse response model to evaluate the risk spillover effects across the oil market, US stock market, and the oil related Credit Default Swap sectors, the existence of significant risk transmission effects across these markets is verified. Additionally, Mensi et al. [6] and Wen et al. [9] found that there exists asymmetric risk spillover effects between oil and major regional developed stock markets in the world. More recently, some scholars have paid attention to the risk transmission effects between oil and stock markets of developing nations. Applying a copula approach and quantifying three risk measures, Shahzad et al. [8] investigated the extreme dependence spillovers between oil and five Islamic stock markets. Their empirical results provide supportive evidence of asymmetric risk spillovers from oil to Islamic stock markets and vice versa, and the risk spillover effects are much larger in the post-crisis period. Similarly, Li and Wei [4] pointed out that the risk spillovers from crude oil to China's stock market could be found in both pre- and post-crisis periods, and larger risk spillover effects are detected after global financial crisis.

By contrast, just a few studies concentrated on appraising the risk spillovers between crude oil and exchange rate markets, crude oil and commodity markets. Applying the copula approach and variational mode decomposition (VMD) method, Mensi et al. [5] examined the risk spillovers between oil and foreign exchange markets for Middle East and North Africa (MENA), other developing and developed nations in different investment time horizons. The empirical results indicated that there is an evidence of asymmetric systemic risks from oil to currencies and vice versa for several countries in the short- and medium time horizons. Ji et al. [3] used conditional values at risk (CoVaRs) to measure risks, and employed six time-varying copula models to analyze the risk dependences between WTI oil prices and the exchange rates of China and the US. Their findings revealed that there exists significant risk spillover effects transmitted from crude oil to exchange rate markets in both China and the US. Additionally, few studies have focused on examining the risk spillovers between oil and other commodity markets. Ji et al. [40] investigated the risk spillovers from energy (oil and gas) to agricultural commodity markets by applying a dependence-switching CoVaR-copula approach. They found that the information spillovers from these two energy markets strengthen the risk exposure of agricultural commodities, especially during the global financial crisis. Meanwhile, the empirical results of Algieri and Leccadito [41] indicated that the risk contagion from oil market makes a significant contribution to the risk of food commodity market.

As shown above, most studies have verified that there exist significant risk spillovers between crude oil and stock, foreign exchange and commodity markets. Accordingly, this paper further focuses on qualifying the magnitude of risk transmission from international crude oil to the three major markets in China. Specifically, the spillover index proposed by Diebold and Yilmaz [28] is employed to obtain the static and time-varying contributions of international oil risk to the risks of China's three major markets.

3. Methodology and variable

3.1. Methodology

The spillover index proposed by Diebold and Yilmaz [28], which is widely used to quantify the connectedness between different financial markets [42–45], is adopted to measure the risk spillover effects between international crude oil and China's stock, exchange rate and commodity markets in this paper. Based on the notion of forecast error variance decomposition in the generalized vector autoregression (VAR) framework, the spillover index is able to study the connectedness across different markets in a more efficient way by eliminating the possible dependence of the variance decomposition results on the ordering of the variable in a sample VAR framework. In this paper, to capture the risk spillover effects, we firstly estimate the VAR model as Eq 1.

$$\mathbf{y}_t = \mathbf{v} + \sum_{i=1}^{p} \mathbf{\Phi}_i \mathbf{y}_{t-i} + \mathbf{u}_t. \tag{1}$$

where $\mathbf{y}_t$ is a 4 × 1 vector of endogenous variables, which include the risks of crude oil, stock, exchange rate and commodity markets; $\{\mathbf{\Phi}_i\}_{i=1}^{p}$ are (4 × 4) autoregressive coefficient matrices; $\mathbf{v}$ and $\mathbf{u}_t$ denotes the vector of interprets and residuals, respectively.

Based on the model, the error variance decomposition can record how much one market contributes to the *H-step-ahead* forecast error of another market. Formally, the vector moving average (VMA) representation included in the model can be described in Eq 2.

$$\mathbf{y}_t = \mathbf{\omega} + \sum_{j=0}^{\infty} \mathbf{A}_j \mathbf{u}_{t-j}. \tag{2}$$

where $\mathbf{A}_j$ are ($N \times N$) matrices that obey to Eq (3).

$$\mathbf{A}_j = \sum_{i=1}^{p} \mathbf{\Phi}_i \mathbf{A}_j. \tag{3}$$

where the initial value being the identity matrix $\mathbf{A}_0 = \mathbf{I}_N$ and $\mathbf{A}_j = \mathbf{0}$ for $j < 0$. The vector $\mathbf{\omega}$ is obtained by applying the infinite order inverse autoregressive lag-operator to $\mathbf{v}$, i.e., $\mathbf{\omega} = (\mathbf{I}_N - \sum_{i=1}^{p} \mathbf{\Phi}_i)^{-1} \mathbf{v}$, and it does not interfere with the variance decomposition. Generally, the infinite-order VMA in Eq (2) is truncated at *H-step-ahead* to forecast the error variance.

Following Koop et al. [46] and Pesaran and Shin [47], the *H-step-ahead* generalized forecast-error variance decomposition is defined as Eq (4).

$$\theta_{ij}^{g} = \frac{\sigma_{ij}^{-1} \sum_{l=0}^{H-1} (\mathbf{e}_i^{'} \mathbf{A}_l \mathbf{\Sigma} \mathbf{e}_j)^2}{\sum_{l=0}^{H-1} (\mathbf{e}_i^{'} \mathbf{A}_l \mathbf{\Sigma} \mathbf{A}_l^{'} \mathbf{e}_i)}. \tag{4}$$

where σ_{jj} is the standard deviation of the error for the *jth* market, and $\mathbf{e}_i$ is a selection column with the *ith* element equals one and zeros elsewhere. Since the variance decomposition is based on the generalized impulse response functions, the sum of each row in the variance decomposition table is $\sum_{j=1}^{N}\theta_{ij}^{g}(H)\neq 1$. Therefore, we should normalize the variance shares to ensure that row sums up to one as Eq (5).

$$\tilde{\theta}_{ij}^{g}(H)=\frac{\theta_{ij}^{g}(H)}{\sum_{j=1}^{N}\theta_{ij}^{g}(H)}. \tag{5}$$

Alternatively, we can compute the directional spillover to explore the contribution of international crude oil risk to the risks of China's three markets vice versa. Specifically, we define the risk spillovers received by crude oil market from all other markets in Eq (6) and the spillovers transmitted from crude oil to all other markets in Eq (7), respectively.

$$S_{\underset{all\to i}{k}}^{g}(H)=\frac{1}{N}\sum_{\substack{j=1\\ i\neq j}}^{N}\tilde{\theta}_{k,ij}^{g}(H). \tag{6}$$

And

$$S_{\underset{i\to all}{k}}^{g}(H)=\frac{1}{N}\sum_{\substack{i=1\\ i\neq j}}^{N}\tilde{\theta}_{k,ij}^{g}(H). \tag{7}$$

3.2. Variable measurement method

Before we employ the spillover index to investigate the risk spillover effects of international crude oil market on China's three major markets, it is necessary to calculate the risks of these four markets.

Value at Risk, defined as the worst loss of a portfolio or security with a prespecified probability over a specific period, is widely adopted to measure the risks of crude oil and financial markets. Overall, the market risk measured by VaR methodologies could be divided into two categories: factor mapping models and portfolio models [48,49]. Among them, the GARCH-type models are extensively used in the calculation of VaR [50–56]. However, these approaches always assume that the distributions of crude oil or financial market returns are invariable across time. Obviously, the returns in such markets cluster over time, and the distributions of them are time-varying [57]. A nature way to formalize this characteristic is to use some type of autoregressive specification. Therefore, consistent with the studies of Chen et al. [58], Dong et al. [59] and Liao et al. [60], we use conditional autoregressive quantile specification proposed by Engle and Managanelli [48] to calculate the VaR in different markets in this paper.

