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The dependence and risk spillover between crude oil market and China stock market: New evidence from a variational mode decomposition-based copula method

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ABSTRACT

This paper examines the dependence structure between crude oil market and China stock market over different investment horizons, before and after the recent financial crisis, by combining the variational mode decomposition (VMD) method with various static and time-varying copulas. Based on the decomposed time series and the copula dependence, the Value-at-Risk (VaR), conditional VaR (CoVaR) and delta CoVaR (ΔCoVaR) are quantified to analyze the upside and downside risk spillovers from oil market to China stock market in raw, short- and long-run investment horizons before and after the financial crisis. The empirical results show that, first, the recent financial crisis enhances the dependences between the crude oil market and China stock market, and the long-run dependence increases more significantly than that of short-run. For the raw return series, there are symmetric upper and lower tail dependencies in full sample and pre-crisis subsample periods, but an average dependence in post-crisis subsample period. Second, the VaR of China stock market increases heavily around the financial crisis, but the average VaR after the crisis deceases compared to the risk before the crisis. Third, the risk spillovers from crude oil price to China stock market are found in each sample periods. Before the crisis, however, it mainly exists in long-run horizon, while after the crisis, it happens in both short- and long-run horizons. Finally, the risk spillovers from oil price to China stock market display strong asymmetric features, with larger long-term, downside risk spillovers in post-crisis subsample.

1. Introduction

Crude oil is one of the critical strategic commodities of nearly all the economies of the world. The volatility of crude oil price will affect the world economic development since it serves as an important industrial feedstock and can ultimately influence the price of consumer goods. In recent years, crude oil is more and more financialized with the increasing use of derivatives, such as futures, options and swaps. The inherent connection of crude oil and industry production as well as the financialization of crude oil market make the relationship between oil price and stock market a central issue in economics. With the increasing importance of crude oil price in real economy, policy makers, economists and investors have paid more and more attentions to the complex correlations between oil and stock markets. Furthermore, after jointing the WTO in 2001, the strengthening economic ties between China and the whole world, as well as the rapid economic growth make the crude oil demand for China increasing year by year. China is now the second biggest crude oil consumer in the world with the oil dependency higher than 67% by the end of 2017. As the variation of crude oil price has significant impact on the Chinese economic growth, it is very meaningful for policy makers, investors and researchers to probe the dependence and risk spillover effect between crude oil price and China stock market.

A large body of the literature has documented the small but significantly negative connections between crude oil and stock markets (Sadorsky, 1999; Papapetrou, 2001; Nandha and Faff, 2008; Chiou and Lee, 2009; Miller and Ratti, 2009; Filis, 2010). However, the status of the individual country being either an importer or an exporter is of utmost importance for the oil-stock relationship (Park and Ratti, 2008). In general, an increase in oil prices may have a positive effect on the equity returns of oil-exporting countries (Bjørnland, 2009). However, Arouri and Nguyen (2010) suggest that an increase in oil prices may lead to a decrease in Dow Jones Stoxx600 equity returns of European countries. Furthermore, due to time-varying market fundamentals and different investor trading strategies, the dependences between crude oil price and stock market may vary across bear and bull markets, and across different investment horizons. There are also plenty of the empirical studies dealing with such issues. For example, Berger and Uddin (2016) provide the multiscale dependence schemes

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among equity markets, commodity futures and uncertainty indexes under different investment horizons. Mensi et al. (2017a) investigate the co-movements of oil prices and developed stock markets across different market conditions (bear and bull markets) and under different investment horizons, and quantify the upside and downside short- and long-run risk spillovers between them. However *little is known* about the dependences and risk spillover effects between crude oil and emerging stock markets under different market conditions and investment horizons, especially for the Chinese stock market, which is the largest emerging stock market with increasingly impact on the global financial system. For instance, 436 IPOs happen in Shanghai and Shenzhen stock exchanges in China mainland totally, which is the largest number of IPO cases in the world in 2017. In addition, the 2008 subprime debt crisis shocks the global economy and financial system heavily, and alters the connections between crude oil and developed stock markets (see Wen et al., 2012 and among others). Thus, to compare the quantitative changes of dependence and risk spillover effects between crude oil and emerging stock markets before and after the crisis, especially for China, under different market conditions and investment horizons is also a meaningful topic for practice of financial risk management and hedging strategies. Thus, to get an actual view of the dependences and risk spillovers between crude oil market and China stock market, we think it valuable and reasonable to model them not only in a full-sample standpoint, but also in two separate subsamples, the pre-crisis and post-crisis periods, respectively.

