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Can asymmetric conditional volatility imply asymmetric tail dependence?

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A B S T R A C T

In this article, we investigate two types of asymmetries, that is, the asymmetry of conditional volatility and the asymmetry of tail dependence in the crude oil markets. We employ the two different sample datasets in which each dataset covers the time period of stable and unstable oil prices, individually. A variety of different copulas and three asymmetric GARCH regression models are used in order to capture the two types of asymmetries. In particular, we extend the TBL-GARCH model proposed by Choi et al. (2012) to the asymmetric GARCH regression type model. The findings from the two different approaches are congruent, in that there is no asymmetry of tail dependence and no asymmetric conditional volatility in crude oil returns over the two different sample periods. Our study reconfirms the findings of Aboura and Wagner (2016) by showing that asymmetric conditional volatility relates to asymmetric tail dependence.

1. Introduction

Crude oil is one of the most important commodities affecting economic activities. In particular, a better understanding of crude oil markets would be crucial for portfolio allocation and risk management and asset pricing in practice. Crude oil markets closely move together. Thus, it is important to consider that financial market agents consider such co-movement, in particular, upper and lower tail dependencies of oil prices across the different crude oil markets. The analysis of the dependence structure could allow them to have portfolio selection and hedging strategies. It is also crucial to understand the volatility of the oil prices because persistent changes in volatility can expose the crude oil market participants to risk.

The relationship between oil returns and trading volume has received considerable attention in the literature. Abba Abdullahi et al. (2014) investigate the impact of trading volume on crude oil returns for the WTI and Brent market, individually. They find the congruent results that neither returns nor trading volume contain any important information to forecast the variance of the other in either market from the variance decomposition analysis. Moosa et al. (2003) find bi-directional causality between the two variables in the WTI market. However, Bhar and Hamori (2005) show the unidirectional relationship by using the AR-GARCH model such that oil returns lead trading volume in the same oil market. Asche et al. (2003) also find the relationship between crude oil and refined product markets by using multivariate Johansen tests. Tong et al. (2012) find some evidence of the asymmetry in the propagation of crisis or bubble between crude oil and refined petroleum markets.

The purpose of this article is to propose an approach using the asymmetric conditional volatility that can imply asymmetric tail dependence. We reconfirm the findings of Aboura and Wagner (2016). By extending the model of Choi et al. (2012), we deliver a model setting, where asymmetric volatility relates to asymmetric tail dependence.[1] In order to illustrate the economic implications of the effect, this study turns to an energy market application over two different sample periods for stable and unstable oil prices. We investigate two types of asymmetries: the asymmetry in tail dependence between West Texas Intermediate (WTI) and Brent crude oil returns and the asymmetry in volatility of the WTI returns conditional on the Brent returns.

Our contribution to the literature is twofold. First, our study provides reconfirmation of the findings in Aboura and Wagner (2016) by using relatively new techniques: copulas and asymmetric generalized autoregressive conditional heteroskedasticity (GARCH) regression models. This article shows a clear relationship between the two apparently different asymmetries. Unlike Aboura and Wagner (2016), we consider asymmetric conditional volatility rather than asymmetric volatility by using three different asymmetric GARCH regression models. Second, we extend the Threshold-Bilinear GARCH (TBL-GARCH) proposed by Choi et al. (2012) to the asymmetric

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[1] See Aboura and Wagner (2016), who provide a review of asymmetric volatility characteristics in detail.

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TBL-GARCH regression model. The method is simple, yet it is powerful and flexible enough to investigate the asymmetric conditional volatility.

The relationship between the asymmetry of conditional volatility and the asymmetry of tail dependence in the crude oil markets has important implications for hedgers and energy policymakers. Market participants can find available alternatives to hedge the possible risk, and regulators can anticipate their oil policy effectiveness in the market. We find symmetric tail dependence for crude oil returns. The link between crude oil returns indicates that the crude oil markets are highly intergraded. Also, dependence does not change in times of extreme upward or downward market movements, indicating that a shock in one market is fully transmitted to the other market. This finding provides important implications for risk management in that investments in the crude oil markets offer limited risk diversification because the markets boomed and crashed together. Energy policymakers should know that conditional volatility and tail dependence respond to the same information flow in the crude oil markets.

An extensive literature well documents both asymmetric volatility and asymmetric tail dependence in the equity and bond markets. For example, Junker et al. (2006) study dependence in the term structure of U.S. Treasury yields by using various copula functions. The transformed Frank copula shows best overall fit in their study. They find upper tail dependence and zero lower tail dependence in yield shocks. In addition, they show that normal copula function systematically provides substantial bias of up to 6% in the portfolio value-at-risk application. Conditional dependence is also examined in the literature such as U.S. dollar exchange rate returns (Patton, 2001) and international stock market returns (Rockinger and Jondeau, 2001).

Bekaert and Wu (2000) provide a framework to investigate volatility asymmetry at both the market and firm level simultaneously. Then, they apply the model to the portfolio level constructed from the Nikkei 225 index. The empirical application shows that the main determinant of asymmetric volatility in the equity market is volatility feedback instead of leverage effects. From their empirical findings, they argue that "the leverage effect" is a misnomer and "asymmetric volatility" would be more appropriate. There is also extensive literature on the study of the relationship between returns and conditional volatility (see Engle et al. (1987), Engle and Ng (1993) and Braun et al. (1995)).

