Economics Bulletin

Volume 37, Issue 4

Crude Oil Price Volatility and Domestic Price Responses in Developing Countries, Accounting for Asymmetry and Uncertainty

Zoundi Zakaria
Graduate School of International Cooperation Studies, Kobe University , Japan

Abstract

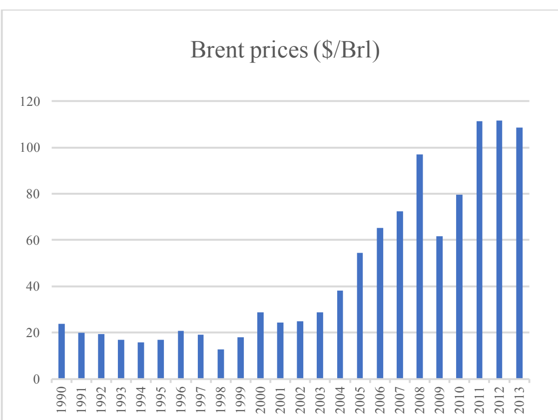
In an attempt to expand on the existing literature on the effect of oil price spillover, this study analyses the impact of oil price volatility on domestic prices in several oil-producing and non-oil-producing developing countries. Focusing on Burkina Faso, Cote d'Ivoire, Niger, Ghana and Nigeria, the analysis tests the null hypothesis of symmetrical responses of domestic prices to news, in addition to the impact of oil price uncertainty on domestic prices. The sign and size-bias tests and the VAR-GARCH model with effect in mean are selected for the analysis. The results indicate evidence of asymmetry in the response of domestic prices to shocks, irrespective of the country's oil resources. The bias in the volatility response of domestic price is driven by the positive size of the shocks rather than the negative size or the sign of the shocks. Furthermore, uncertainty of oil price has a positive and significant effect on domestic prices. The degree of the impact of oil price uncertainty on domestic prices appears positively correlated with the country's oil reserves.

Citation: Zoundi Zakaria, (2017) "Crude Oil Price Volatility and Domestic Price Responses in Developing Countries, Accounting for Asymmetry and Uncertainty", *Economics Bulletin*, Volume 37, Issue 4, pages 2466-2482
Contact: Zoundi Zakaria - zakariazoundi@yahoo.fr.
Submitted: August 01, 2017.   **Published:** November 19, 2017.

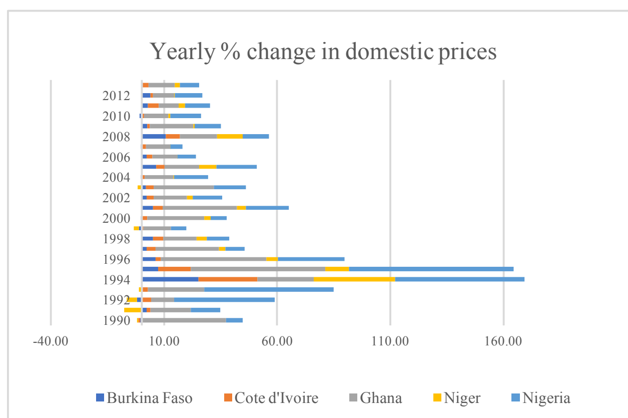
1. Introduction

In early 2008, a domestic price surge in Burkina Faso (called "*La vie chère"* by the population) drove the country into a series of demonstrations and protests, pushing the government to suspend consumption tax for a few months. Although there were numerous contributory factors to this price hike, the fundamental reason was found to be the increased crude oil price, which had been steadily rising over the past several years (National Archive, 2008). From $27.65 in June 2003, the price of barrel exceeded $122.80 in May 2008, which represented an almost 77.5% increase (EIA, 2017). A few months later, the price suddenly plummeted, and lost 70% of its' value within two quarters (see graph 1). In the domestic market, however, no significant effect on price of goods was recorded. This bias in the reaction of domestic prices to oil price shocks displays the influence of oil price uncertainty on domestic prices, and the possible asymmetry that can stem from consumers and producers' behaviours due to oil price movements. Everything elsewhere held constant, price uncertainty can prompt producers to alter their pricing strategies (Moschini et al., 2001), and the consumers to readjust their consumption bundle (the neoclassical theory of consumer choice under certainty, Savage, 1954; Neumann and Morgenstern, 1944), each economic agent being precautious. Burkina Faso is an example of all West African economies constantly facing the spillover effects of oil price volatility. In countries with low living standards, price of goods plays an important role in the dynamism of the economy. High inflation typically leads to the stagnation of the economy and occasionally to political turmoil. A close look at domestic prices (proxied by the consumer price index) in Burkina Faso, Niger, Ghana, Cote d'Ivoire and Nigeria reveals that the countries have been facing constant increases to their domestic prices, with larger contributions for Nigeria and Ghana. In 1994 and 1995, the combined inflation rate in these countries outpaced 160%, with approximately 50% contribution for Nigeria (graph 2).