Let $\{R_{o,t}\}_{t=1}^{T}$ be a series of international crude oil return, and T is the length of sample (Risks of other three markets are similar to the process of crude oil market risk). It can be calculated as follows:

$$R_{o,t}=\ln(y_{o,t})-\ln(y_{o,t-1}) \tag{8}$$

where $y_{o,t}$ and $y_{o,t-1}$ are the crude oil price at time t and t-1, respectively.

VaR can be defined as the left $\theta-quantile$ of the conditional probability distribution of crude oil return, which is subject to Eq 9.

$$\Pr[R_t < VaR_t \,|\, \Omega_{t-1}] = \theta \tag{9}$$

where VaR_t represents the oil risk at time *t*, and Ω_{t-1} denotes the information set available at time *t*-1.

The general CAViaR specification is defined as followed.

$$VaR_{o,t}(\boldsymbol{\beta}) = \beta_0 + \sum_{i=1}^{q} \beta_i VaR_{o,t-i}(\boldsymbol{\beta}) + \sum_{j=1}^{r} \beta_j l(R_{o,t-j}). \tag{10}$$

where $VaR_{o,t}(\boldsymbol{\beta}) \equiv VaR_{o,t}(R_{o,t-1}, \boldsymbol{\beta}_\theta)$ denote the time t $\theta - quantile$ of the distribution of oil returns formed at time *t*-1. The autoregressive terms $\beta_i VaR_{o,t-i}(\boldsymbol{\beta})$, $i = 1, 2, \cdots, q$ ensure the oil risk changes smoothly over time. Specially, β_2 depicts the cluster feature of oil risk. The role of $l(R_{o,t-j})$ is to link $VaR_{o,t}(\boldsymbol{\beta})$ to oil returns that belong to Ω_{t-1}.

In most practical situations, the general CAViaR model might reduce to a first-order model. Specifically, the four CAViaR specifications could be described as Eqs 11–14.

Symmetric absolute value:

$$VaR_{o,t}(\boldsymbol{\beta}) = \beta_1 + \beta_2 VaR_{o,t-1}(\boldsymbol{\beta}) + \beta_3 \left| R_{o,t-1} \right|. \tag{11}$$

Asymmetric slope:

$$VaR_{o,t}(\boldsymbol{\beta}) = \beta_1 + \beta_2 VaR_{o,t-1}(\boldsymbol{\beta}) + \beta_4 (R_{o,t-1})^+ + \beta_3 (R_{o,t-1})^-. \tag{12}$$

Indirect GARCH (1,1):

$$VaR_{o,t}(\boldsymbol{\beta}) = (\beta_1 + \beta_2 VaR_{o,t-1}^2(\boldsymbol{\beta}) + \beta_3 R_{o,t-1}^2)^{1/2}. \tag{13}$$

Adaptive:

$$VaR_{o,t}(\beta_1) = VaR_{o,t-1}(\beta_1) + \beta_1 \left\{ [1 + \exp(G[R_{o,t-1} - VaR_{o,t-1}(\beta_1)])]^{-1} - \theta \right\}. \tag{14}$$

where $(R_{o,t-1})^+ = \max(R_{o,t-1}, 0)$, $(R_{o,t-1})^- = -\min(R_{o,t-1}, 0)$ and G is some positive finite number.

Furthermore, Engle and Managanelli [48] has proposed a dynamic quantile (DQ) test, DQ_{IS} and DQ_{OOS}, to check the adequacy of CAViaR models. Specifically, DQ_{IS} is a specification test for the particular CAViaR process under study and it can be useful for model selection purposes. The simpler version of the DQ_{OOS}, instead, can be used by regulators to check whether the VaR forecast submitted by a financial institution satisfy some basic requirements[1].

4. Data and data preprocessing

4.1. Data

As described above, we focus on exploring the risk spillovers from international crude oil market to stock, exchange rate and commodity markets in China. In this aspect, we should firstly consider the return risks in these markets, which are calculated based on the corresponding prices.

[1] The detail of DQ test could be found in Engle and Manganelli [48].

The Brent crude oil price system, covering over 65% of the world's real crude oil, plays a leading role in the pricing of crude oil [61]. Thus, in this paper, the Brent oil price is used to reflect the international crude oil price, which is in consistent with the studies of Mensi [38], Arouri et al. [62], Zhang and Wang [63]. Considering that Europe Brent spot price is widely accepted as a major benchmark price for trades of oil worldwide [63], the weekly closing spot price for Brent is eventually selected for this study. Following studies of Zhang and Wang [63], Guo [64], Zheng and Chen [65], the Shanghai Stock Exchange Composite Index (SSECI) is chosen as the proxy of China's stock price in this paper. The Chinese RMB exchange rate is measured by RMB/USD rate (i.e., the RMB value of one dollar). Additionally, the China Commodity Price Index (CCPI) which covers 26 commodities in 9 key categories (i.e., energy, steel, mineral products, non-ferrous metals, rubber, agricultural products, livestock, oil and oilseed, and sugar), is selected to fully reflect the status of China's commodity price.

Due to the data availability of CCPI, our sample period is set from June 9, 2006, to December 31, 2018 on a weekly frequency. We obtain the data of Europe Brent spot price from the U.S. Energy Information Administration (https://www.eia.gov/). The closing price of SSECI, RMB exchange rate as well as CCPI are all collected from Wind database.

4.2. Data preprocessing

In this subsection, we initially present the estimation result of CAViaR model based on the series of international oil return. As noted already, we will forecast 1% and 5% weekly oil return risk (VaR_o), using the four CAViaR specifications described in Section 3.2. The sample is split into two parts: an in-sample period of 512 observations to estimate the parameters and an out-of-sample period of 129 observations for the DQ test. For the adaptive model, we set G = 10. In principle, the parameter G itself could be estimated. However, this would go against the spirit of CAViaR, which is simplicity. What's more, we test different values of G, such as 5, 15, 20, and get the same result as G = 10. All the results are reported in Table 1.

Table 1. The estimation results for the four CAViaR specifications of international crude oil risk.

Panel a: 1% VaR				
	Symmetric	Asymmetric	Indirect GARCH	Adaptive
β_1	0.0005	0.0012*	0.0000	−7.641e-05***
	(0.002)	(0.000)	(0.000)	(0.000)
β_2	0.8640***	0.9481***	0.8794***	
	(0.026)	(0.011)	(0.018)	
β_3	0.4087**	−0.0047	0.8029**	
	(0.151)	(0.029)	(0.473)	
β_4		0.2450***		
		(0.042)		
Hit in-sample (%)	1.172	1.171	0.976	0.976
Hit out-of-sample (%)	0.775	0.775	0.775	0.000
DQ in-sample (p)	0.996	0.997	0.998	0.136
DQ out-of-sample (p)	0.867	0.968	0.995	0.564

Continued on next page

Panel b: 5% VaR				
	Symmetric	Asymmetric	Indirect GARCH	Adaptive
β_1	0.0039** (0.0022)	0.0044** (0.0011)	0.0002* (0.000)	−3.921e-05 (0.000)
β_2	0.7725*** (0.0498)	0.8225*** (0.0265)	0.7678*** (0.052)	
β_3	0.3547*** (0.0612)	0.0099 (0.0578)	0.5437** (0.231)	
β_4		0.4286*** (0.0732)		
Hit in-sample (%)	5.078	4.882	4.882	5.078
Hit out-of-sample (%)	3.876	5.426	5.426	3.101
DQ in-sample (p)	0.745	0.652	0.888	0.000
DQ out-of-sample (p)	0.476	0.437	0.765	0.035

Note: ***, ** and * indicate significance levels of 0.1%, 1% and 5%, respectively. Standard errors are shown in parentheses.

