Energy Economics 39 (2013) 169–176

Contents lists available at SciVerse ScienceDirect

Energy Economics

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

Modeling returns and volatility transmission between oil price and US–Nigeria exchange rate

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ARTICLE INFO

Article history:
Received 1 January 2013
Received in revised form 30 April 2013
Accepted 4 May 2013
Available online 13 May 2013

JEL classification:
C5
F3
Q43

Keywords:
Exchange rate
Oil price
Portfolio management
VAR-GARCH models
Nigeria

ABSTRACT

This paper models returns and volatility transmission between oil price (OP) and US–Nigeria exchange rate (EXR). Consequently, it provides five main innovations: (i) it analyzes OP and EXR using the recently developed test by Narayan and Popp (2010) (NP) which allows for two structural breaks in the data series (ii) it employs the Narayan and Liu (2011) (NL) GARCH unit root test to evaluate robustness of NP test (iii) it considers the newly developed VAR-GARCH model to capture the spillover effects in the returns and volatility of OP and EXR; (iv) it modifies the VAR-GARCH model to account for structural breaks obtained from the NP procedure and (v) using the results obtained from the VAR-GARCH model, it examines the optimal weights of holding oil and foreign exchange (FX) assets and also computes the hedging ratios in the presence of oil risk. Based on the NP and NL tests, it finds robust structural breaks that coincide with the period of global financial crisis as well as period of FX crisis in Nigeria. Also, it establishes a bidirectional returns and spillover transmission between oil and FX markets. Finally, its findings reveal evidence of hedging effectiveness involving oil and FX markets in Nigeria and thus, the inclusion of oil into a diversified portfolio of FX will improve its risk-adjusted return performance.

1. Introduction

The development of a theoretical framework for modeling the relationship between oil price and exchange rate was pioneered by Golub (1983) and Krugman (1983). The argument for the oil price–exchange rate volatility transmission is usually premised on the fact that oil is quoted in US dollars (USD) and therefore, fluctuations in oil price may affect exchange rate behavior of the trading countries through the USD. This relationship is not expected to be generalized for both net oil-exporters and net oil-importers that are running floating exchange rate. For example, when the USD depreciates, oil-exporting countries would raise oil prices in order to stabilize the purchasing power of their (USD) export revenues. Conversely however, the oil importers may have to deplete their USD based reserves to settle their high oil import bills. Thus, increasing oil prices may enhance the appreciation of net oil-exporters currencies (due to increased USD reserves) and may cause depreciation of net oil importers currencies due to higher import bills and higher production costs (see Ding and Vo, 2012).

Evidently, several attempts have been made to establish the empirical link between oil price and exchange rate (see Reboredo and Rivera-Castro, 2013 for a survey of recent literature). In addition to the mixed and therefore inconclusive results of these extensive studies, the issue of returns and volatility spillover transmission between oil and foreign exchange markets covering both interactions and portfolio management in these markets has remained uninvestigated. Therefore, the present study attempts to fill this research gap while drawing evidence from Nigeria.

There are several convincing reasons justifying the need for empirical analysis of oil-price–US/Nigeria exchange rate nexus. First, Nigeria is ranked among the top ten oil producers and net oil exporters and therefore, fluctuations in oil price are expected to affect its USD reserves and by implication the purchasing power of its local currency relative to USD. Second, oil revenue accounts for over 90% of the total revenue of Nigeria annually and therefore, changes in oil price are expected to have serious implications on the Nigerian macroeconomy which have to be dealt with by the relevant authority. Thus, an empirical investigation into the nexus between oil price and US–Nigeria exchange rate will provide useful insights into effective policy formulation by policy makers. Similarly, information about the probable return and spillover transmission between oil

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0140-9883/$ – see front matter
http://dx.doi.org/10.1016/j.eneco.2013.05.003

and exchange rate will offer plausible ideas to investors on how to diversify their portfolios or hedge their risks.

To achieve the main objective, the study employs the newly developed VAR-GARCH model introduced by Ling and McAleer (2003) and subsequently applied by Chan et al. (2005), Hammoudeh et al. (2009), Arouri et al. (2011a) to various economic analyses.[1] This modeling framework has, to the best of our knowledge, never been employed to study returns and volatility transmission between oil price and exchange rate. Apart from the less computational complications in obtaining estimates of the unknown parameters compared to other multivariate specifications, the VAR-GARCH model facilitates the estimation of the spillover effects of conditional returns, volatility and correlations between/among commodity markets.

In all, this study adds to the existing literature in the following distinctive ways (i) it analyzes oil price (OP) and US–Nigeria exchange rate (EXR) using the recently developed test by NP which allows for two structural breaks in the data series[2] (ii) it employs the NL GARCH unit root test to evaluate robustness of NP test (iii) it considers the newly developed VAR-GARCH model to capture the spillover effects in the returns and volatility of OP and EXR; (iv) it modifies the VAR-GARCH model to account for structural breaks obtained from the NP procedure and (v) using the results obtained from the VAR-GARCH model, it examines the optimal weights of holding oil and foreign exchange (FX) assets and also computes the hedging ratios in the presence of oil risk.

The remainder of the paper is organized as follows. Sec. 2 presents a review of relevant empirical papers and Sec 3 describes the data and also provides some preliminary analyses. While Sec. 4 discusses the model and the empirical results, Sec. 5 further applies the model to evaluate portfolio management in the presence of oil risk. Sec. 6 however concludes the paper.