Graph 1. Brent prices overtime



Graph 2. Yearly percentage change in domestic prices across countries



The high volatility of oil prices and the various effects oil price shocks have on global economic activities since the large recession of the 1970s are perhaps the reasons for the spate of research that has been conducted to identify the spillover effects of oil price movements on the economy. Thus far, the results have varied in terms of regions and time periods (Borenstein et. Al., 1997; Glub, 1983; Hamilton, 1996, 2003 among others) therefore researchers have attempted different approaches to determine the spillover effects of oil price fluctuations on the economy. One suggestion is to isolate the component of oil price changes that is explained by purely exogenous factors such as political turmoil (in the Middle East for instance) by using a non-linear transformation (Mork, 1989; Lee et al., 1995; Hamilton, 1996, 2003). This exogeneity assumption is rejected by authors like Kilian (2008b), who shows that the non-linear transformation posited by Hamilton (2003) suffers from weak instruments, and the estimation was set when exogenous oil supply shock was absent in the Middle East. Yet, there have been numerous exogenous incidents that were not followed by oil price shocks. Another group of authors underscore different hypotheses that should lead to reconsidering the effects of oil price shocks. As the first hypothesis, economic agents respond proportionately to oil price changes, irrespective of the magnitude of the change (Edelstein and Kilian 2007a, 2007b). The second hypothesis is that economic agents only respond to larger shocks (Goldberg, 1998). And finally, the third hypothesis argues that economic agents respond only to energy prices that are not captured in the memory of price changes. This hypothesis concurs with Hamilton (1996, 2003). Killian (2009) suggests that solely using oil price movements in shock analyses can neglect important information that can alter the interpretation of oil price effects on the economy. He proposes to disentangle oil price volatility into demand and supply shocks and incorporate the analysis into a structural VAR framework.

Oil price shocks are transmitted to the economy through several mechanisms. For the supply side argument (Lardic and Mignon, 2008), oil constitutes a vital input for industries. Increased oil prices mean raised operating costs for organisations, and consequently decreases production output. This reduction leads to a shrink in growth followed by a recession, and a decline in real wage and employment levels (Brown and Yücel, 1999, 2002). The decline in employment is explained by the rigidity and high-cost related to the reallocation of labour and capital from one specialised sector to another (Davis and Haltiwanger, 2001; Davis, 1987; Hamilton, 1988). Workers therefore chose to wait for a better economic environment and an improvement in their activity sector. The demand side argument incorporates the discretionary income effect (Kilian, 2008) and explains recession (following an oil price surge) by the contraction in domestic demand as consumers have limited resources left after paying their energy bills. The contraction of domestic demand depends upon the energy share in total consumption, and there is a correlation between the rate this occurs and the level of inelastic energy consumption (the more the faster). Robert (1991) argues that the fluctuation in energy prices can lead to uncertainty of future prices, thus pushing consumers to postpone their consumption of durables.

The pass-through oil price-inflation can be direct or indirect. In the first configuration, a change in oil price is reflected in either input cost variations that directly impacts the level of domestic prices (see supply sides effects, Lardic and Mignon, 2008), or in the cost of energy that causes households to change their consumption bundles (Lee et al., 1995). The indirect effect can stem from the central bank's policy. The policy chosen by the central bank is driven by the degree of anticipation of shocks, as well as the national or regional policy directives (such as the Central Bank of West Africa). The Central Bank can decide to raise interest rates in anticipation of inflation pressures resulting from oil price hikes (Bernanke, Gertler and Watson, 1997). Although this intervention can be efficient in stabilizing GDP, the impact on domestic prices can be detrimental to the economy and can jeopardise future growth (Barsky and Kilian, 2002).

