Energy Policy 65 (2014) 729–742

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Volatility persistence in crude oil markets

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HIGHLIGHTS

- We study the impact of outliers on volatility persistence of crude oil markets.
- We identify outliers and patches of outliers due to specific events.
- We show that outliers can bias (i) the estimates of the parameters of GARCH models, (ii) the regularity and non-negativity conditions of GARCH-type models, (iii) the detection of structural breaks in volatility of crude oil markets.

ARTICLE INFO

Article history:
Received 22 October 2012
Accepted 14 October 2013
Available online 19 November 2013

Keywords:
Crude oil
Volatility persistence
Structural breaks

ABSTRACT

Financial market participants and policy-makers can benefit from a better understanding of how shocks can affect volatility over time. This study assesses the impact of structural changes and outliers on volatility persistence of three crude oil markets – Brent, West Texas Intermediate (WTI) and Organization of Petroleum Exporting Countries (OPEC) – between January 2, 1985 and June 17, 2011. We identify outliers using a new semi-parametric test based on conditional heteroscedasticity models. These large shocks can be associated with particular event patterns, such as the invasion of Kuwait by Iraq, the Operation Desert Storm, the Operation Desert Fox, and the Global Financial Crisis as well as OPEC announcements on production reduction or US announcements on crude inventories. We show that outliers can bias (i) the estimates of the parameters of the equation governing volatility dynamics; (ii) the regularity and non-negativity conditions of GARCH-type models (GARCH, IGARCH, FIGARCH and HYGARCH); and (iii) the detection of structural breaks in volatility, and thus the estimation of the persistence of the volatility. Therefore, taking into account the outliers on the volatility modelling process may improve the understanding of volatility in crude oil markets.

1. Introduction

The price of crude oil is one of the most important global economic indicators. Policy-makers, producers, consumers and financial participants monitor its behavior. Since the end of the 1990s oil prices have been steadily increasing, reflecting rising demand for crude oil, particularly from developing nations. Oil prices have been very volatile, changing their trajectories and behavior with respect to the economic situation. Understanding the behavior of volatility in crude oil prices is important for pricing financial assets, for implementing hedging strategies and for assessing regulatory proposals to restrict international capital flows. For example, changes in volatility can affect the risk exposure of producers and industrial consumers of oil. These changes may alter their respective investments in oil inventories and facilities for production and transportation.

Crude oil prices are characterized by high volatility and some drastic shocks, such as the day Operation Desert Storm with a negative return of −34% for WTI (Askari and Khrichene, 2008; Larsson and Nossman, 2011). Financial market participants and policy-makers can benefit from a better understanding of how shocks can affect volatility over time, especially whether the shocks are persistent or short lived. Autoregressive conditionally heteroscedastic (ARCH) models introduced by Engle (1982) and extended to generalized ARCH (GARCH) by Bollerslev (1986) have been developed to capture the two most important stylized facts of crude oil returns (e.g., Cheong, 2009; Kang et al., 2009; Mohammadi and Su, 2010; Wei et al., 2010; Arouri et al., 2012; Hou and Suardi, 2012; Salisu and Fasanya, 2013), which are heavy-tailed distribution and volatility clustering. According to these models, the information available in a period is important for predicting future variance. It is interesting to consider how the available information affects forecast uncertainty as the forecast

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0301-4215/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.enpol.2013.10.042

horizon increases, in other words, the degree of persistence. Persistence in the variance of a random variable evolving through time refers to the property of momentum in conditional variance; past volatility explains current volatility.

As underlined by Aragó and Fernandez-Izquierdo (2003), the degree of persistence of the variance has evident economic implications, arising from the effect that this aspect has on the predictability of their future value. Poterba and Summers (1986) argue that, for multiperiod assets such as stocks, shocks have to persist for a long time for a time-varying risk premium to be able to explain the large fluctuations observed in the stock market. Likewise, this aspect is important in the valuation of options, since the shocks that permanently influence the variance will affect their price to a greater degree than those that are temporary. This aspect can have a direct influence on dynamic hedging policies that try to minimize the risk of the hedged position with futures contracts, since the value of that ratio will depend on the capacity to predict the variance of the futures contract correctly (Wilson et al., 1996). Traders who participate in both the cash and futures markets choose a hedging strategy that reflects their risk and return preferences. The risk and return of the portfolio depend on the hedge ratio. An optimal hedge ratio is one that minimizes the variance of the hedged portfolio return. The time-varying hedge strategy depends critically on the predictability of the future variances and, consequently, assumes no sudden changes in the variance of the series.