2. Literature review

After the seminal papers of Golub (1983) and Krugman (1983), several efforts have emerged to empirically validate or refute their propositions regarding the interactions between oil price and exchange rate and the findings from these various studies have been mixed. For example, Yousefi and Wirjanto (2004), Krichene (2005) and Zhang et al. (2008) find that the relationship runs from exchange-rate to oil-price while studies such as Benassy-Querea et al. (2007), Chen and Chen (2007), and Coudert et al. (2008) provide evidence supporting the direction of relationship from oil price to exchange rate. Ding and Vo (2012), among others, however find a bidirectional association.

These studies have adopted different methodologies ranging from cointegration and causality (see Benassy-Querea et al., 2007; Chen and Chen, 2007; Coudert et al., 2008; and Lizardo and Mollick, 2010), univariate GARCH models (see Ghosh, 2011; and Narayan et al., 2008), to multivariate models such as VAR, VECM, Multivariate GARCH models and Simultaneous Equation Models (see Rautava, 2004; Krichene, 2005; Huang and Guo, 2007; Cifarelli and Paladino, 2010; and Ding and Vo, 2012).

A number of recent papers have also extended the analysis of oil price–exchange rate nexus to account for non-linearities and structural breaks (see for example, Issa et al., 2006; Razgallah and Smimou, 2011; and Benhmad, 2012) and they show that ignoring these properties when modeling oil price dynamics may yield biased and inconsistent results.

In Nigeria, empirical research into the oil price–exchange rate nexus is very recent (see Adeniyi et al., 2012 for a survey of the literature) and the findings have remained inconclusive as well. In addition, the issue of both returns and volatility spillover transmission between exchange rate and oil price has remained unresearched in the literature. This is the contribution of the present study to the existing literature. The study also accounts for non-linearities and structural breaks using recent methodological approaches.

3. Data and preliminary analyses

Essentially, this study covers two variables namely the oil price (denoted as OP) and USD–Nigeria exchange rate (denoted as EXR) and data on these variables were collected from the work book of Thomson Reuters and the Nigerian Statistical Bulletin respectively over the period January 02, 2002 to March 20, 2012. The OP is measured as the price of crude oil per barrel in USD and the EXR is quantified as the exchange rate of USD to 1 *Naira* (the Nigerian currency). The choice of measurement of the latter is underscored by the fact that Nigerian reserves are denominated in USD and since oil exports account for over 90% of the country's total revenue, it is anticipated that oil price fluctuations will drive the *Naira* through USD, *ceteris paribus*. By the same token, we expect movements in USD to influence oil price in the international crude oil market as crude oil price is also denominated in USD.

This section provides some preliminary analyses involving the description of relevant statistical properties of the variables under consideration. These analyses are carried out in four phases: the first provides descriptive statistics for the two variables including their returns; the second involves performing ARCH LM test to verify the existence ARCH effects in the series; the third conducts unit root test using the NP unit root test with structural breaks and the fourth tests the robustness of NP unit root using NL GARCH unit root test. The returns are computed as follows:

$$OPR_t = 100 * [\Delta \log(OP_t)] \quad (1)$$

$$EXRR_t = 100 * [\Delta \log(EXR_t)] \quad (2)$$

where Δ is a first difference operator. Table 1 below shows the descriptive statistics for OP and EXR including their returns denoted by OPR and EXRR respectively. There seems to be evidence of significant variations in the OP trends as shown by the large difference between the minimum value of 18.02 USD and the maximum value of 149.25 USD as well as when these values are compared with the mean value of 66.859 USD. However, the magnitude of fluctuations in EXR appears less volatile when compared to OP as shown by the standard deviations of 27.201 USD and 0.0007 USD/*Naira* for OP and EXR respectively. This evidence is also corroborated by the difference in the EXR values in relation to the minimum value of 0.0064 USD/*Naira* and the maximum value of 0.0088 USD/*Naira* as well as when they are compared with the mean value of 0.0075 USD/*Naira*.

We also evaluate the degree of relationship between the returns of the two series (OPR and EXRR) using the unconditional correlation analysis. The results indicate that the OPR and EXRR are inversely related with about 4% degree of relationship. Although, cross-market correlations between EXRR and OPR are not high, the negative sign is an indication that exchange rate and oil price move in opposite directions on average.

In relation to the statistical properties of the returns (i.e. OPR and EXR), the findings are in agreement with the evidence obtained from the descriptive statistics for OP and EXR. For example, the standard

[1] Arouri et al. (2011a,b) document the various advantages of using the VAR-GARCH model over other existing multivariate GARCH models such as BEKK-GARCH, CCC-GARCH, DCC-GARCH and VECH-GARCH.

[2] The various advantages of using these new methods over the existing ones have been well documented by Narayan and Popp (2010) and Narayan and Liu (2011). In a recent paper by Narayan and Popp (2013), they compare the size and power of properties of Narayan and Popp (2010)) test with two other prominent tests which are Lumsdaine and Papell (LP) (1997) and Lee and Strazicich (LS) (2003) and they find that the NP test not only detects the structural breaks more accurately than the LS and LP tests, but also has better size and power properties (see also Salisu and Fasanya, 2013).