The incorporation of asymmetries and uncertainty in the response of macroeconomic aggregates to oil price volatility contributed to the rekindling of the debate on oil price shocks. The first theoretical frameworks integrating the concepts of uncertainty and asymmetries emerged in the 1980s (without any empirical evidence) when the 1979 oil price hike was followed by a major recession while the strident plunge of oil prices in 1986 did not cause any expansion in the global economic activity. This shocking observation prompted researchers to revisit oil price pass-through to the economy (Hamilton, 1988; Pindyck, 1991; Hooker, 1996a, 1996b, 2002). Many of the studies attempted to establish a correlation between asymmetry and uncertainty. For Bernanke (1983) and Pindyck (1991), changes in energy prices creates uncertainty about future energy costs.

This uncertainty leads to postponing irreversible investment decisions, and jeopardising future growth. In addition, the behaviours of firms differ, whether it is an increase or a decrease in energy prices, due to the uncertainty effect. For example, when the energy price increases, uncertainty impels the firm to reduce its investments due the rise in energy cost and contraction of domestic demand. However, when energy prices decrease, costs reduce, and demand upturns. Nevertheless, investment does not increase, as the firm delays its reactions due to the offset effect that uncertainty has on investment under this price fall. Different authors including Managi and Okimoto (2013), Beckmann and Czudaj (2013), Balcilar and Ozdemir (2013) have brought new insights in the methodology and debate on the interaction between oil price and macroeconomic and financial aggregates by applying Markov-Switching models. The Markov-Switching model offers several advantages, which are discussed in the last section of the paper. Managi and Okimoto (2013) combined a vector autoregressive and a Markov-switching models on oil prices, clean energy stock prices, and technology stock prices. They finding suggests that clean energy prices and oil prices are positively correlated in the period following the 2007 oil price spike, implying a regime switching. Similarly, Basher et al. (2016) use a Markov-switching model to analyze the impact of oil price shocks on real exchange rates in oil exporting and oil importing countries, and highlight the presence of regime switching for the effects of oil shocks on real exchange rates.

Note that the majority of these analyses are purely theoretical. The most formal empirical analysis was conducted by Edelstein and Kilian (2007a, 2007b), when they tested the symmetrical/asymmetrical response of a non-residential fixed investment to positive and negative energy price shocks. They failed to reject the null hypothesis of symmetry in the response of a non-residential fixed investment to energy price shocks. However, Killian (2008) opposes this finding by arguing that the high p-value of the statistical tests is due to sampling issues of the energy consumption data and weak statistical power. Other economists such as Elder and Serletis (2010) tested the effects of oil price uncertainty on GDP, durables consumption and several measures of investment using a VAR GARCH with effect in Mean. They found that accounting for uncertainty contributes to a deteriorating negative dynamic response of economic activity to a negative oil price shock, while weakening the response to a positive oil price shock.

Most of the existing research on oil uncertainty and asymmetry deals solely with developed economies, and primarily focuses on the United States. This interest is justifiable as the United States is a good representation of economic dynamism and shocks in the U.S. economy has knock-on effects on global activity. However, the results and interpretations ascertained from developed countries cannot be broadly applied to developing economies, as they differ greatly, particularly in terms of risk and uncertainty. Also, the literature lacks comparative studies between countries as well as the incorporation of uncertainty and asymmetry in the oil price-domestic prices relationship, making this study the first to investigate this matter. This study extends the literature on the effects of oil price volatility on domestic prices by considering the uncertainty and asymmetry framework in the context of developing countries. The remainder of this paper is comprised as follows: section 2 presents a description of the data; the econometric approach and interpretation of the results are provided in sections 3 and 4, respectively; section 5 concludes.