Table 1 presents the values of estimated parameters and their p values as well as p-values of the DQ test, both in-sample and out-of-sample. The first striking result shows that the autocorrelation coefficient β_2 is highly significant in all models, which illustrates that the clustering of risk is also relevant in tails. A second interesting notice is the precision of four CAViaR specifications, as measured by the percentage of in-sample or out-of-sample hits. Specifically, the results for 5% show that the symmetric, asymmetric slope and indirect GARCH models do a good job, whereas, the Adaptive model is not sensitive enough to depict the evolution of oil return risk. In addition, the DQ tests, which is used to select different models for different confidence levels, suggest that the tail behavior might change as we move further out in the tail. In particular, there are differences between β_3 and β_4, which denote to the asymmetric effects of positive and negative parts of lagged oil returns. Moreover, the asymmetric slope model generates a remarkable precision of the percentage of out-of-sample hits (5.426%). As mentioned above, we can conclude that the estimation of asymmetric slope could be regarded as oil return risk.

Similarly, we further use the first 512 observations to estimate the parameters and the last 129 for out-of-sample testing to forecast the risks of stock, exchange rate and commodity in China. In order to present the estimation results in a succinct way, this paper only reports the estimation results of 5% VaR. Additionally, although GARCH might always be a useful model for describing the evolution of risk, the estimation results in this study indicate that asymmetric slope might provide a satisfactory approximation about the return risks in China's stock, exchange rate and commodity markets. The estimation of asymmetric slope of these three markets is depicted in Table 2.

Table2. The estimation of asymmetric slope of China's three major markets.

	Stock market	Foreign exchange market	Commodity market
β_1	−0.0006	0.0001*	0.0030***
	(0.001)	(0.0000)	(0.001)
β_2	0.8975***	0.8852***	0.7387***
	(0.049)	(0.0533)	(0.073)
β_3	0.2035**	0.1900**	0.8472***
	(0.076)	(0.0787)	(0.124)
β_4	0.2828**	0.2196**	−0.4924***
	(0.106)	(0.0950)	(0.151)
Hit in-sample (%)	5.078	4.882	5.273
Hit out-of-sample(%)	6.201	9.302	5.426
DQ in-sample(p)	0.852	0.804	0.969
DQ out-of-sample(p)	0.231	0.002	0.908

Note: ***, ** and * indicate significance levels of 0.1%, 1% and 5%, respectively. Standard errors are shown in parentheses.

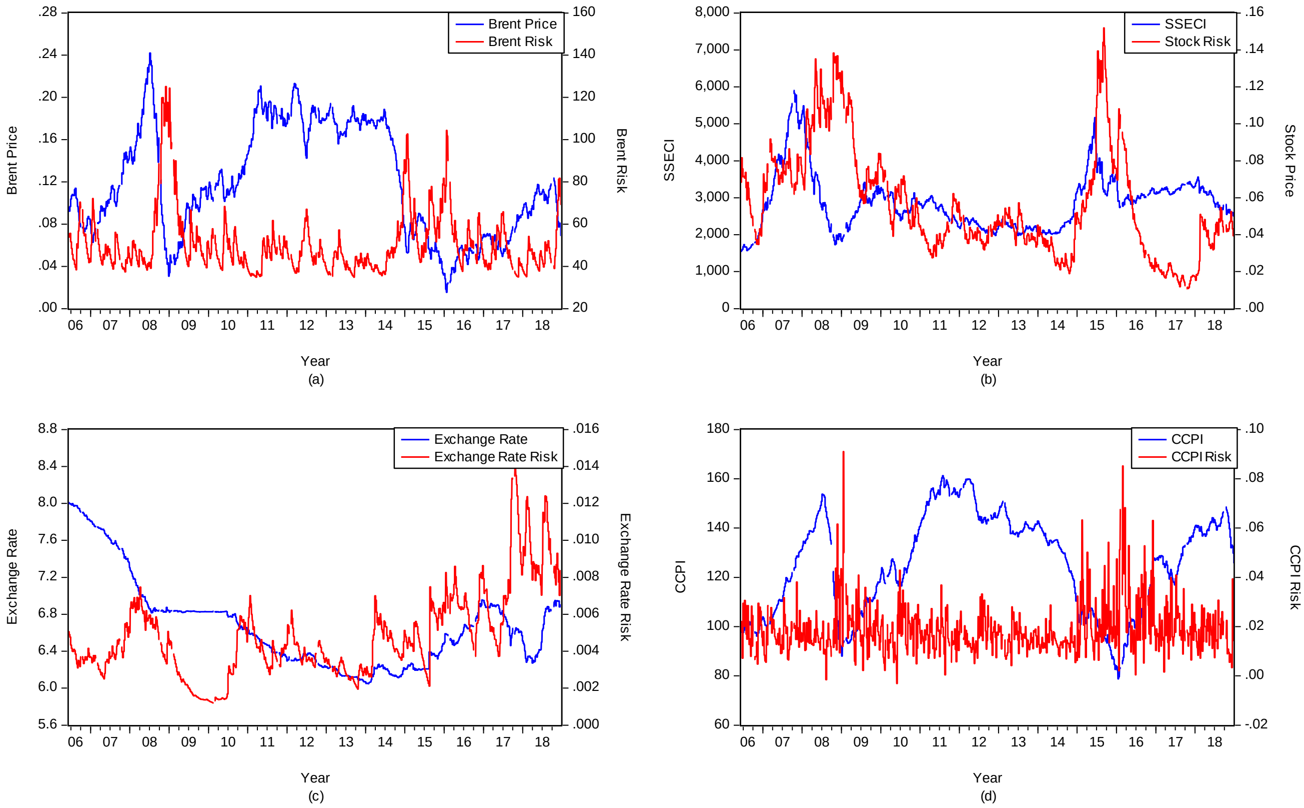

Figure 1. The evolution of the risks of Brent oil, stock, exchange rate and commodity in China.

According to the estimation results above, the 5% risk estimates for Brent spot oil, SSECI, RMB exchange rate and CCPI are plotted in Figure 1. As shown in Figure 1, we observe that there may exist heterogeneous risk spillover effects between international crude oil and China's three major markets. By contrast, the risks of international crude oil and China's commodity markets show a more similar trend, revealing the international oil risk may exert a larger effect on the risk of commodity market in China. In the following context, we will attempt to quantify the risk spillovers originated from international crude oil market to China's three major markets.

5. Estimation results and discussion

5.1. Full-sample results

In this subsection, we will calculate the spillover index to determine the risk spillovers from international crude oil market to China's three major markets. Following the methodology introduced in Section 3.1, a four-variable VAR is firstly estimated, which includes international crude oil risk and the risks of stock, exchange rate and commodity in China in the full sample period. Specifically, we use the Schwarz Criterion to select the lag specification of VAR model. Then, a VAR (3) model (p = 3) and a forecast horizon of 24 weeks (H = 24) are employed to obtain the static DY spillover connectedness which is shown in Table 3.

Table 3. Constant shock table for risks of international crude oil and China's major markets (%).

	Brent	Stock	Foreign exchange	Commodity	From
Brent	91.44	2.61	0.42	5.53	2.14
Stock	1.11	98.18	0.37	0.33	0.45
Foreign exchange	0.51	0.43	98.82	0.24	0.30
Commodity	21.58	0.67	1.30	76.45	5.89
To	5.80	0.93	0.52	1.52	Total = 8.78

Note: This table reports shock matrix with pairwise contribution $\tilde{\theta}_{ij}^{g}$ (shown in Eq (5)) to the variance of 24-week-ahead forecast error decomposition and the sum of *From* and *To* measures for international crude oil market risk and three major market risks in China. The diagonal elements in the matrix show self-contributions.

