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Extreme risk spillovers between crude oil and stock markets

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ABSTRACT

This paper investigates the spillovers of extreme risks between crude oil and stock markets using daily data of the S&P 500 stock index and West Texas Intermediate (WTI) crude oil futures returns. Based on the method of Granger causality in risk, Value at Risk (VaR) is employed to measure market risk, and a class of kernel-based tests is used to detect negative and positive risk spillover effects. Empirical results reveal that there are significant risk spillovers between the two markets. Extreme movements, past or current, in one market may have a significant predictive power for those in the other market. Prior to the recent financial crisis, there are positive risk spillovers from stock market to crude oil market, and negative spillovers from crude oil market to stock market. After the financial crisis, bidirectional positive risk spillovers are strengthened markedly. The risk spillovers may occur instantaneously, and/or with a (long) time delay. Both positive and negative risk spillover effects exhibit asymmetric correlations.

1. Introduction

Controlling and monitoring market risk is an important issue for investors, policymakers and academic researchers. This is because huge risk usually implies extreme market movements that could lead to substantial capital changes and even economic recessions. Due to the increasing trend of economic and financial integration, it is commonplace that the current and past risk in one market can generate or affect risk in another market. The mechanism of how risk spillover occurs across different markets is always of great concern to financial market participants.

Crude oil and stock markets play crucial roles in economic development and investment decisions. Considerable transmission of risk may exist between the two markets. In theory, crude oil returns could be derived from the implications of stock returns for real economic conditions. Meanwhile, given the nontrivial importance of oil to the world economy, the reaction of stock market to crude oil shocks could be justified by changes in real cash flows and expected returns. In addition to market fundamentals, market contagion and speculative dynamics (i.e., fads, investor sentiment, and overreaction to news) are also possible reasons for the risk spillovers.

In recent years, increasing empirical studies have found significant links between crude oil and stock market returns.[1] However, these studies mainly focus on the conditional mean and the conditional variance which cannot disclose the whole picture of risk relations. It is well known that the mean and the variance are only two elements of an overall summary for the conditional distribution of returns. In the risk investigation, we are interested in the relations of distribution tails, either left for downside risk or right for upside risk. If the distributions involved are fat tailed as is to be expected with financial returns, a tail area relation may be quite different (Jeong et al., 2012).

Currently a few studies have used copula models to investigate the risk dependence between crude oil and stock returns.[2] For example, Geman and Kharoubi (2008) estimate copula functions between crude oil futures and the S&P500 stock index from May 1990 to August 2006, and find that when the S&P 500 index was declining extremely,

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[1] See, for example, Jones and Kaul (1996), Sadorsky (1999), Papapetrou (2001), Huang, et al. (2005), Basher and Sadorsky (2006), Cong et al. (2008), Nandha and Faff (2008), Park and Ratti (2008), Aloui and Jammazi (2009), Apergis and Miller (2009), Kilian and Park (2009), Miller and Ratti (2009), Filis, et al. (2011), Masih, et al. (2011), Vo (2011), Zhang and Chen (2011), Zhu et al. (2011), Arouri et al. (2012), Basher et al. (2012), Jammazi (2012), Li, et al. (2012), Lee et al. (2012), and Ciner (2013).
[2] e.g., Geman and Kharoubi (2008), Aloui et al. (2013), Nguyen and Bhatti (2012), Wen et al. (2012), and Zhu et al. (2014).

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the crude oil market was increasing extremely, and vice versa; Wen et al. (2012) find significantly increasing tail dependence between crude oil and the U.S. stock market after the occurrence of the recent financial crisis. Strong evidences are provided in favor of contemporaneous dependence of risks between crude oil and stock returns. Several important issues still remain to be solved.

First, the copula approaches do not uncover lagged effects at the *risk* level. In fact, there are theoretical underpinnings for risk spillovers with a time delay. Given the growing evidence of time-variation in expected returns, past price movements of crude oil could affect current expected stock returns (Jones and Kaul, 1996). Besides, it usually takes time for investors to interpret information, make decision and take action. Therefore, it appears natural to ask questions about the risk relations at (higher) lags.

Second, contemporaneous dependence is hard to specify the causality (in the Granger sense) of risk transmissions. The bridge between crude oil and stock markets is economic and financial activities. Therefore, the direction of causation can help understand how economic information is transmitted across the two markets. Of course, it also has valuable implications for predicting and monitoring risks.

