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Modelling oil price volatility with structural breaks

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HIGHLIGHTS

- We analyze oil price volatility using NP (2010) and LN (2010) tests.
- We modify the LN (2010) to account for leverage effects in oil price.
- We find two structural breaks that reflect major global crisis in the oil market.
- We find evidence of persistence and leverage effects in oil price volatility.
- Leverage effects and structural breaks are fundamental in oil price modelling.

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ABSTRACT

In this paper, we provide two main innovations: (i) we analyze oil prices of two prominent markets namely West Texas Intermediate (WTI) and Brent using the two recently developed tests by Narayan and Popp (2010) and Liu and Narayan, 2010 both of which allow for two structural breaks in the data series; and (ii) the latter method is modified to include both symmetric and asymmetric volatility models. We identify two structural breaks that occur in 1990 and 2008 which coincidentally correspond to the Iraqi/Kuwait conflict and the global financial crisis, respectively. We find evidence of persistence and leverage effects in the oil price volatility. While further extensions can be pursued, the consideration of asymmetric effects as well as structural breaks should not be jettisoned when modelling oil price volatility.

1. Introduction

The concept of volatility in oil price is increasingly gaining prominence both in theory and practice. The reasons for this development are obvious: (i) oil price data are available at a high frequency and therefore, there is increasing evidence of the presence of statistically significant correlations between observations that are large distance apart; and (ii) also in connection with the high frequency of oil price data, there is possibility of time varying volatility (referred to as conditional Heteroscedasticity) (see Harris and Sollis, 2005). More practically, variability in the oil price implies: (i) huge losses or gains to oil producing and exporting nations particularly the oil dependent economies and hence are confronted with economic instability; and (ii) huge losses or gains to independent investors in the oil markets and hence they are confronted with greater uncertainty. Thus, both the government and profit-maximizing investors are keenly interested in the extent of volatility in oil price to make policy/investment decisions.

Evidently, the modelling and forecasting of oil price volatility have followed different dimensions in the literature (see Sadorsky, 2006; Narayan and Narayan, 2007; Wei et al., 2010 and Arouri et al., 2012 for a survey of the literature).[1] The Narayan and Narayan (2007) paper appears to be the first notable work that attempts to model and forecast oil price volatility using various subsamples. This paper however did not account for structural changes in the data series and Lee et al. (2006) provide that structural breaks and trends are important considerations for commodity prices. Evaluating the probable existence of these breaks in energy prices and volatilities over time is of great interest to individuals and firms who are essentially concerned about how well they can manage the risks associated with frequent changes in energy markets (see Lee and Lee, 2009; Lee et al., 2010). Also, there is a growing literature providing justification for significant variations in the price of oil. Some of these studies have argued that oil price is sensitive to socio-political

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[1] We also provide a review of the relevant literature in this paper.

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and economic instabilities as well as changes in both global supply of and demand for energy, such factors as market regulation, oil crises, technological changes in the renewable energy sector, and modifications in the storage and logistic infrastructure of international oil markets (see Charles and Darné, 2009). Thus, a test that does not take account of these breaks in the series will have very low power (see Harris and Sollis, 2005). A recent survey of studies on- and the significance of modelling volatility of energy prices with structural breaks can be found in the works of Narayan and Liu (2011) and Arouri et al. (2012).

In the present paper, we evaluate the comparative performance of volatility models for oil price using daily returns of two prominent crude oil prices namely Brent and WTI. The innovations of this paper are in two folds: (i) we analyze these prices using the two recently developed unit root tests namely the Narayan and Popp (2010) (NP) test and the Liu and Narayan (2010) (LN) test both of which allow for two structural breaks in the data series; (ii) the latter method is modified to include both symmetric and asymmetric volatility models. Narayan et al. (2010) (NP) and Narayan and Liu (2011) document the various advantages of using these new methods over the existing ones.[2] In addition, in a recent paper by Narayan and Popp (2013), they compare the size and power of properties of Narayan et al. (2010) (NP) test with two other prominent tests which are Lumsdaine and Papell (2007) (LP) and Lee and Strazicich (2003) (LS) and they find that the NP test not only detects the structural breaks more accurately than the LS and LP tests, it also has better size and power properties. The application of the previous tests such as LS, LP and Perron unit root tests with structural breaks in dealing with volatility in energy prices including oil price has dominated the literature (see Arouri et al., 2012 and Narayan and Liu, 2011 for a survey of literature).

