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Volatility regimes, asymmetric basis effects and forecasting performance: An empirical investigation of the WTI crude oil futures market

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ABSTRACT

This study employs a flexible regime-switching EGARCH model with Student-t distributed error terms to investigate whether volatility regimes and basis affect the behavior of crude oil futures returns, including the conditional mean, variance, skewness, kurtosis as well as the extent of heavy-tailedness. The study also examines whether volatility regimes and asymmetric basis effects can improve the forecasting accuracy. The main merit of the empirical model is that the basis effect is allowed to be asymmetric and to vary across volatility regimes. Empirical results suggest that the conditional mean and variance respond to the basis asymmetrically and nonlinearly, and that the responses of transition probabilities to the basis are symmetric. Furthermore, the conditional higher moments are sensitive to the absolute value of basis, and the heavy tailed characteristic can be greatly alleviated by taking into account the asymmetric basis effects and regime switches. Finally, the regime switches and asymmetric basis effects play decisive roles in forecasting return, volatility and tail distribution.

1. Introduction

The price of crude oil plays a decisive role in global economic and financial stability. The negative relationship between oil price and output growth is due to factors underlying the positive relation between oil price and price level (Alvarez et al., 2011; Chen, 2009a, 2009b; Taylor, 2000) and the negative relation between price level and economic growth (Barro, 1996; Fischer, 1993; Friedman, 1977; Pindyck, 1991).[1] An increase in oil price and the uncertainty of price movements will reduce future cash flows, resulting in decreased stock prices and financial system instability.[2] Consequently, understanding the dynamics of oil prices is important for market participants, such as government authorities, oil importers and investors. The purpose of this paper is to investigate the time series behavior of the crude oil futures market, and to examine the effects of regime switches and the basis on the precision of return forecasts, volatility forecasts and Value-at-Risk (VaR) forecasts.

In recent years, the issue as to whether the crude oil markets have stylized facts observed in the stock markets, such as volatility asymmetric effects, regime switching effects, time-varying skewness, kurtosis and fat-tailed distribution, and basis effects, has received a great deal of attention. Rather than use symmetric GARCH-type specifications (Agnolucci, 2009; Hung et al., 2008; Kang et al., 2009; Lien and Yang, 2008), Giot and Laurent (2003), Sadorsky (2006), Fan et al. (2008), Chang et al. (2009) and Cheong (2009) use the asymmetric GARCH-type model to investigate the oil market volatility, in order to explore the distinct response of volatility to positive and negative innovations of equal magnitude.

It is well documented that variations in energy prices increase extraordinarily when the energy market undergoes critical events, such as military conflicts (the Gulf War in 1990, the Iraq War in 2003, etc.), economic crises (the Asian financial crisis in 1997, the financial tsunami in 2008, etc.) and environment changes (e.g., cold weather in 1996).[3] To take this feature into account, the GARCH-type volatility models have to be extended to allow the volatility to change between two different dynamic processes. Studies such as those by Fong and See (2002, 2003), Alizadeh et al. (2008), Vo (2009) and Nomikos and Pouliasis (2011) have demonstrated that the energy price shows two distinct volatility patterns, namely, high and low volatility

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[1] Studies, including Lardic and Mignon (2008), Jimenez-Rodriguez (2008,2009), Zhang (2008), Cologni and Manera (2009), have documented the adverse effect of oil price on output growth.

[2] Some recent studies have shown that oil shock will reduce stock prices. See, for example, Aloui and Jammazi (2009) and Chen (2010).

[3] See the WTRG Economics website (http://www.wtrg.com/prices.htm) for an exhaustive explanation of the causes of energy price fluctuations.

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regimes, and that the occurrences of high volatility regimes are coincident with episodes of energy market turbulence.

Another important issue in the existing literature relates to the distribution assumption. In the traditional GARCH-type specifications without regime shift effects, replacing the normal distribution by the heavy-tailed distributions is the most popular approach for describing the distribution of oil price returns. Empirical studies, including those by Giot and Laurent (2003), Fan et al. (2008), Hung et al. (2008), Agnolucci (2009) and Cheong (2009), demonstrate that in terms of the VaR forecasts, the fat-tail distribution can capture the occurrence of extreme oil prices more successfully than the normal distribution. Another widely used specification for analyzing energy price behavior is combining the regime-switching GARCH effects and the assumption of normal distributed error terms (see, for instance, Vo, 2009; Nomikos and Pouliasis, 2011).[4] Vo (2009) shows evidence that the regime-switching model has better volatility performance than the GARCH model. Nomikos and Pouliasis (2011) support the superiority of the regime-switching model in calculating VaR forecasts. Moreover, in order to give the regime switching model more flexibility in data fitting, Fong and See (2002, 2003) investigate the WTI (West Texas Intermediate) oil futures market by using the student t distribution instead of the normal distribution. They indicate that the regime-switching GARCH model with student-t distributed error terms has superior volatility forecasting ability. Unfortunately, the performance of density forecasts is not discussed in their papers.