According to Table 3, we find that there exists significant heterogeneous risk spillover effects transmitted from international crude oil market to China's three major markets. Clearly, the percentage of international crude oil risk in Chinese commodity market risk forecast error variance decomposition reaches a remarkable value of 21.58%, which is much higher than the contribution of China's foreign exchange market (1.30%) and stock market (0.67%), indicating that the risk originating from international crude oil market is a leading driving force of the risk in China's commodity market. By contrast, the international oil risk only accounts for 0.51% and 1.11% of the variability in the risks of China's stock and exchange rate, respectively, suggesting that the international oil risk shocks do not affect much of the risks of China's stock and foreign exchange markets in general.

Additionally, it is observed that the contribution of risk transmission from Chinese commodity market to international crude oil market is 5.53%, which is remarkably higher than that of China's stock market (2.61%) and exchange rate market (0.42%). Overall, there exists a closer interrelationship between the risks of international crude oil and China's commodity market. This is mainly because the primary components of China's commodity market index, such as energy price and basic raw material price, are highly correlated with the fluctuation of international oil price, especially when China developed a closer relationship of its commodity market with the world markets after 2007 [66]. Meanwhile, as the world's second largest economy, the condition of China's commodity market also affects the international oil price to a certain extent.

5.2. Rolling-windows analysis

The DY spillover connectedness analysis in the full sample thus far only investigates the stable impact of global crude oil risk on the macro-financial risks in China. However, given the fact that global oil price as well as the prices of China's three major markets all experienced dramatic changes during the sample period, it would be interesting to look at the dynamic risk spillovers from global crude oil market to China's three major markets. Accordingly, we perform a rolling-windows estimation of the risk spillover effects transmitted from international crude oil market using 100-week rolling window to capture such potential time-varying characteristics.

Figure 2, Figure 3 and Figure 4 depict the directional risk spillovers emanating from international crude oil market to China's stock, foreign exchange and commodity markets, respectively. Overall, it is observed that the impact of international oil price risk on the risks of China's three major markets varies significantly over time. Simultaneously, there is an evidence of heterogeneous risk spillover effects transmitted from crude oil to different markets in China. More specifically, on one hand, it is obvious that the risk spillover effect originated from crude oil to commodity market is always much larger than that of to the stock and exchange rate markets in China, which is line with the static results based on the full sample analysis. On the other hand, there exists various features of dynamic influence of international oil price risk on the risks of China's different markets.

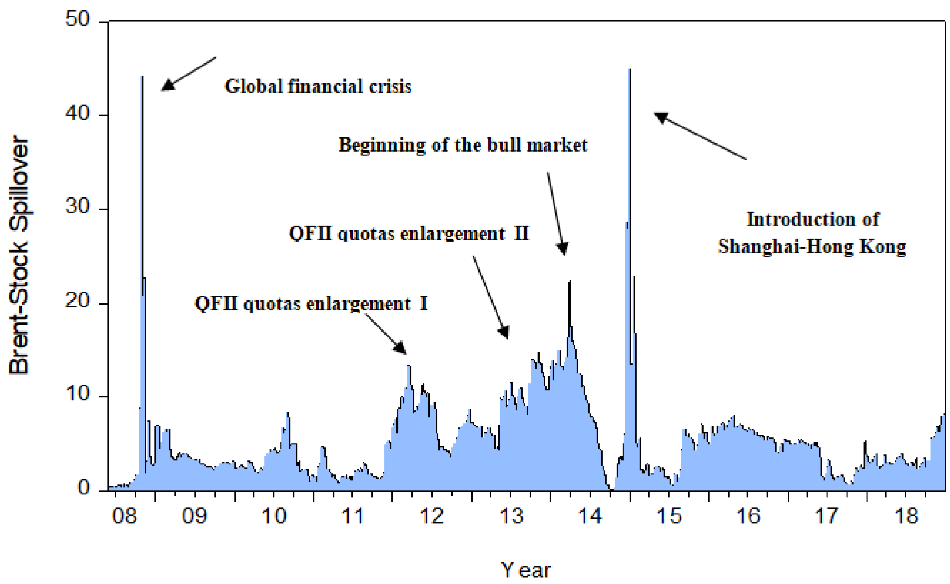

Figure 2. Directional spillovers from international crude oil to stock market in China (%).

Note: The directional spillovers are calculated from the forecast error variance decompositions on 24-week-ahead forecasts, with a 100-week rolling window.

According to Figure 2, it is observed that the international crude oil risk does not have any strong impact on China's stock risk in general. However, it occasionally contributes to the risk of Chinese stock market markedly. More specifically, the contribution of international oil risk shocks to China's stock risk varies over time, ranging from 0.12% to 44.94%. On average, the risk spillover emanating from international oil market only accounts for 5.38% to the risk of China's stock market. Simultaneously, it is reported that the international oil risk shocks always explain less than 10% of the variability of China's stock risks except for the following periods: 1) October 2008 to November 2008; 2) March 2012 to May 2012; 3) June 2013 to May 2014; 4) December 2014 to January 2015.

What's more, we believe that the significant risk spillovers from international crude oil to China's stock market in the above specific periods may be closely associated with the occurrence of some notable events as well as the introduction of several major policies. Specifically, since the global financial crisis triggered after Lehman Brothers bankruptcy, the global oil price risk has improved dramatically and become the primary source of China's stock market risk. It is observed that the contribution of global oil risk reached more than 40% at the end of November 2008. On the other hand, in order to introduce foreign capital to the Chinese equity market, Chinese government implemented several important polices to accelerate the internationalization process of capital market. The Qualified Foreign Institutional Investor (QFII) program was introduced in 2002, which relaxes the cross-trading restrictions, enables qualified foreign institutional investors to enter China's domestic share market directly. In April 2012, Chinese government enlarged the quotas for QFII from $30 billion (issued in 2007) to $80 billion, and further increased it to $150 billion in July 2013. With the progress of stock market liberalization, more foreign capitals flowed into China's capital market, and the external risk shocks originated from international oil market played a more important role in China's stock market risk. This may be the main reason why the contribution of global oil risk to the risk of China's stock market always exceeded 10% during the periods of March 2012 to May 2012 and June 2013 to May 2014. Simultaneously, it is noteworthy that the directional spillover index peaked at about 25% in April 2014, which coincided with the beginning of the super bull market in the Chinese stock exchange during the period 2014–2015. The bull market is likely to attract more foreign investor and capital inflow. As a result, the international oil risk had a significant impact on the risk of China's stock market. Additionally, the launch of the Shanghai-Hong Kong Stock Connect Program in November 2014, which is regrade as an important step in China's capital account liberalization [67], further improved the opening of stock market to the global investment community. In this context, the contribution of risk spillovers from global oil market to China's stock risk exceeded 30% in December 2014 on average, and a peak value of 44.94% was observed at the end of December 2014.