Third, the prior empirical works are often concerned about downside and upside risk dependence. The downside (upside) risk dependence refers to a relation between downside (upside) risks across markets. Obviously, these two types of risk dependence stand out based on a default assumption of positive correlation between market returns. However, as often mentioned in the literature, crude oil and stock markets might be negatively correlated (See Jones and Kaul, 1996; Hammoudeh and Li, 2005; Park and Ratti, 2008; Kilian and Park, 2009; Basher et al., 2012; Mollik and Assefa, 2013 etc.). Kilian and Park (2009) suggest that the response of aggregate stock returns may differ greatly depending on the cause of the oil price shock. The negative response of stock prices to oil price is found when the price of oil rises due to concerns about future crude oil supply shortfalls. Considering this situation, this paper points out that risk spillovers from crude oil to stock markets exhibit negative relations. For instance, downside (upside) risk in crude oil could spill over to the stock markets, generating upside (downside) risk in stock returns. To what extent these types of risk spillovers exist is an empirical question.

Addressing these issues, this paper comprehensively investigates both contemporaneous and lagged correlations of extreme movements, namely the risk spillovers between crude oil and stock markets. The nature of causality relations at the risk level is examined by the econometric method developed by Hong et al. (2009). Value at Risk (VaR) is employed to measure extreme market risk, and then a class of kernel-based tests is used to detect four types of Granger causality in risk between the two markets. The econometric method used in this paper has a number of appealing features. The VaR calculation nowadays is a very popular measure of price risks. Compared with those experiential measures in the literature, such as Hamilton's (1996) normalized oil variable (NOPI), VaR provides a standardized statistical way to capture huge price movements. Conventional tests using a large number of lags have low power because of loss of a large number of degrees of freedom. In contrast, the kernel-based statistical tests can check a large number of lags that ensures a good power.

In order to investigate the possible negative effects of risk spillovers, we first follow Fan et al. (2008) to introduce a notion of upside risk to capture extreme increase in market returns. The reason is that crude oil, as a special commodity, has its own traits of market risk. When crude oil price returns increase extremely, the crude oil buyers may incur losses, and business profits tend to decrease, which may in turn affect the stock market. Then, we define two types of negative risk spillovers in each causality direction. From stock to oil, for instance, down-to-up risk spillover captures the effects of stock downside risk on oil upside risk, and up-to-down risk spillover captures the effects of stock upside risk on oil downside risk. To the best of our knowledge, this is the first study that focuses on the dynamics of negative risk relations between crude oil and stock markets.

Our study is based on a daily-based dataset of the WTI crude oil and the S&P500 stock index from September 1, 2004 to September 11, 2012. Several interesting findings are summarized as follows.

(1) Risk spillovers between crude oil and stock markets are statistically and economically significant. On one side, downside risk of the S&P500 significantly Granger causes similar risk of the WTI during normal periods. It is a positive risk spillover effect. On the other side, WTI downside (upside) risk Granger causes S&P500 upside (downside) risk, which are negative risk spillover effects. This implies that extreme movements, past or current, in one market may have a significant predictive power for those in the other market.
(2) Risks are usually transmitted quickly. Substantial spillovers also occur with a time delay. Particularly, the spillover effect of upside risk in crude oil market could be significant within one month. This proves the vital necessity of investigating risk spillovers at (higher) lags.
(3) After the occurrence of the financial crisis, the structure of risk spillovers is changed. Positive risk spillovers between the two markets are strengthened markedly. It indicates that the origin of oil shocks is an important determinant of the risk spillovers.
(4) Asymmetric behaviors are found in both negative and positive spillover regions. Market participants are more vulnerable to downside risks in the short run. The asymmetric effects in a negative risk spillover aspect enrich findings in the literature.

Our empirical findings demonstrate the necessity of emphasizing negative correlations and lagged effects in a study of risk relationship between crude oil and stock markets. The two types of negative risk spillovers, along with the downside and the upside risk spillovers, can cover all facets of the risk relationship between the two markets. The lagged effects of risk spillovers shed light on the Granger causality relations in risk which help understand how information is transmitted between the two markets. From the perspective of actual practices, crude oil and stock markets are highly associated at the risk level. Awareness of the dynamics (or Granger causality) of risk transmissions will motivate market traders to accurately gauging and effectively guarding against extreme risks in the future, and also support the scientific decision makings of governmental departments for energy purchase and storage.

The rest of this paper is organized as follows. In Section 2, we introduce the notion of various Granger causality in risk and the methodology of econometric tests. Section 3 presents the data and their descriptive statistics. Section 4 provides empirical results, and Section 5 concludes.

2. Methodology

2.1. VaR estimation

Value at Risk (VaR) is a widely used quantitative measure of extreme downside market risk. For a given time period horizon and confidence level of $100(1-\alpha)\%$, VaR is defined as the maximum amount that can be lost with probability α. The conventional definition of VaR involves the downside risk, so it is called as downside VaR. For a given time series of returns Y_t, the downside VaR, denoted by $V_t(down)$, is written as

$$P(Y_t < -V_t(\text{down})|I_{t-1}) = \alpha \tag{1}$$

where $I_{t-1} = \{Y_{t-1}, Y_{t-2}, \ldots\}$ is the information set available at time $t-1$. Mathematically, the downside VaR is the negative of α-quantile of conditional probability distribution of Y_t.What makes VaR approach