Aboura and Wagner (2016) investigate asymmetric volatility for the S & P 500 and VIX index returns and document contemporaneous asymmetric effect. They provide empirical evidence that substantial equity market declines can be partially explained by extreme volatility feedback. However, they could not find directional causality between returns and volatility in either way. Their main finding is that the extreme asymmetric volatility effect exists, as they show volatility-return tail dependence during the market stress. Our study reconfirms this finding in that there is a relationship between the asymmetry of the conditional volatility and the asymmetry of tail dependence.

The existing studies investigate the link between oil returns and other financial asset returns, such as stock returns, exchange rate returns, and interest rates. For example, Chen and Chen (2007) show a cointegrating relationship between oil prices and exchange rates. Akram (2004) finds a non-linear relationship between oil prices and the Norwegian exchange rate. Wu et al. (2012) examine the tail dependence of crude oil and the U.S. dollar exchange rate. In addition, Cologni and Manera (2008) and Arora and Tanner (2013) provide empirical evidence of co-movement between oil prices and interest rates. The previous empirical literature presents the negative relationship between oil price returns and stock returns, such as Filis (2010), Chen (2010) and Miller and Ratti (2009). Sadorsky (1999) finds that oil price volatility has impacts on the U.S. real stock returns and Oberndorfer (2009) shows a similar effect of oil price volatility on European stock markets.

Batten et al. (2015) examine the degree of integration between financial markets and commodity markets by using an asset pricing framework. They find that emerging market investors benefit from positive risk adjusted returns for gold and rice markets. In addition, Gérard et al. (2003), Chi et al. (2006) and Jeon et al. (2006) study the degree of integration between stock and world markets. Basher and Sadorsky (2016) examine volatility dynamics, conditional correlations and hedge ratios between oil and other various assets, such as stock, VIX, gold, and bonds by using multivariate GARCH models. They find empirical evidence of a positive asymmetric volatility of oil prices. Also, their study suggests that oil is the most effective hedge for emerging market stock prices. Khalfaoui et al. (2015) focus on the mean and volatility spillovers and hedging between WTI crude oil and stock market prices for the G-7 countries. Their empirical results show time-varying correlations and volatility spillover effects across markets. Arouri and Nguyen (2010) examine the short-term linkage between oil price changes and stock returns. They find that the reaction of stock returns to oil price shocks considerably varies across disaggregated sector level.

The more recent studies on the oil and stock market relationship include Balcilar et al. (2017) and Batten et al. (2017). Balcilar et al. (2017) investigate the short- and long-run co-movement of the S & P 500 and WTI oil prices. In particular, the framework of common cyclesand common trends is employed. They find that the two financial assets share a commonstochastic trend from 1859 to 2015, and common cycle exists only during the post-World War II period. Their empirical analysis also provides evidence that the short-run oil price isdetermined by transitory shocks, and the stock market is affected by permanent shocks inshort- and long-runs. Batten et al. (2017) examine the link between a stock market and anenergy portfolio, consisting of coal, natural gas, and oil. They find time-varying integrationbetween individual stock markets and the energy portfolio in Asia. This finding impliesthat benefits can arise for Asian stock market investors by successfully hedging the commonfactor caused by energy price risk.

There is a limited amount of recent literature on using copulas to study dependence across financial markets. Chang (2012a) investigates both the interdependence between spot and futures returns and the individual dynamic process of the return series. Li and Yang (2013) attempt to find the relationships between the volatility of rubber futures and the oil index via the copula-based GARCH model. Other studies focus on the dependence structure and co-movements in stock markets using copulas. See Mensah and Alagidede (2017) for the dependence structure across African stock markets and Nguyen et al. (2016) for the dependence structure of dependency between gold and stock markets.

While the above literature focuses on the dependence structure and co-movements, we utilize the copula approach in order to assess asymmetry in the dependence structure between crude oil markets. The asymmetry of tail dependence in Uhm et al. (2012) is a case in which the level of dependence at the upper tail is not equal to the level of dependence at the lower tail. Tong et al. (2013) find asymmetry in tail dependence between crude and heating oil returns and between crude oil and jet fuel returns by using the asymmetric copulas. Reboredo (2011) employs various copula models with time-invariant and time-varying dependence structures and finds no evidence of asymmetric tail dependence between different crude oil spot market prices for WTI, Brent, Dubai, and Maya.

To study the asymmetry of tail dependence between WTI and Brent crude oil returns, we specify a joint model for dependence with various dependence structures. For example, the Normal copula has no tail dependence, the Clayton copula has lower tail dependence, the Plackett copula has symmetric tail dependence, the Frank copula has symmetric tail dependence, the Gumbel copula has upper tail dependence, the Student-*t* copula has symmetric tail dependence, and the symmetrized Joe-Clayton (SJC) copula by Patton (2006) allows for asymmetric tail dependence and nest symmetry as a special case.

One of the well-established features in the financial time series is