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Interpreting the movement of oil prices: Driven by fundamentals or bubbles?

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ABSTRACT

Based on the historical data of crude oil, diesel and gasoline markets during November 2001–December 2015, this paper employs the state-space model and log-periodic power law (LPPL) model to explore the dynamic bubbles of oil prices and predict their crash time. The results indicate that, first, oil price bubbles only exist during November 2001–July 2008, and crude oil and diesel prices are significantly driven by bubbles, whereas gasoline prices are mainly driven by fundamentals. Second, the state-space model captures the time-varying bubbles of crude oil and diesel prices. Finally, the LPPL model well predicts the crash time of bubbles.

1. Introduction

As a crucial commodity, oil proves to be of great importance in both economic growth and financial markets. First, oil price generally has a negative and non-linear effect on economic growth, and usually acts as a predictor variable in economic growth (Kilian, 2008; Narayan et al., 2014). The effect of high oil prices on economic activities lies in that the purchasing power has shifted from the oil-importing to oil-exporting countries through the financial asset market and trade channel (Narayan et al., 2014). Specifically, the oil-importing countries suffer a significant reduction of purchasing power and endure significant downward pressure on economic growth (Leung, 2010; Narayan and Narayan, 2007), while the oil-exporting countries increase the income (Brook et al., 2004). Second, the changes in oil prices may effectively predict stock market returns, especially the stock returns of oil producers (Driesprong et al., 2008; Narayan and Sharma, 2011; Phan et al., 2015a, 2015b, 2015c). Besides, the oil market is profitable (Narayan et al., 2015).[1] Both investors in oil producer sectors and in oil consumer sectors can make profits by designing proper trading strategies,[2] especially the strategies fully considering the information on the future's market (Westerlund et al., 2015; Narayan et al., 2013b).

Since the 21st century, oil has become a more significant indicator in economic and financial domain. At the same time, oil prices have experienced drastic fluctuations. Specifically, there exist a collective upsurge of oil prices in the sub-sample periods from 2001 to mid-2008 and from 2009 to 2011 while a sharp drop in the sub-sample period from mid-2014 to 2015. However, exploring the significant driver of oil price fluctuations is a vital and complex issue. As a commodity, in theory, the movement of international oil price is essentially influenced by the fundamentals (such as global oil demand and production) (Kilian, 2009); however, oil also has strong financial and political properties; for instance, oil futures have been a profitable channel in the financial market (Westerlund and Narayan, 2013) and geopolitics in main oil-exporting regions usually affects oil price fluctuations (Makin et al., 2014). Hence some non-fundamental factors (such as speculation, geopolitics and US dollar exchange rate) also contribute a lot to oil price movement (Wang and Wu, 2012; Zhang and Zhang, 2015), which often lead oil prices to deviate from the fundamentals. According to the most widely recognized definition of bubbles, if the asset prices are deviated from the fundamentals, we can say that there exist bubbles (Stiglitz, 1990). Hence, we can define the main drivers of oil price movement into bubbles and fundamentals.

Unfortunately, the significant drivers of oil price fluctuations are always controversial. Especially from November 2001 to July 2008, several types of oil prices experienced a collective upsurge. Specifically, the monthly spot prices of WTI crude oil, Brent crude oil, diesel and gasoline have increased 579%, 606%, 509% and 517% during the period, respectively. However, the controversy on the drivers of crude oil price rise during 2001 to mid-2008 is ongoing, and the empirical results are unambiguous. Some experts hold that the fundamentals (especially the strong oil demand in the advanced economies and emerging economies) drive the increasing surge of international oil prices (Hamilton,

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[1] According to Narayan et al. (2015), the profits are calculated as the raw returns minus the transaction costs that are paid whenever the trading position is changed.

[2] In order to make profit, usually there are two main kinds of strategies, i.e., applying moving averages to design trading (sell or buy) behaviors and using momentum-trading rules.

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2008, 2009; Kilian, 2009; Kilian and Hicks, 2013). In contrast, some other experts insist that the oil price surge is influenced more by non-fundamentals, and there exist bubble components in the nominal oil prices, which may be mainly caused by active speculation (Zhang, 2013; Sornette et al., 2009; Zhang et al., 2008; Wu and Zhang, 2014; Kesicki, 2010).

To detect the existence of oil price bubbles, many approaches have been proposed. Different from the common approach that detects oil price bubbles by identifying the fundamentals (Zhang and Wang, 2015; Zhang et al., 2015), the log-periodic power law (LPPL) model works by diagnosing the super-exponential behavior (growth in positive bubbles and decline in negative bubbles) in asset prices along with the log-periodic oscillations (Johansen et al., 2000). Compared with the definition of fundamentals as the trend growth of stock prices (Narayan et al., 2013a), the demand–supply fundamentals, in the context of the LPPL model, are processes of sustainable changes (growth or decline); while the bubbles are processes of unsustainable changes in which price series are gradually pushed to a critical point (Sornette and Cauwels, 2014). The crucial ingredient that drives unsustainable change process is positive feedback which consists of imitation and herb behaviors.[3] Specifically, imitation sets off self-reinforced behaviors which can be formulated by the super-exponential behavior (growth or decline) (Sornette and Andersen, 2002), while herb causes log-periodic oscillations for the price dynamics in a potential bubble (Geraskin and Fantazzini, 2013).