In terms of research methods, many approaches have been used to depict the linkages between crude oil and stock markets. Considering the autocorrelation of return series, VAR or VECM frameworks are often used (Kling, 1985; Cong et al., 2008; Apergis and Miller, 2009). As the improved forms of VAR or VECM model, the time-varying parameter VAR model (Kang et al., 2015; Lu et al., 2017), the Markov switching VAR (Balcilar and Ozdemir, 2013) and the Markov switching vector error-correction model (Balcilar et al., 2015) are also commonly used to investigate the time-varying relationships between oil prices and stock markets. The VAR or VECM framework has the advantages that it is no need to assume endogeneity and exogeneity of the variables and it is able to control for serial correlation in asset returns. However, when Yang et al. (2016) consider a VAR method to examine the cross-correlations between Brent crude oil price and ten sector stock indices in China, they reveal that the VAR model cannot be used to describe the dynamics of the cross-correlations between them. The main defect of the VAR and VECM is that they often assume normality and homoscedasticity for the time series investigated, neglecting the possible stylized fact of fat tails and heteroscedasticity commonly shared in asset returns. Moreover, traditional VAR and VECM models can only be used to capture the linear dependence of asset returns. Whereas the non-linear tail dependence or the asymmetric dependence between upper and lower tails of crude oil and stock markets are well documented in many empirical studies (see for example, Wen et al., 2012; Raza et al., 2016).

As the relationship between asset returns may be non-linear, Longin and Solnik (2001), Bae et al. (2003) and Poon et al. (2004) estimate the tail dependence based on extreme-value theory (EVT); Chesnay and Jondeau (2001) employ Markov regime switching model (MRS) to accommodate the structural break in return variance; Chiang et al. (2007), Sadorsky (2012) and Liu et al. (2017) use the multivariate GARCH models (MVGARCH) to study the correlations between oil and stock markets. It is worth noting that, however, these models are still confronted with several problems. With regard to extreme-value approach, how to define a threshold for extreme observations is a quite arbitrary decision (Rodriguez, 2007). In addition, for Markov switching and multivariate GARCH models, they mainly assume multivariate normality for the return distributions, ignoring the stylized facts of asymmetric and fat-tailed asset returns in crude oil and stock markets.

First, to facilitate all the problems mentioned above, we adopt the variational mode decomposition (VMD) approach and a range of time-invariant, time-varying, symmetric and asymmetric copulas to explore the oil and stock co-movements under different investment horizons. VMD is a method that can decompose the non-stationary signal into couple Intrinsic Mode Functions adaptively and non-recursively (Li et al., 2017). Recently, discrete wavelet transform (DWT) is also combined with copula to model the relationships between financial markets at different investment horizons (Berger, 2015; Berger and Uddin, 2016; Mensi et al., 2017b). Although DWT approach can also decompose the original time series into short- and long-run ones, the VMD method used in this study has at least three advantages over it (Mensi et al., 2017a): (1) DWT is not as adaptive as the VMD technique; (2) DWT requires a pre-determined wavelet function and a scale of decomposition; (3) the number of observations decreases with the level of decomposition, and this negatively affects the linear estimates.

Second, in this paper, a range of time-invariant, time-varying, symmetric and asymmetric copula functions, i.e., Gaussian, Student-t, Gumbel, rotated Gumbel and SJC copulas are used to capture the possible dependence structures between crude oil and the Chinese stock market. Copula functions are introduced by Sklar (1959) and have some important applications in the research of economics and finance over the past years (Cherubini and Luciano, 2002; Reboredo, 2011; Wen et al., 2012; Avdulaj and Barunik, 2015; Aloui et al., 2016; Pircalabu et al., 2017). Copula approach has several superiorities to the VAR, VECM, EVT, MRS or MVGARCH models mentioned above, for example, it can relax the assumption of normality or multi-normality for assets returns held in those traditional models, and can adopt any non-elliptical distributions to describe the return marginal distribution. Furthermore copula functions can model both linear and non-linear dependences, such as upper-tail or lower-tail dependence, i.e. the asymmetric tail dependences.

Last, using the best fitted copula functions, we measure the upside and downside Value-at-Risk (VaR), Conditional VaR (CoVaR) and delta CoVaR (ΔCoVaR) to explore the risk spillovers from crude oil price to China stock market at different investment horizons. The CoVaR proposed by Adrian and Brunnermeier (2011) and generalized by Girardi and Ergün (2013) can capture the risk spillovers from crude oil price to China stock market by providing the VaR of China stock market conditional on the VaR of crude oil market under financial distress. The spillover effects can be tested through the significant difference between CoVaR and VaR using the Kolmogorov-Smirnov (KS) bootstrapping approach proposed by Abadie (2002) and applied by Bernal et al. (2014). Then ΔCoVaR measurement is used as a robustness check to further analyze the asymmetric feature of the risk spillover effects during bear and bull market conditions and at different investment horizons.

This paper contributes to the literature as it not only deals with upside and downside risk spillovers effects and examines the dependence structure between crude oil and China stock market under diverse time horizons (short- and long-run), but also quantifies the changes of the dependence structure and the upside and downside risk spillover effects before and after the recent financial crisis under different investment horizons. The main findings of this study are quite different from the results reported for developed stock market in Mensi et al. (2017a). They are summarized as follows and may have some important implications for risk management and policy making.

(1) In general, the recent financial crisis enhances the dependences between the crude oil market and China stock market. For raw return series, the empirical results based on copula method provide strong evidence of symmetric upper and lower tail dependence between crude oil and China stock market in the full sample period and pre-crisis subsample period, but an average dependence after the outbreak of financial crisis. When considering investment horizons, the average dependence is found in both short- and long-run horizons in each sample periods, but the long-run dependence seems smoother and