2. Data and series properties

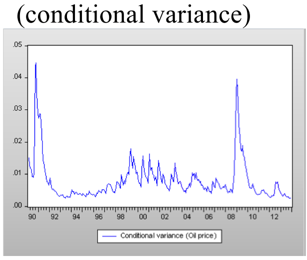
Monthly data on the consumer price index (CPI, constant December 2010) and Brent oil (the most used benchmark in west Africa) are collected from the IMF International Financial Statistics and the Energy Information Administration (EIA), respectively. The price of oil is converted in real terms by deflating by the U.S. consumer price index (collected from EIA). Five west African countries have been selected for the analysis, namely Burkina Faso, Cote d'Ivoire, Ghana, Niger and Nigeria. The selection was made based on the countries' differences in terms of oil endowment and the absence of missing value in the data, as the model favoured in the analysis requires continuous observations. The period of study covers January 1990 through December 2013 for a total of 288 observations. From the data (table 1), it is observed that in most countries, the consumer price index is above 50. The highest deviation around the mean is found in Nigeria and Ghana. The standard deviation of CPI of the two countries is approximately 40, which represents double that of the three other countries. In other words, domestic prices have the highest fluctuations in Ghana and Nigeria. All CPI distributions are platykurtic (less fat tail) as they present negative excess kurtosis. Also, the non-zero skewness of CPI indicates that the distribution of the variable is asymmetric for all countries. These two characteristics of the data series show that the series are not normally distributed, and justify the rejection of the Jarque Bera normality hypothesis for all countries.

Table 1. Summary statistics

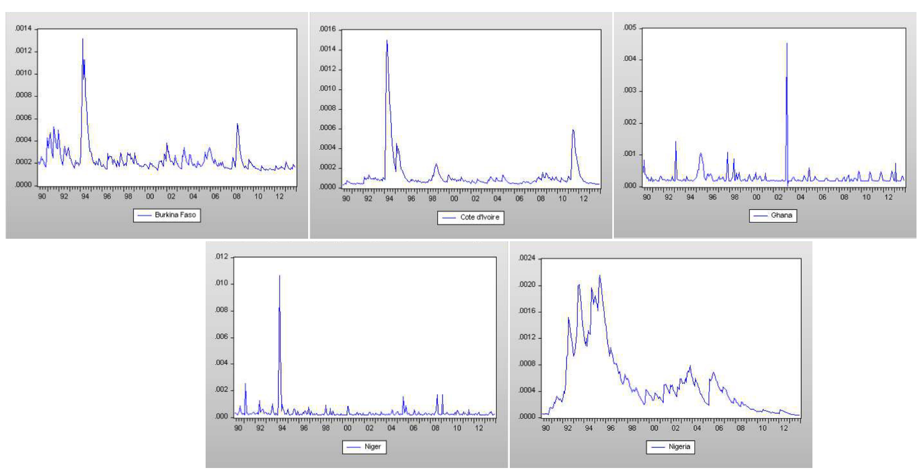
Country	Variables	Mean	Med.	Max	Min	Std. Dev.	Skewness	Excess kurtosis	J. Bera Normality	Obs.
	Oil price	50.30	34.48	131.86	13.07	30.39	0.91	-0.50	42.369(0.000)	288
Burkina Faso	CPI	79.11	79.59	109.33	48.12	18.10	-0.18	-0.89	11.166(0.004)	288
Cote d'Ivoire	CPI	77.91	79.86	109.46	41.64	20.41	-0.34	-0.89	15.148(0.001)	288
Ghana	CPI	43.68	29.85	138.39	1.83	40.42	0.78	-0.67	34.291(0.000)	288
Niger	CPI	79.35	81.25	109.02	43.79	18.17	-0.42	-0.71	14.555(0.001)	288
Nigeria	CPI	49.27	37.92	139.82	2.35	39.16	0.69	-0.62	27.286(0.000)	288

The implementation of GARCH-type models requires the presence of non-constant variance and volatility clustering in the data generating process. Graphs 3 and 4 depict the conditional variance of oil price and CPI, and are obtained from the arch estimation. In absence of arch effect, the conditional variance is represented by a line, implying a zero variance (homoscedasticity). From the graphs, the volatility clustering appears apparent in each series, implying a presence of an arch effect. Each graph shows periods of surge and plunge (referring to oil shocks history), and temporal clustering of large and small deviations.