However, financial markets are subject to specific events that have a dramatic impact on modelling financial time series (e.g., Balke and Fomby, 1994; Charles and Darné, 2005; Bali and Guirguis, 2007). This type of event includes, for example, oil shocks, wars, financial slumps, changes of policy regimes, natural disasters. Due to their unpredictable nature and large impact on financial relationships, these extraordinary events are referred to as (infrequent) large shocks and are often identified as outliers. The occurrence of such type of shocks may have undesirable effects on the estimates of the parameters of the equation governing volatility dynamics (e.g., van Dijk et al., 1999; Ng and McAleer, 2004; Charles, 2008), the tests of conditional homoscedasticity (e.g., van Dijk et al., 1999; Carnero et al., 2007), and the out-of-sample volatility forecasts (e.g., Franses and Ghijsels, 1999; Carnero et al., 2007; Charles, 2008). To the best of our knowledge, there is no study that takes into account the presence of outliers in crude oil markets when modelling the volatility of crude oil markets with GARCH-type models. Indeed, Cheong (2009), Kang et al. (2009), Mohammadi and Su (2010), Wei et al. (2010), Arouri et al. (2012), Hou and Suardi (2012), and Salisu and Fasanya (2013) do not take into account the outliers when they model and forecast crude oil volatility. In this paper we thus detect outliers in the crude oil returns before we attempt to identify the variance changes. The large shocks in volatility of the Brent, OPEC and WTI crude oil prices are identified from a new semi-parametric test for additive outliers in GARCH models proposed by Laurent et al. (2013). We determine when these (positive and negative) large changes in volatility of daily returns occur. We try to associate the date of each additive outlier with a specific (economic, political or financial) event that occurred near that date, and many of them seem to be associated with the same event patterns. We find that large shocks in volatility of the crude oil prices are principally due to the Iran–Iraq war, the invasion of Kuwait by Iraq, the Operation Desert Storm, the Operation Desert Fox, and the Global Financial Crisis as well as OPEC announcements on production reduction or US announcements on crude inventories.

To model the volatility persistence in crude oil markets we use different GARCH-type models which capture short and long memory, namely GARCH, IGARCH, FIGARCH and HYGARCH models.[1] As suggested by Ng and McAleer (2004) and Conrad (2010) who advise that the regularity and non-negativity conditions "are a first inevitable check of model validation", we check these conditions for the GARCH-type models and find that some GARCH, FIGARCH and HYGARCH models do not satisfy the regularity and non-negativity conditions when the outliers are taken into account, suggesting that outliers can bias these conditions.

Further, financial markets are periodically subject to sudden large shocks, such as the financial crisis. These types of shocks can cause abrupt breaks in the unconditional variance of returns and are equivalent to structural breaks in the parameters of the GARCH processes governing the conditional volatility of returns. It is well known that these shocks can bias the estimated persistence of volatility (see, e.g., Lamoureux and Lastrapes, 1990; Mikosch and Starica, 2004; Hillebrand, 2005; Krämer and Azamo, 2007). Wilson et al. (1996), Ewing and Malik (2010), Kang et al. (2011), Vivian and Wohar (2012) and Arouri et al. (2012) analyze sudden changes in oil prices from the iterative cumulative sums of squares (ICSS) algorithm developed by Inclán and Tiao (1994) and Sansó et al. (2004).[2] They find mixed results in the presence or not of variance changes in crude oil markets. Recently, Rodrigues and Rubia (2011) study the size properties of ICSS algorithm for detecting structural breaks in variance under the hypothesis of additive outliers. Their results indicate that neglected outliers tend to bias the ICSS test. We use the modified ICSS test proposed by Sansó et al. (2004) to identify breakpoints and sudden shifts in volatility and do not find structural breaks in the volatility when taking into account the outliers, whereas structural breaks in volatility are found from the original series.

Therefore, taking into account the outliers in the volatility of crude oil markets is very important for modelling because they can bias (i) the estimates of the parameters of the equation governing volatility dynamics; (ii) the regularity and non-negativity conditions of GARCH-type models; and (iii) the detection of structural breaks in volatility. Finally, it seems that the volatility of crude oil markets is more affected by outliers (or patches of outliers) than by structural breaks. Further, the IGARCH model with Skewed Student-*t* distribution appears to be the most relevant to fit the Brent, OPEC and WTI returns.

This paper is organized as follows. The literature review is given in Section 2. Section 3 describes the statistical procedure for detecting outliers in crude oil prices, and the modified ICSS algorithm used to identify sudden variance breaks in crude oil prices. The data set is presented in Section 4. The empirical results on outliers and variance changes are discussed in Section 5. Section 6 displays the study of the degree of persistence. Finally, Section 7 concludes.

2. Literature review

Wilson et al. (1996), Ewing and Malik (2010), Kang et al. (2011), Vivian and Wohar (2012) and Arouri et al. (2012) are the only studies that analyze sudden changes in oil prices from the ICSS algorithm. Wilson et al. (1996) examine daily data of oil futures and oil-producing companies from January 1, 1984 to December

[1] We do not examine the leverage effect from asymmetric GARCH-type models, but this point will be examined in future research.

[2] This algorithm allows for detecting multiple breakpoints in variance and has been extensively used for identifying changes in the volatility of financial time series (Hammoumdeh and Li, 2008; Kasman, 2009; Wang and Moore, 2009, among others). Fong and See (2002, 2003) and Vo (2009) model conditional volatility of crude oil futures prices with a Markov switching GARCH model and find regime shifts. In our paper, we detect the shift points in (unconditional) variance, not the probabilities associated with those shifts and without restricting the number of regimes to two as in the Markov switching model.