However, existing methods for testing the super-exponential behaviors are basically expressed from a static and average perspective, and may fail to dynamically measure oil price bubbles. In view of this, we extend the existing D test approach proposed by Zhou and Sornette (2009) into a dynamic one (i.e., the improved D test approach below) by using the state-space model, which proves to be an efficient and excellent tool for identifying the time-varying super-exponential behaviors for oil prices. Combining the improved D test approach with log-periodicity detection, we can distinguish potential oil price bubbles; and then by employing the LPPL model, we can further describe the evolving path of oil price bubbles.

Therefore, in this paper, we dynamically detect the existence of oil price bubbles during 2001–2015. Meanwhile, we also would like to explore whether the significant drivers of diesel and gasoline price fluctuations are in line with crude oil price fluctuations, given that diesel and gasoline are the downstream products of crude oil thus from the perspective of oil supply chain, there may exist close intrinsic relationship among their price movements. The empirical results in this paper will be conducive to market investors and policy makers: (1) to better understand the drivers of the fluctuant prices of oils (including Brent crude oil, WTI crude oil, diesel and gasoline) and their different pricing mechanisms; (2) to comprehend the influence of bubbles on the four types of oil prices; and (3) to shape more targeted regulatory policies for oil market traders so as to evade the market extreme risks to a larger extent.

The remainder of the paper is structured as follows. Section 2 proposes the related literature review. Section 3 provides methods and data definitions. Section 4 presents the empirical results and discussions. Then Section 5 offers the conclusions along with some important policy implications.

[3] There are no positive feedback mechanisms in the standard financial models, and the change of oil prices is assumed to follow a stochastic proportional process, fuelled by the mechanism of compound returns or interest rates; when the financial model involves positive feedback, the dynamics change sharply, and the change rate is not constant, but starts growing itself, which makes the prices follow a super-exponential change until the price reaches the critical point and the model breaks down (Sornette and Cauwels, 2014).

2. Related literature review

Asset price bubble is not a new topic but has been shed light upon by numerous studies (Narayan et al., 2013c). Among them, the widely applied methodologies mainly include the momentum threshold autoregressive (MTAR) model (Engle and Granger, 1987), the Supremum Augmented Dickey Fuller (SADF) approach (Phillips et al., 2011), the Markov regime switching model (Driffill and Sola, 1998) and the log-periodic power law (LPPL) model (Johansen et al., 2000). Each of them has their own characteristics and functions in empirical studies.

The Momentum Threshold Autoregressive (MTAR) model tends to estimate whether there exists a periodically collapsing bubble by testing the asymmetries of deviation from the long-term equilibrium relationship. For example, Payne and Waters (2007) concentrate on the equity REIT market, and detect the periodically collapsing bubbles originally proposed by Evans (1991), by means of the MTAR model and the residual-augmented Dickey–Fuller (RADF) test. Vishwakarma (2013) employs the MTAR model to examine the existence of a periodically collapsing bubble in the real estate market in India. Similarly, Bohl (2003) studies the US stock market using the MTAR model and argues that the sub-sample 1871–1995 cannot be well explained by the periodically collapsing bubbles, and there exist periodically collapsing bubbles during the sample period 1871–2001. However, we cannot obtain the time series of bubbles with the MTAR model, and the results are difficult to validate.

Similarly, the Supremum Augmented Dickey–Fuller (SADF) approach is also widely used for detecting the existence of price bubbles. For instance, Gutierrez (2011) applies the SADF approach to the Nasdaq stock price index and Case–Shiller house price index, and finds speculation in both indexes. However, it seems that the empirical results by the SADF approach are fairly sensitive to the sample period selection. For example, Homm and Breitung (2012) do not find significant bubbles from January 1995 to June 2008, no matter using the monthly, weekly or daily data. Nevertheless, Phillips and Yu (2011) focus on the period from January 1990 to January 2009, and the results indicate that oil price bubbles appeared from March to July 2008. Therefore, the robustness of the SADF approach needs to be improved, and the corresponding results are far less definite.

Meanwhile, some studies identify price bubbles by means of the regime switching model. For example, Zhang and Wang (2015) confirm the existence of oil price bubbles during 2003–2012 by investigating the regime switching processes of the fundamental prices and market trading prices of WTI crude oil. Similarly, Lammerding et al., (2013) combine the state-space model with Markov regime switching model to measure the bubbles in oil prices, and find solid evidence for the presence of bubbles. However, there is certain ambiguity in the regime switching model; that is, although we may reject the null hypothesis that there does not exist a bubble, we cannot eliminate the probability of wrong setting. For example, Driffill and Sola (1998) examine the bubbles in the US stock market and the empirical results indicate that the goodness-of-fit of the regime switching model without bubbles is similar to that of a bubble model without regime switching. Therefore, the nonlinear characteristic identified by the regime switching model is likely from the nonlinear setting of the model.

Comparatively, the LPPL model proposed by Johansen et al. (2000) and Sornette (2003) has been well recognized to measure the dynamic process of asset bubbles, and it is powerful for predicting the crash time of bubbles. According to the LPPL model, the traders have two actions, i.e., buying and selling. In addition, the trading actions of the traders are influenced by those of other traders and the external environment (Geraskin and Fantazzini, 2013). As a result, the non-linear positive feedback causes unsustainable processes, which are defined as bubbles. Positive feedback consists of self-similar herb and self-reinforced imitation. The self-similar phenomenon can be described by the log-periodic oscillations (Saleur and Sornette, 1996). Besides, the self-reinforced