Graph 3. Oil price volatility (conditional variance)



Graph 4: CPI volatility (conditional variance) by country



A battery of unit root tests is conducted on the logarithm first difference of each variable to evaluate their order of integration and determine the appropriate model specification. The unit root tests are reported in table 2. As benchmarks, the following tests are selected: Augmented Dickey-Fuller (ADF, Dickey and Fuller,1981), Phillips Perron (PP, Phillips and Perron, 1988), Dickey–

Fuller GLS detrended (DF–GLS, Elliott et al. 1996) and KPSS (Kwiatkowski et al. 1992). While the ADF, PP and DF-GLS tests are based on the null hypothesis of no unit root in the data series, the KPSS test has an opposite null hypothesis (the series is stationary). For each test, the Bartlett (1963) kernel is employed as the spectral estimation method, and the bandwidth is selected using the Newey-West automatic lag selection (Newey and West, 1987, 1994). The ADF and PP results indicate that the first difference of all series is stationary. With the exception of Ghana, where the null hypothesis of no unit root in the logarithm first difference of CPI is not rejected, the results are similar for the DF-GLS test. However, this result is contrasted by the KPSS test. The non-rejection of the KPSS null hypothesis implies that the series is stationary. Similarly, for Nigeria, the KPSS test rejects the null hypothesis of stationarity at a 10% level. As the ADF, PP and DF-GLS tests show stationarity, it can be concluded that the logarithm first difference of both CPI and oil price series are I (0).

Table 2: Unit root

Country	Variables	ADF	P. Perron	DF-GLS	KPSS
	$\Delta ln\ oil$	-12.968***	-12.556***	-5.490***	0.108
Burkina Faso	$\Delta ln\ cpi$	-16.780***	-16.921***	-16.382***	0.115
Cote d'Ivoire	$\Delta ln\ cpi$	-11.102***	-11.215***	-9.719***	0.289
Ghana	$\Delta ln\ cpi$	-8.067***	-7.891***	-0.279	0.067
Niger	$\Delta ln\ cpi$	-11.637***	-11.389***	-7.917***	0.081
Nigeria	$\Delta ln\ cpi$	-7.151***	-10.342***	-7.012***	0.145*

ADF, P. Perron and DF-GLS null hypothesis: the variable has a unit root. KPSS null hypothesis: the variable is stationary * significance at 10% ** significance at 5% ***significance at 1%

Additionally, to investigate the possible existence of a long-term relationship between CPI and oil prices, the Johansen cointegration test (Johansen 1988, 1991) is conducted on the log-level of the variables for each country (table 3). Both the maximum Eigen statistic and the trace statistic are lower than their 1% and 5% critical values, implying that series are not cointegrated. As no cointegration is found between CPI and oil price series, the error correction term is therefore excluded from the model specification.

Table 3: Johansen cointegration test

Country	Eigenvalue	Max Eigen Statistic	Trace Statistic	Result
Burkina Faso	0.035	10.270	10.595	No cointegration
Cote d'Ivoire	0.033	9.626	10.357	No cointegration
Ghana	0.030	7.757	12.494	No cointegration
Niger	0.029	8.293	9.010	No cointegration
Nigeria	0.032	8.515	14.025	No cointegration

1 % CV of the trace statistic: 15.494 . 5% CV of max eigenvalue statistic: 14.264

3. Econometric methodology

The selected model for this analysis is the Generalized Autoregressive Conditional Heteroskedasticity with effects in mean, referred to as GARCH-M. The model is an extended version of the ARCH-M model introduced by Engel et al., (1987) to capture the risk associated with the return of three measures of debt instruments (six-month treasury bills, two-months treasury bills, and Aaa corporate bonds), where the risk is due to unexpected yield fluctuations.

The GARCH model, which was developed by Bollerslev (1986), is more efficient in dealing with heteroskedasticity as the conditional variance equation includes both ARCH and GARCH terms. In other words, the predicted deviation of a variable around the mean in the next period is a weighted average of the long-term average deviation, the current variance and a new set of information (the recent squared residual). In addition to modeling heteroskedasticity and volatility clustering, GARCH allows tracking the persistence of volatility. In the GARCH model with effects in mean, the heteroskedasticity term is assumed to affect the mean equation. This effect has often been used as a proxy for uncertainty (Engle, 1982; Engel et al., 1987; Bollerslev, 1986; Elder, 1995, 2004; Elder and Serletis 2009, 2010).