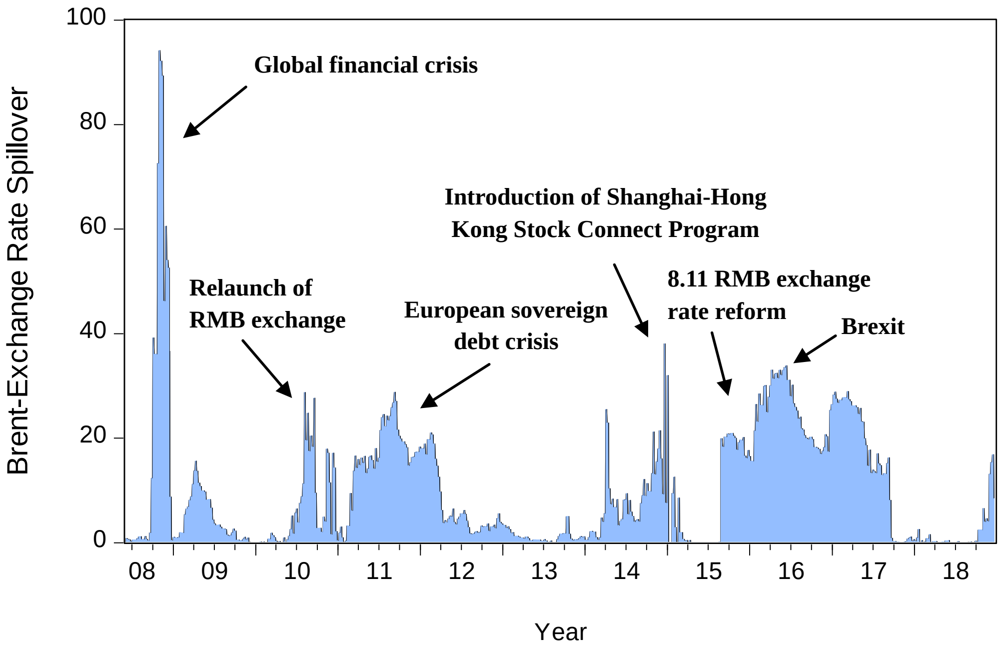

Figure 3. Directional spillovers from international crude oil to foreign exchange market in China (%).

Note: The directional spillovers are calculated from the forecast error variance decompositions on 24-week-ahead forecasts, with a 100-week rolling window.

As shown in Figure 3, the spillovers emanating from international oil risk to exchange rate risk in China are found to fluctuate more dramatically, and the directional spillovers index ranges from 0.01% to 94.35%. Additionally, features of different phases of the risk spillover from international oil market are clearly evident. It is observed that global oil price risk shock always explained more than 15% of the variability in China's exchange rate risk during the following periods: 1) from September 2008 to November 2008; 2) from July 2010 to September 2010; 3) from March 2011 to March 2012; 4) from November 2014 to December 2014; 5) from August 2015 to August 2017.

Similarly, the considerable risk spillover effects transmitted from international crude oil to China's foreign exchange market in these specific periods can be attributed to the occurrence of several notable events in the world as well as financial reforms in China. Due to the global financial crisis, the contribution of risk spillovers from international crude oil to China's foreign exchange market in October and November 2008 reached 68.34% on average, and the highest contribution was observed in the third week of October 2008 (94.35%). The contribution of international crude oil risk fluctuated consistently around 20% during March 2011 to March 2012 in response to the European sovereign debt crisis. In terms of the policy factors, Chinese government relaunched the exchange rate reform to expand the flexibility of RMB in mid-June 2010. Under this background, the external factors played a more dominant role in the fluctuation of China's exchange rate. Accordingly, the contribution of risk spillovers from international oil market to foreign exchange market in China increased significantly during the period of July 2010 to September 2010. Meanwhile, we find that there were several spikes of directional spillover index in November and December 2014 in connection with Shanghai-Hong Kong Stock Connect Program. Finally, on August 11, 2015, Chinese government conducted the so-called '8.11 RMB exchange rate reform' to improve the central parity mechanism of RMB exchange rate and shift RMB exchange rate regime toward a more flexible and market-determined system [68]. Clearly, the directional spillover index had increased remarkably since the reform but the index fluctuated around 25% between August 2015 and August 2017. It is noteworthy that the global oil risk shocks even accounted for over 30% of China's exchange rate risk during the period from April 2016 to June 2016, which should be also in relation with the Brexit.

According to Figure 4, we observe that international oil risk has considerable effects on the risk of China's commodity market. Specifically, during the sample period, the contribution of risk spillovers from international crude oil to China's commodity market reaches 22.63% on average, which is much higher than that to stock market (5.38%) and foreign exchange market (10.41%). Simultaneously, it is seen that the directional spillovers index always fluctuates consistently around high levels. Additionally, it is obvious that the contribution of international oil price risk shock to the risks of China's commodity market had increased dramatically since September 2008, and peaked at 84.72% and 77.99% in the first and fourth week of November 2008, respectively, which can be explained by the outbreak of the global financial crisis. Our empirical results confirm that the increasing international oil risk under the impact of the global financial crisis is the primary source of the risks of all China's stock, foreign exchange and commodity markets, revealing that the risk spillovers transmitted from international oil market make a great contribution to China's macro-financial risks during the period of the global financial crisis.

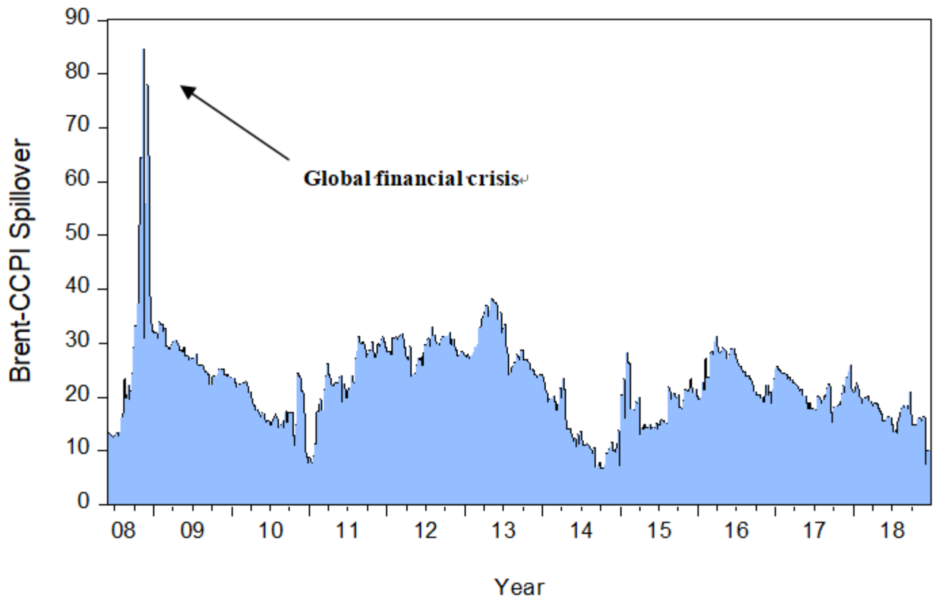

Figure 4. Directional spillovers from international crude oil to commodity market in China (%).

Note: The directional spillovers are calculated from the forecast error variance decompositions on 24-week-ahead forecasts, with a 100-week rolling window.

5.3. Robustness check

In order to check the robustness of the rolling-windows estimation results, several robustness checks are carried out in this study. Specifically, this study investigates whether our results will be affected by the choice of H-step-ahead forecast error variance decompositions and alternative rolling windows width W, following the studies of Ahmad et al. [69], Antonakakis and Kizys [70] and

Gillaizeau et al. [71]. We first allow the forecast horizon *H* to range from 20 to 30 weeks, while holding constant the rolling windows of 100 weeks. The results presented in Figure 5 (*H* = 20, *W* = 100) and Figure 6 (*H* = 30, *W* = 100) are not statistically significantly different from those presented in the baseline (Figures 2–4, *H* = 24, *W* = 100). Second, we utilize alternative rolling windows from 90 to 100 weeks, while holding the forecast period as 24 weeks. The results depicted in Figure 7 (*H* = 24, *W* = 90) and Figure 8 (*H* = 24, *W* = 95) are similar to those shown in Figure 2 to Figure 4, further confirming the validity of the baseline results.