Narayan and Liu (2011) appear to be the first notable paper to have applied these two new tests on volatility modelling. However, our paper differs from Narayan and Liu (2011) in the following ways: (i) Narayan and Liu (2011) although cover several commodities (i.e., gold, silver, platinum, copper, aluminum, iron ore, lead, nickel, tin, and zinc) however they did not include crude oil that is considered to be one of the most widely traded commodities and a critical input in energy pricing; (ii) in their volatility modeling, they only considered the standard GARCH model which does not account for the probable existence of leverage effects. In the context of time series analysis, the asymmetry effect refers to the characteristics of time series on stock prices that an unexpected drop tends to increase volatility more than an unexpected increase of the same magnitude (or, that ‘bad news’ tends to increase volatility more than ‘good news’) (see Harris and Sollis, 2005). Thus, in this paper, we allow for structural breaks both in the symmetric as well as asymmetric GARCH models.

Our analyses are carried out in three phases. The first phase deals with some pre-tests to ascertain the statistical properties of oil price. The Narayan et al. (2010) (NP) unit root test coupled with some descriptive statistics is used to evaluate the stochastic properties of oil price as well as identify the structural breaks while the autoregressive conditional heteroscedasticity (ARCH) Lagrangian multiplier (LM) test proposed by Engle (1982) is used to determine the existence of volatility in oil price. The second phase proceeds to estimation of both symmetric and asymmetric volatility models. Model selection criteria such as Schwartz Information Criterion (SIC), Akaike Information Criterion (AIC) and Hannan–Quinn Information Criterion (HQC) are used to determine the model with the best fit. The third phase provides some post-estimation analyses using the same ARCH LM test to validate the selected volatility models.

Following the NP procedure, we identify two structural breaks that occur in 1990 and 2008 which coincidentally correspond to the Iraqi/Kuwait conflict and the global financial crisis, respectively. These two events indeed affected the demand and supply of crude oil and consequently its price and future contracts. We find evidence of persistence in the oil price volatility of WTI and Brent although the latter appears more persistent than the former. Our results also lend support for the consideration of leverage effects when modelling oil price volatility. Comparatively, the asymmetric models seem more appropriate in modelling oil price volatility than the symmetric ones. More specifically, the EGARCH model gives the best fit and therefore, we propose that the latter should be considered when dealing with oil price volatility. While further extensions can be pursued, the consideration of asymmetric effects as well as structural breaks should not be jettisoned when modelling oil price volatility.

The remainder of the paper is organized as follows. Section 2 provides a review of relevant literature. Section 3 describes data used and relevant preliminary statistics. Section 4 deals with the methodological framework of the study and analysis of empirical results. Section five concludes the paper.

2. Literature review

Recently, the number of papers dealing with volatility measuring and modelling has significantly increased and more sophisticated techniques are now being widely used. The general framework that allows for time varying conditional heteroscedasticity has been proven to work better over high-frequent time series models in financial markets such as Autoregressive (AR) process and Autoregressive Moving Average (ARMA) process. Initially, the autoregressive conditional heteroscedaticity (ARCH) model was introduced by Engle (1982) and was further modified in the seminal work of Bollerslev (1986). Since then, several extensions have continued to emerge to address different statistical complications and methodological challenges in financial time series modelling.

Recent studies on oil price volatility cover a number of different areas and issues and examine the characteristics of oil markets in various respects. Many empirical studies show evidence that time series of crude oil prices, likewise other financial time series, are characterized by fat tail distribution, volatility clustering, asymmetry and mean reverse (see Morana, 2001; Bina and Vo, 2007). The standard GARCH model has been used by several studies to evaluate oil markets in different regions. For example, the model has been used by Yang et al. (2002) for U.S. oil market; by Oberndorfer (2009) for the oil market of Eurozone and by Hwang et al. (2004) for major industrialized countries. Morana (2001) uses the semi-parametric approach that exploits the GARCH properties of the oil price volatility of Brent market. Fong and See (2002) employ a Markov regime-switching approach allowing for GARCH-dynamics and sudden changes in both mean and variance in order to model the conditional volatility of daily returns on crude-oil futures prices. They document that the regime-switching model performs better than non-switching models regardless of evaluation criteria in out-of-sample forecast analysis. Vo (2009) also employs the concept of regime-switching stochastic volatility and explains the behaviour of crude oil prices of WTI market in order to forecast their volatility. More specifically, the paper models the volatility of oil return as a stochastic volatility process whose mean is subject to shifts in regime.

[2] Prominent among the previous methods that allow for the considerations of structural breaks include Perron (1989) and Lee and Strazicich (2003).