To evaluate the effect of oil price uncertainty on domestic price, the analysis employs the bivariate VAR GARCH-M as in Elder (1995, 2004) and Elder and Serletis (2009, 2010). As no cointegration was found between oil price and CPI, taken at level (table 3), the structural specification does not contain any error correction term. The data generating process underlining the structural system is specified as follows:

$$By_t = \Phi + \sum_{i=1}^{p} \Gamma_i \, y_{t-i} + \Psi\sqrt{h_t} + \varepsilon_t \qquad (1)$$

where

$\varepsilon_t | \Omega_{t-1} \sim iid\ N(0, H_t)$

Ω_{t-1} is the information set in period $t-1$; ψ is a matrix polynomial included in the lag operator; 0 the null vector; H_t is a matrix of conditional variance-covariance; Φ is a vector of constants; Γ_i a matrix of coefficients on the lagged variables y_{t-i} where i is the number of lags (p is the maximum number of lags). Furthermore,

$$H_t = \begin{bmatrix} h_{\Delta ln\ cpi \Delta ln\ cpi,t} & h_{\Delta ln\ cpi \Delta ln\ oil,t} \\ h_{\Delta ln\ oil \Delta ln\ cpi,t} & h_{\Delta ln\ oil \Delta ln\ oil,t} \end{bmatrix}; \quad y_t = \begin{bmatrix} \Delta ln\ cpi \\ \Delta ln\ oil \end{bmatrix}; \quad h_t = \begin{bmatrix} h_{\Delta ln\ cpi \Delta ln\ cpi,t} \\ h_{\Delta ln\ oil \Delta ln\ oil,t} \end{bmatrix};$$

$$\Phi = \begin{bmatrix} \varphi_{\Delta ln\ cpi} \\ \varphi_{\Delta ln\ oil} \end{bmatrix}; \quad \Gamma_i = \begin{bmatrix} \gamma_{11}^{(i)} & \gamma_{12}^{(i)} \\ \gamma_{21}^{(i)} & \gamma_{22}^{(i)} \end{bmatrix}; \quad \Psi = \begin{bmatrix} \psi_{11} & \psi_{12} \\ \psi_{21} & \psi_{22} \end{bmatrix}; \ \varepsilon_t = \begin{bmatrix} \epsilon_{\Delta ln\ cpi} \\ \epsilon_{\Delta ln\ oil} \end{bmatrix}; \ corr\ \ (\epsilon_{\Delta ln\ cpi}, \epsilon_{\Delta ln\ oil}) = 0$$

(errors are assumed not correlated) ; $B = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}$

The matrix of conditional standard deviation $\sqrt{h_t}$ is added to the mean equation (1) to capture the effect of oil price uncertainty. The hypothesis tested is whether an increasing uncertainty of oil prices impacts domestic prices. A positive and significant coefficient on $\sqrt{h_t}$ in the $\Delta ln\ cpi$ equation implies that higher uncertainty of oil prices has a heightening effect on domestic prices. In other words, uncertainty regarding oil prices can cause domestic prices to rise up.

The specification of the conditional variance equation follows Engle and Kroner (1995), who extended Engle's (1982) ARCH and Bollerslev's (1986) GARCH models to multivariate settings. The zero-restriction version of the conditional structural variance equation is given by:

$$vec(H_t) = W + X_1 vec(\varepsilon_{t-1}\varepsilon'_{t-1}) + X_2 vec(\varepsilon_{t-2}\varepsilon'_{t-2}) + \cdots + X_j vec(\varepsilon_{t-j}\varepsilon'_{t-j}) + Y_1 vec(H_{t-1}) + Y_2 vec(H_{t-2}) + \cdots Y_i vec(H_{t-i}) \qquad (2)$$

Where $\varepsilon_t = H_t^{1/2} z_t,\ z_t \sim iid\ N(0, \mathrm{I})$, W is a parameter vector and $dim(W) = N \times 1$, X and Y are squared matrices and $dim(X)=dim(Y)=N \times N$, *vec(.)* is the vector operator that stacks the columns of the matrix.

Assuming $i=j=1$, the number of parameters to estimate is $(N^2+N+1)(N^2+N)/2$. The identification of such a system requires numerous restrictions in the parameterization. One frequently employed is the diagonal representation. This method was used by Engle, Granger, and Kraft (1984) in their ARCH model, and by Bollerslev et al., (1988) in their capital asset pricing model applied in a GARCH framework. Recently, Elder (2004) used a similar procedure in the VAR GARCH-M model. In the diagonal representation, conditional variances are set as functions of their own past squared residuals and covariance functions of residuals cross-products (Engle and Kroner, 1995). If equation (2) is expressed in terms of structural disturbances (for example $\varepsilon_t = H_t^{1/2} z_t$ implies that $H_t = (\varepsilon_t {z_t}^{-1})^2$ and replace in equation (2)), and common identifying assumptions are imposed on the system, the equation becomes a diagonal one, as contemporaneous structural shocks are assumed not correlated. It ends up with the following specification to be estimated:

