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Measuring contagion between energy market and stock market during financial crisis: A copula approach

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ABSTRACT

In this paper, we apply time-varying copulas to investigate whether a contagion effect existed between energy and stock markets during the recent financial crisis. Using the WTI oil spot price, the S&P500 index, the Shanghai stock market composite index and the Shenzhen stock market component index returns, evidence was found for a significantly increasing dependence between crude oil and stock markets after the failure of Lehman Brothers, thus supporting the existence of contagion in the sense of Forbes and Rigobon's (2002) definition. Moreover, increased tail dependence and symmetry characterize all the paired markets. This indicates that significant increases in tail dependence are an actual dimension of the contagion phenomenon and that crude oil and stock prices are linked to the same degree regardless of whether markets are booming or crashing during the sample period. Finally, the contagion effect is found to be much weaker for China than the US. The empirical results have potentially important implications for risk management.

1. Introduction

The relationship between energy and stock markets is a central issue in energy economics. With the increasing importance of oil price in the economy, policy makers, economists and investors have paid more attention to correlations between energy and stock markets. Many recent papers have documented small but significantly negative connections between crude oil and stock markets (Chiou and Lee, 2009; Filis, 2010; Miller and Ratti, 2009; Nandha and Faff, 2008; Oberndorfer, 2009; Park and Ratti, 2008). Additionally, Geman and Kharoubi (2008) found that investors tend to introduce crude-oil futures into an equity portfolio because of the remarkable rise in crude-oil prices over the past few years and the low, negative correlation between crude oil and stock markets. However, will these co-movement patterns of crude oil and stock markets be retained during the recent financial crisis?

Generally, the financial crisis will cause asset prices to plunge across markets and will create speculative runs and capital flight, leading to considerable market instability. Moreover, it will produce a huge loss of confidence of investors, which will jeopardize economic growth. As the transmission of a shock across markets is hard to explain based on changes in macroeconomic fundamentals, many researchers use the word "contagion" to refer to this phenomenon and focus on measuring contagion by providing evidence of a significant increase in cross-market linkages. Thus, to discover the co-movement patterns of crude oil and stock markets during the recent financial crisis, it is necessary to test whether such a contagion effect exists between the markets.

Very little of the existing empirical research has aimed at analyzing the contagion effect between crude oil and stock markets during a financial crisis. Although some very recent papers discuss the evolution of correlations between commodities and financial assets in a period that includes the failure of Lehman Brothers and its aftermath (Buyuksahin and Robe, 2010; Lautier and Raynaud, 2011; Silvennoinen and Thorpy, 2010; Tang and Xiong, 2010), their focus was not on the contagion effect between crude oil and stock markets during the recent financial crisis. For example, Buyuksahin and Robe (2010), Silvennoinen and Thorpy (2010) and Tang and Xiong (2010) stressed how financialization of commodities affects the linear correlations between different commodities or the correlations between commodities and financial assets, while Lautier and Raynaud (2011) focused on integration in energy-derivative markets. In spite of this, it is worth noting that these studies provide a sound background for investigating the contagion effect between crude oil and stock markets during the recent crisis. First, Lautier and Raynaud (2011) used a graph theory to investigate integration in energy-derivative markets with a sample taken between 2000 and

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2009. They found crude oil to be at the center of the graph, linking with both agriculture products and financial assets, so it is the best candidate for the transmission of price shocks. We could thus identify the crude-oil market as the source of turmoil delivered to stock markets during the recent financial crisis. Second, Buyuksahin et al. (2010) showed that equity and commodity markets could behave like a "market of one" in times of extreme events. Buyuksahin and Robe (2010) and Tang and Xiong (2010) both found that the commodity–equity correlations significantly increased after the demise of Lehman Brothers in September 2008. Silvennoinen and Thorpy (2010) reported that all of the oil futures returns series switched to a high correlation with US stocks (around 0.4, from low negative levels) largely in step, during high stock-market volatility, with a sustained increase during the "08–09" period. Thus, it is reasonable for us to expect a contagion effect between crude oil and stock markets during the recent financial crisis. Finally, Buyuksahin and Robe (2010) found that a time dummy for the crisis period was always highly significant among the variables explaining commodity–equity correlations. They suggested that further study is needed to explain this dummy. By this token, analysis of the contagion effect between energy and stock markets seems urgently required.

By contrast, the literature on the relationship between crude oil and stock markets primarily discusses the effect of crude-oil shock on stock returns before the recent financial crisis, and does so mostly within a VAR or VECM framework (Apergis and Miller, 2009; Cong et al., 2008; Filis, 2010; Huang et al., 1996; Jones and Gautam, 1996; Miller and Ratti, 2009; Park and Ratti, 2008). VAR or VECM models do indeed have some advantages. For instance, they are quite simple and flexible for modeling the relationship between markets; there is no need to assume endogeneity and exogeneity of the variables; they are able to control for serial correlation in asset returns; and it is easy to observe the interactions between variables from the equations of the models. We can thus ascertain the effect of oil price in one market on another market via an impulse-response function. However, these models also have some disadvantages. They often assume that asset returns follow normal distributions, neglecting the stylized facts, which means that we cannot obtain time-varying correlations considering heteroskedasticity with them. Moreover, they cannot capture non-linear dependence or changes in the tails of asset returns curves. VAR or VECM may thus not be suitable for measuring the contagion effect between markets.