The basis, which is defined as the difference between the logarithms of spot and futures prices, reflects the inconsistent price movement between spot and futures markets. According to the cost of carry theorem, the basis can also be regarded as the disequilibrium adjustment term.[5] For example, Bekiros and Diks (2008), Lien and Yang (2008), Huang et al. (2009) and Chang et al. (2010) find that the basis is an important factor in explaining the time series behavior of crude oil returns. Alizadeh et al. (2008) demonstrate that the effects of the basis on returns are associated with the volatility of energy prices.

Another strand of literature investigates the influence of the basis on conditional variance. For example, Huang et al. (2009) discover that the volatility of crude oil prices becomes larger when the basis is positive.[6] Alizadeh et al. (2008) find that the oil market belongs to the low volatility regime as the absolute value of basis approaches zero. On the other hand, Kogan et al. (2009) demonstrate that, from the viewpoint of production side, there is a V-shaped relationship between the slope of the term structure and the volatility of oil futures prices; that is, the asymmetric effect exists. Lien and Yang (2008) use the bivariate GARCH model to investigate whether the basis has asymmetric effects on oil price volatility. They find that both a positive and negative basis will lead to an increase in volatility and that the former has a stronger effect than the latter. On the other hand, Nomikos and Pouliasis (2011) indicate that the squared value of the basis has a significant and positive effect on the volatility of the WTI crude oil market only in the low volatility regime, not in the high volatility regime. Contrary to studies that focus on the impact of the basis on the conditional mean and variance, Fong and See (2002, 2003) examine its effects on the probabilities that the crude oil market will stay in high and low volatility states. They find that when the basis rises, the transition probabilities of high and low volatility states increase. The response of high volatility probability to the basis is larger than that of low volatility probability.

Although Fong and See (2002, 2003), Alizadeh et al. (2008) and Nomikos and Pouliasis (2011) have used the Markov switching specification to examine the effects of basis on the conditional mean, or on the conditional variance or on the transition probabilities, they ignore the possible asymmetric effects of the basis on the dynamics of the conditional mean and variance. The second drawback is that they do not discuss the asymmetric effect of unobserved innovations on volatility. The third disadvantage is that they overlook the impact of an asymmetric basis and regime switches on higher order moments and conditional density. Subsequently, they do not analyze simultaneously the importance of the two factors mentioned above on the return forecasts, volatility forecasts and VaR forecasts.

The aim of this study is to respond to the abovementioned drawbacks. The paper adopts a variation of the Markov switching EGARCH model to investigate the impact of volatility regimes and basis effects on the dynamics of WTI crude oil futures returns and on forecasting precision. To the best of the author's knowledge, the empirical model used here is the first one to simultaneously discuss at least five important issues of interests. First, this paper explores whether there is an asymmetric response of volatility to shocks and whether the asymmetric response relies on the volatility behavior of futures returns. Secondly, it investigates whether and how the basis asymmetrically affects the conditional mean, conditional variance and transition probabilities. Thirdly, the study analyzes the relationship between the basis and the third and fourth conditional moments. Fourthly, this paper investigates whether the basis and volatility regimes provide important information that can help the researcher assess the degree of fat-tailedness in the futures return distribution. Lastly, the study analyzes the accuracy of the flexible regime-switching model in predicting the one-step-ahead return, volatility and VaR.

The paper is organized as follows. The following section (Section 2) introduces the econometric model. It also introduces the regime-dependent news impact curve and basis impact curve. Section 3 provides the parameter estimation results and then reports the state-dependent asymmetric error effects and basis effects. Section 4 analyzes the relationship between the basis and conditional higher order moments. The effect of basis and regime switches on the fat-tailedness of the distribution and the forecasting performance will also be discussed here. Finally, Section 5 provides the conclusions.

2. The regime switching EGARCH model

2.1. Model specification

To take the possible asymmetric effects of the basis and shock into account, this study uses a variation of the Markov switching EGARCH model of Perez-Quiros and Timmermann (2001), Aloui and Jammazi (2009) and Henry (2009); it can be expressed as

$$r_t = a_{s_t} + b^+_{s_t} B^+_{t-1} + b^-_{s_t} B^-_{t-1} + \varepsilon_t \tag{1}$$

$$\varepsilon_t \Big| I_{t-1} \sim t\left(0, h_{t,s_t}, \nu\right) \tag{2}$$

$$\ln\left(h_{t,s_t}\right) = \omega_{s_t} + \alpha_{s_t} \frac{|\varepsilon_{t-1}|}{\sqrt{h_{t-1}}} + \beta_{s_t} \ln(h_{t-1}) + \lambda_{s_t} \frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}} + \theta^+_{s_t} B^+_{t-1} + \theta^-_{s_t} B^-_{t-1} \tag{3}$$

where r_t refers to the futures return, h_{t,s_t} refers to the state-dependent conditional variance, I_{t-1} refers to the information set, $B^+_t = \max$

[4] A great deal of research has examined the macroeconomic and financial data by employing the regime switching model with normal distribution (e.g., Cologni and Manera, 2009; Garcia and Perron, 1996; Gray, 1996; Hamilton, 1989; Kanas, 2008b; Kawata and Kijima, 2007; Marcucci, 2005).

[5] See, for example, Kanas (2008a) and Lien and Yang (2006, 2010).

[6] Alizadeh and Nomikos (2004) and Chen and Tsay (2011) demonstrate that the basis has a significant influence on the conditional variance of stock returns.