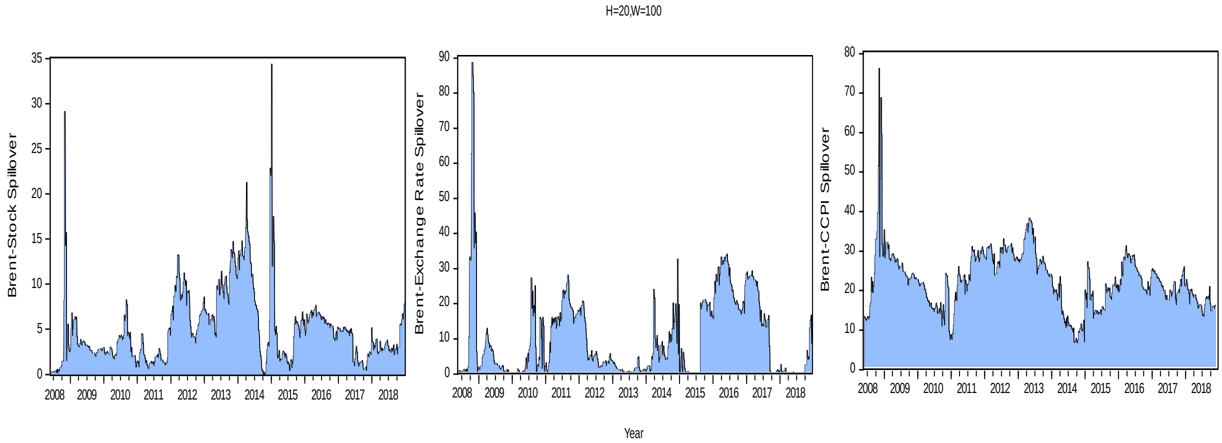

Figure 5. Directional spillovers from international crude oil to China's three major markets (%).

Note: The directional spillovers are calculated from the forecast error variance decompositions on 20-week-ahead forecasts, with a 100-week rolling window.

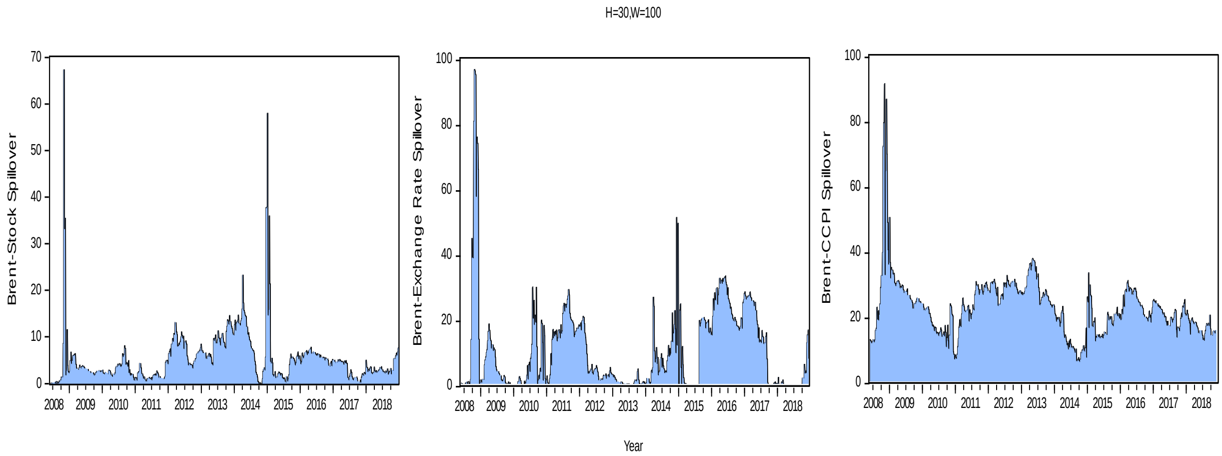

Figure 6. Directional spillovers from international crude oil to China's three major markets (%).

Note: The directional spillovers are calculated from the forecast error variance decompositions on 30-week-ahead forecasts, with a 100-week rolling window.

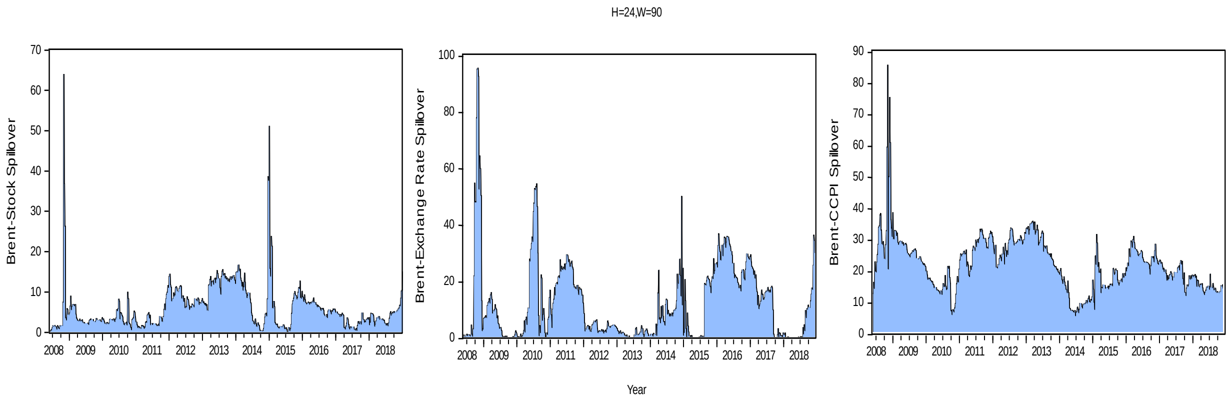

Figure 7. Directional spillovers from international crude oil to China's three major markets (%).

Note: The directional spillovers are calculated from the forecast error variance decompositions on 24-week-ahead forecasts, with a 90-week rolling window.

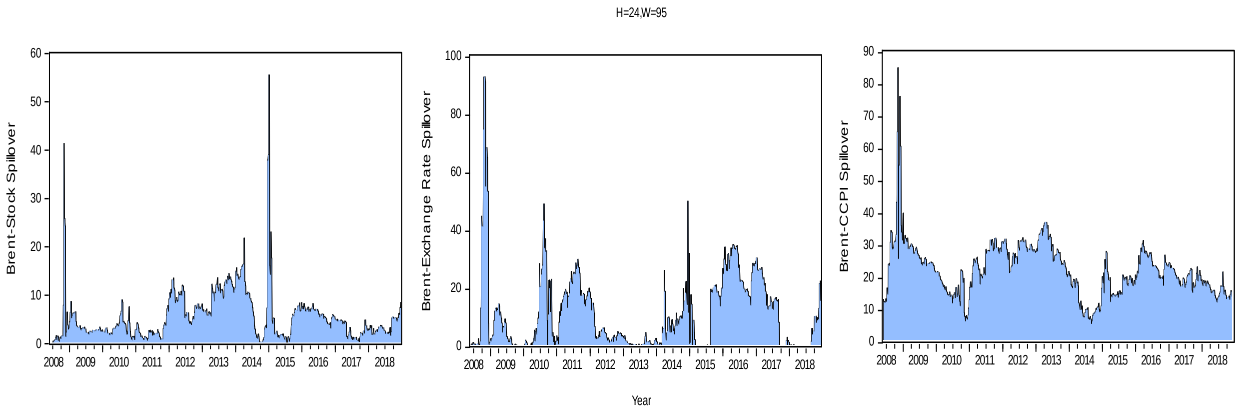

Figure 8. Directional spillovers from international crude oil to China's three major markets (%).

Note: The directional spillovers are calculated from the forecast error variance decompositions on 24-week-ahead forecasts, with a 95-week rolling window.