The question of which model is the best for measuring the contagion effect between markets is, in fact, constantly being considered by researchers. To date, many different modeling techniques have been used to investigate the contagion effect between financial markets, mainly between stock markets across a country, but these methods all seem to have some drawbacks. Studies during the 1990s were mostly conducted around the notion of correlation breakdown: a statistically significant increase in correlation during the crash (Calvo and Reinhart, 1996; King and Wadhwani, 1990; Ramchand and Susmel, 1998). Soon afterwards, some authors argued that tests for contagion based on the correlation coefficient were inadequate. The correlation coefficient doesn't consider conditional heteroskedasticity (Boyer et al., 1999; Forbes and Rigobon, 2002; Longin and Solnik, 2001) and it is a linear measure that is inappropriate if contagion is an event that is characterized by non-linear changes of market association (Bae et al., 2003). The authors above were unable to reach a consensus about the very existence of contagion, motivating researchers to continue to search for more accurate methods to address the issue. For example, as contagion may be a non-linear phenomenon, Bae et al. (2003), Chan-Lau et al. (2004), Longin and Solnik (2001) and Poon et al. (2004) based models on extreme-value theory to estimate the tail dependence; Ramchand and Susmel (1998) and Chesney and Jondeau (2000) both employed Markov switching models to accommodate the structural break in variance; and Chiang et al. (2007) explored bivariate GARCH models for studying the contagion effect, as these models consider the heteroskedasticity problem and provide a mechanism to trace the time-varying correlations between markets. Conversely, Rodriguez (2007) pointed out the potential shortcomings of extreme-value models in that there is always discretion when defining an extreme observation. Boyer et al. (1999) suggested that the choice of sub-samples on the basis of high and low volatility is both arbitrary and subject to selection bias. Moreover, Markov switching models and multivariate GARCH models often assume a fit to bivariate normality. This assumption neglects the stylized facts of asset returns and ignores the non-linearity of the contagion phenomenon.

To overcome the limitations evident in the literature, this paper employs time-varying copulas (similar to the method used in energy economics: e.g. Bastianin, 2009; Westner and Madlener, 2012) to study the contagion effect between crude oil and US/Chinese stock markets during the recent financial crisis. In comparison with the methods discussed above, the advantages of the copula method are obvious. By not assuming the bivariate normality of asset returns, copula functions allow us to consider the marginal distribution and build a more-effective joint distribution so that the functions contain all the information about the joint behavior of the random variables; copulas can describe non-linear dependence, while correlation is only a linear measure of dependence; and by not using discretion to define extreme observations, copulas can also exhibit rich patterns of tail behavior, making it possible to test whether periods of increased dependence are also characterized by changes in tails.

The main findings of this paper are summarized as follows and may have important implications for risk management and policy making.

(1) Using WTI oil spot prices, the S&P500 index, the Shanghai stock market composite index and the Shenzhen stock market component index, evidence has been found for a significantly increasing dependence between crude oil and stock markets since the failure of Lehman Brothers. The result demonstrates the existence of contagion in the sense of Forbes and Rigobon's (2002) definition: a significant increase in cross-market linkages after a shock to one country (or a group of countries). It also answers the question of whether crude oil and stock markets will continue to have a low, negative correlation in a period of financial crisis: the existence of a contagion effect means that the benefits of diversification will diminish.
(2) Consistent with Rodriguez (2007), the paper also holds that increased tail dependence is an actual dimension of contagion between crude oil and stock markets. It indicates that relying on tail independence or neglecting changes in tail dependence may lead to underestimation of financial risk during a crisis.
(3) The conditional dependence structure between crude oil and US/Chinese stock markets is described more adequately by the DCC Student-*t* copula; thus, lower and upper tail dependencies were symmetric over the sample period, which implies that crude oil and US/Chinese stock prices were linked to the same degree regardless of whether markets were booming or crashing.
(4) Concordant with the International Energy Agency's (IEA) conclusion that China is one of the two nations least affected by the global recession, the empirical results show that the contagion effect was much weaker for China than for the US; thus, China is expected to lead the world's economic growth and growth in energy demands.
(5) Awareness and knowledge of the contagion effect between crude oil and stock markets can assist regulatory authorities to make more effective policies to guard against market risks. This can also guide governments in determining suitable purchase and storage of energy, especially the US and China, the two biggest energy consumers in the world.