6. Conclusions

This paper contributes to the empirical literature by systematically investigating the influence of international crude oil risk on Chinese macro-financial risks through quantifying the risk spillovers effects transmitted from international crude oil to China's stock, foreign exchange and commodity markets. More specifically, this paper initially calculates the international crude oil risk as well as the risks of China's three major markets by adopting the CAViaR models, then the spillover index proposed by Diebold and Yilmaz [28] is employed to capture the risk spillovers effects transmitted from international crude oil to China's three major markets.

The empirical results indicate that there exists significant heterogeneous risk spillover effects transmitted from international crude oil market to China's three major markets. To be more specific, the risk derived from international crude oil market is always a dominant driving force of risk in China's commodity market. By contrast, the shocks of global oil risk do not affect much of the risks of China's stock and foreign exchange markets in general.

Additionally, our results further report that international oil risk has considerable effects on China's macro-financial risks during several specific periods, which can be attributed to several major events. Specifically, the risk spillovers originated from international crude oil market remarkably contribute to the risk of China's commodity market during the period of global financial crisis. The significant risk spillovers transmitted from international crude oil to China's stock market were observed during the periods of October 2008 to November 2008, March 2012 to May 2012, June 2013 to May 2014 and December 2014 to January 2015. This is closely associated with the outbreak of the global financial crisis, as well as the implementation of major policies (e.g., the quotas for QFII enlargement and the introduction of Shanghai-Hong Kong Stock Connect Program), which accelerate the liberalization process of China's equity market. With regards to foreign exchange rate market, the global oil price risk shock always makes great contribution to its risk during the periods of September 2008 to November 2008, July 2010 to September 2010, March 2011 to March 2012, November 2014 to December 2014 and August 2015 to August 2017. This should be corresponded with the occurrence of several notable events in the world such as global financial crisis, European sovereign debt crisis and Brexit, as well as major exchange rate reforms and the implementation of Shanghai-Hong Kong Stock Connect Program in China.

The implications of this study are manifold. Firstly, considering that the shocks of global oil risk especially that associated with notable events in the world has a considerable influence on China's macro-financial risks, policy oriented at maintaining the financial stability should not ignore the potential risk spillovers emanating from international crude oil market, particularly when the global oil price experiences a sharp decline. Secondly, given that the risk spillovers from international crude oil to China's commodity market fluctuate consistently around high levels, the international oil price risk should be paid special attention by policymakers and market participants, who concern about the risk of commodity market. Finally, our empirical results indicate that the risk spillovers originated from international crude oil market significantly contribute to the risk of stock and exchange rate markets in China during specific periods, especially when Chinese government implemented the major reform of financial liberalization and opening. Thus, in the process of China's capital account liberalization and RMB internationalization, the authorities should select the opportune moment to avoid the significant influence of international oil price on the stability of China's stock and foreign exchange markets. In term of financial practitioners, it is necessary to conduct portfolio investment decisions and risk management actions dynamically, in light of the condition of the global oil market as well as potential impact of the introduction of relative major policies.

As part of future research, the current paper can be extended into at least two directions. On one hand, this paper just evaluates the risk spillovers effects transmitted from international crude oil to China's three major markets from a macro perspective. We aim to further explore the heterogeneous risk spillover effects of oil market on different sectors of China's stock market as well as the commodity market. On the other hand, it would also be interesting to analyze whether international oil risk has an asymmetric impact on the risks of China's major markets.

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Conflict of interest

The authors declare no conflict of interest.

References

1. Balcilar M, Hammoudeh S, Toparli E (2018) On the risk spillover across the oil market, stock market, and the oil related CDS sectors: A volatility impulse response approach. *Energy Econ* 74: 813–827.
2. Bouri E (2015) A broadened causality in variance approach to assess the risk dynamics between crude oil prices and the jordanian stock market. *Energy Policy* 85: 271–279.
3. Ji Q, Liu B, Fan Y (2019) Risk dependence of CoVaR and structural change between oil prices and exchange rates: A time-varying copula model. *Energy Econ* 77: 80–92.
4. Li X, Wei Y (2018) The dependence and risk spillover between crude oil market and China stock market: New evidence from a variational mode decomposition-based copula method. *Energy Econ* 74: 565–581.
5. Mensi W, Hammoudeh S, Shahzad S, et al. (2017) Oil and foreign exchange market tail dependence and risk spillovers for MENA, emerging and developed countries: VMD decomposition based copulas. *Energy Econ* 67: 476–495.
6. Mensi W, Hammoudeh S, Shahzad S, et al. (2017) Modeling systemic risk and dependence structure between oil and stock markets using a variational mode decomposition-based copula method. *J Bank Financ* 75: 258–279.
7. Pavlova I, De Boyrie ME, Parhizgari AM (2018) A dynamic spillover analysis of crude oil effects on the sovereign credit risk of exporting countries. *Q Rev Econ Financ* 68: 10–22.
8. Shahzad S, Mensi W, Hammoudeh S, et al. (2018) Extreme dependence and risk spillovers between oil and Islamic stock markets. *Emerg Mark Rev* 34: 42–63.
9. Wen D, Wang GJ, Ma C, et al. (2019) Risk spillovers between oil and stock markets: A VAR for VaR analysis. *Energy Econ* 80: 524–535.
10. Du L, He Y (2015) Extreme risk spillovers between crude oil and stock markets. *Energy Econ* 51: 455–465.
11. Hong Y, Liu Y, Wang S (2009) Granger causality in risk and detection of extreme risk spillover between financial markets. *J Econometrics* 150: 271–287.
12. Elyasiani E, Gambarelli L, Muzzioli S (2017) The information content of corridor volatility measures during calm and turmoil periods. *Quant Financ Econ* 1: 454–473.
13. Hamao Y, Masulis RW, Ng V (1990) Correlations in price changes and volatility across international stock markets. *Rev Financ Stud* 3: 281–307.
14. Hong Y (2001) A test for volatility spillover with applications to exchange rates. *J Econometrics* 103: 183–224.
15. Madaleno M, Vieira E (2018) Volatility analysis of returns and risk: family versus nonfamily firms. *Quant Financ Econ* 2: 348–372.
16. Kang W, Ratti RA, Yoon KH (2015) The impact of oil price shocks on the stock market return and volatility relationship. *J Int Financ Mark Inst Money* 34: 41–54.
17. Xu W, Ma F, Chen W, et al. (2019) Asymmetric volatility spillovers between oil and stock markets: Evidence from China and the United States. *Energy Econ* 80: 310–320.

18. Peng C, Zhu H, Guo Y, et al. (2018) Risk spillover of international crude oil to China's firms: Evidence from granger causality across quantile. *Energy Econ* 72: 188–199.
19. Zhang J (2019) Oil and gas trade between China and countries and regions along the 'Belt and Road': A panoramic perspective. *Energy Policy* 129: 1111–1120.
20. Ren YH, Gu WW (2017) The impact on RMB internationalization process: Exchange rate expectation and foreign trade. *Quant Financ Econ* 1:114–124.
21. Babalos V, Stavroyiannis S, Gupta R (2015) Do commodity investors herd? Evidence from a time-varying stochastic volatility model. *Resour Policy* 46: 281–287.
22. Irwin SH, Sanders DR (2011) Index funds, financialization, and commodity futures markets. *Appl Econ Perspect Policy* 33: 1–31.
23. Tang K, Xiong W (2012) Index investment and the financialization of commodities. *Financ Anal J* 68: 54–74.
24. Wen S, An H, Huang S, et al. (2019) Dynamic impact of China's stock market on the international commodity market. *Resour Policy* 61: 564–571.
25. Zhang YJ, Chevallier J, Guesmi K (2017) 'De-financialization' of commodities? Evidence from stock, crude oil and natural gas markets. *Energy Econ* 68: 228–239.
26. Adams Z, Glück T (2015) Financialization in commodity markets: A passing trend or the new normal? *J Bank Financ* 60: 93–111.
27. Cheng IH, Xiong W (2013) The financialization of commodity markets. NBER Working Paper No.19642.
28. Diebold FX, Yilmaz K (2012) Better to give than to receive: Predictive directional measurement of volatility spillovers. *Int J Forecasting* 28: 57–66.
29. Hamilton JD (1983) Oil and the macroeconomy since World War II. *J Polit Econ* 91: 228–248.
30. An Y, Sun M, Gao C, et al. (2018) Analysis of the impact of crude oil price fluctuations on China's stock market in different periods–Based on time series network model. *Physica A* 492: 1016–1031.
31. Atems B, Kapper D, Lam E (2015) Do exchange rates respond asymmetrically to shocks in the crude oil market? *Energy Econ* 49: 227–238.
32. Bildirici ME, Badu MM (2018) The effects of oil prices on confidence and stock return in China, India and Russia. *Quant Financ Econ* 2: 884–903.
33. Chen H, Liu L, Wang Y, et al. (2016) Oil price shocks and U.S. dollar exchange rates. *Energy* 112: 1036–1048.
34. Ghosh S, Kanjilal K (2016) Co-movement of international crude oil price and Indian stock market: evidences from nonlinear cointegration tests. *Energy Econ* 53: 111–117.
35. Kang SH, Mciver R, Yoon SM (2017) Dynamic spillover effects among crude oil, precious metal, and agricultural commodity futures markets. *Energy Econ* 62: 19–32.
36. Khalfaoui R, Boutahar M, Boubaker H (2015) Analyzing volatility spillovers and hedging between oil and stock markets: Evidence from wavelet analysis. *Energy Econ* 49: 540–549.
37. Luo J, Ji Q (2018) High-frequency volatility connectedness between the US crude oil market and China's agricultural commodity markets. *Energy Econ* 76: 424–438.
38. Mensi W, Beljid M, Boubaker A, et al. (2013) Correlations and volatility spillovers across commodity and stock markets: Linking energies, food, and gold. *Econ Model* 32: 15–22.
39. Turhan MI, Sensoy A, Hacihasanoglu E (2014) A comparative analysis of the dynamic relationship between oil prices and exchange rates. *J Int Financ Mark Inst Money* 32: 397–414.

40. Ji Q, Bouri E, Roubaud D, et al. (2018) Risk spillover between energy and agricultural commodity markets: A dependence-switching CoVaR-copula model. *Energy Econ* 75: 14–27.
41. Algieri B, Leccadito A (2017) Assessing contagion risk from energy and non-energy commodity markets. *Energy Econ* 62: 312–322.
42. Wang GJ, Xie C, Jiang ZQ, et al. (2016) Who are the net senders and recipients of volatility spillovers in China's financial markets? *Financ Res Lett* 18: 255–262.
43. Demirer M, Diebold FX, Liu L, et al. (2018). Estimating global bank network connectedness. *J App Econom* 33: 1–15.
44. Wang GJ, Xie C, Zhao LF, et al. (2018) Volatility connectedness in the Chinese banking system: Do state-owned commercial banks contribute more? *J In Financ Mark Inst Money* 57: 205–230.
45. Yi SY, Xu ZS, Wang GJ (2018) Volatility connectedness in the cryptocurrency market: Is Bitcoin a dominant cryptocurrency? *Int Rev Financ Anal* 60: 98–114.
46. Koop G, Pesaran MH, Potter SM (1996) Impulse response analysis in nonlinear multivariate models. *J Econometrics* 74:119–147.
47. Pesaran MH, Shin Y (1998) Generalised impulse response analysis in linear multivariate models. *Econ Lett* 58: 17–29.
48. Engle RF, Manganelli S (2004) CAViaR: Conditional autoregressive value at risk by regression quantiles. *J Bus Econ Stat* 22: 367–381.
49. Qureshi K (2016) Value-at-Risk: The effect of autoregression in a quantile process. arXiv preprint arXiv: 1605.04940.
50. Bernardi M, Catania L (2016) Comparison of Value-at-Risk models using the MCS approach. *Comput Stat* 31: 579–608.
51. Ferraty F, Quintela-Del-Río A (2016) Conditional VAR and expected shortfall: A new functional approach. *Econ Rev* 35: 263–292.
52. Gerlach R, Lu ZD, Huang H (2013) Exponentially smoothing the skewed laplace distribution for Value-at-Risk forecasting. *J Forecasting* 32: 534–550.
53. Gkillas K, Katsiampa P (2018) An application of extreme value theory to cryptocurrencies. *Econ Lett* 164: 109–111.
54. Li ZH, Dong H, Huang ZH, et al. (2018) Asymmetric effects on risks of Virtual Financial Assets (VFAs) in different regimes: A case of bitcoin. *Quant Financ Econ* 2: 860–883.
55. Righi MB, Ceretta PS (2015) Forecasting value at risk and expected shortfall based on serial pair-copula constructions. *Expert Sys Appl* 42: 6380–6390.
56. Whitea H, Kimb TH, Manganelli S (2015) VAR for VaR: Measuring tail dependence using multivariate regression quantiles. *J Econometrics* 187: 169–188.
57. Gong X, Wen F, Xia XH, et al. (2017) Investigating the risk-return trade-off for crude oil futures using high-frequency data. *Appl Energy* 196: 152–161.
58. Chen SL, Liu SM, Cai RJ, et al. (2019) The factors that influence exchange-rate risk: Evidence in China, Emerg Mark Financ Tr.
59. Dong H, Liu Y, Chang JQ (2019) The heterogeneous linkage of economic policy uncertainty and oil return risks. *Green Financ* 1: 46–66.
60. Liao GK, Li ZH, Du ZQ, et al. (2019) The heterogeneous interconnections between supply or demand side and oil risks. *Energies* 12: 2226.

61. An Y, Sun M, Gao CX, et al. (2018) Analysis of the impact of crude oil price fluctuations on China's stock market in different periods—based on time series network model. *Physica A* 492: 1016–1031.
62. Arouri MEH, Jouini J, Nguyen DK (2012) On the impacts of oil price fluctuations on European equity markets: Volatility spillover and hedging effectiveness. *Energy Econ* 34: 611–617.
63. Zhang YL, Wang J (2019) Linkage influence of energy market on financial market by multiscale complexity synchronization. *Physica A* 516: 254–266.
64. Guo J (2018) Co-movement of international copper prices, China's economic activity, and stock returns: Structural breaks and volatility dynamics. *Glob Financ* J 36: 62–77.
65. Zheng X, Chen BM (2014) Identification of stock market forces in the system adaptation framework. *Inform Sci* 265: 105–122.
66. Zhang C, Chen X (2014) The impact of global oil price shocks on China's bulk commodity markets and fundamental industries. *Energy Policy* 66: 32–41.
67. Burdekin RCK, Siklos PL (2018) Quantifying the impact of the November 2014 Shanghai-Hong Kong stock connect. *Int Rev Econ Financ* 57: 156–163.
68. Ruan Q, Bao J, Zhang M, et al. (2019) The effects of exchange rate regime reform on RMB markets: A new perspective based on MF-DCCA. *Physica A* 522: 122–134.
69. Ahmad W, Rais S, Shaik AR (2018) Modelling the directional spillovers from DJIM Index to conventional benchmarks: Different this time? *Q Rev Econ Financ* 67: 14–27.
70. Antonakakis N, Kizys R (2015) Dynamic spillovers between commodity and currency markets. *Int Rev Financ Anal* 41: 303–319.
71. Gillaizeau M, Jayasekera R, Maaitah A, et al. (2019) Giver and the receiver: Understanding spillover effects and predictive power in cross-market Bitcoin prices. *Int Rev Financ Anal* 63: 86–104.