$$diag(H_t) = W + X_1 diag(\varepsilon_{t-1}\varepsilon'_{t-1}) + X_2 diag(\varepsilon_{t-2}\varepsilon'_{t-2}) + \cdots + X_j diag\left(\varepsilon_{t-j}\varepsilon'_{t-j}\right) + Y_1 diag(H_{t-1}) + Y_2 diag(H_{t-2}) + \cdots Y_i diag(H_{t-i}) \quad (3)$$

Due to their minimal powers in the international market, any volatility in the domestic prices of the selected countries is considered insignificant in terms of impacting the global oil market. As such, shock on oil is assumed to affect domestic prices, with no feedback from domestic prices to oil prices. The purpose of this exclusion restriction is to reduce the number of parameters and thereby simplify the system in terms of estimation. The estimation procedure is consistent with the efficiency of GARCH (1,1) found in various empirical research and widely applied in studies (such as Hansen and Lunde, 2005; Sadorsky, 1999). In addition, the approach follows Elder and Serletis' (2010) procedure for the case of bivariate VAR GARCH-M. Thus, i=j=1, the model is estimated by maximizing, with respect to the structural parameters B, Φ , Γ_i(i=$\overline{1,p}$), Ψ , W, X and, the log likelihood function of the full information maximum likelihood (FIML) given by:

$$l_t = -\frac{1}{2} N \ln(2\pi) + ln\,|B| - \frac{1}{2} ln|H_t| - \frac{1}{2}(\varepsilon'_t H_t^{-1} \varepsilon_t) \quad (4)$$

The pre-sample values of the conditional matrix H_0 are set to their unconditional expectations and conditions on the pre-sample values $y_t(t = \overline{0, t-p+1})$. A non-negativity constraint is imposed on the matrices W, X and Y in the conditional variance equation (3) as follows: W=0 if W<0; X=0 if X<0; and Y=0 if Y<0. This restriction aims to ensure that H_t is positive definite (Engle and Kroner, 1995; Elder, 2004; Elder and Serletis, 2010). The overall estimation uses number of lags determined by the Schwarz Information Criterion, with a maximum number set to 12.

Prior to evaluating the impact of oil price uncertainty on domestic prices, the analysis applies a set of asymmetry tests to capture the volatility response to news of both domestic prices and oil prices, although the latter is not too mandatory, given the focus of this study. The tests follow the Engle and Ng (1993) tests for *sign-bias*, *negative size-bias*, and *positive size bias* in variance, and is based on the following steps:

1. Estimate the symmetric GARCH (1,1)
2. Generate the residual denoted $\hat{\varepsilon_t}$and the squared value $\hat{\varepsilon}_t{}^2$
3. Generate a dummy variable S_{t-1}^- that takes the value 1 if $\hat{\varepsilon}_{t-1}$is strictly negative and 0 otherwise.

The sign-bias, negative size-bias, and positive size-bias are tested using the following equation:

$$\hat{\varepsilon}_t{}^2 = \alpha_0 + \alpha_1 S_{t-1}^- + \alpha_2 S_{t-1}^- \hat{\varepsilon}_{t-1} + \alpha_3 S_{t-1}^+ \hat{\varepsilon}_{t-1} + \lambda_t \quad (5)$$

$$S_{t-1}^+ = 1 - S_{t-1}^-$$

$$S_{t-1}^- = \begin{cases} 1, & \hat{\varepsilon}_{t-1} < 0 \\ 0, & \hat{\varepsilon}_{t-1} \geq 0 \end{cases}$$

Where α_0 is a constant, $\alpha_i(i = \overline{1,3})$ are the parameters used for testing the presence of biases, and λ_t is the error term. The sign bias test assesses the effect of both positive and negative shocks on domestic price volatility (not captured by the model). The sign-bias test is a test of exclusion restriction on α_1 (H_0: $\alpha_1 = 0$). Thus, a significant α_1 implies that positive and negative news have different implications for domestic price volatility, irrespective of the size of the shocks. The size-bias is captured by α_2 and α_3. While α_2 tests for a presence of negative size bias in the response of domestic price to news (α_2 tests the null hypothesis that large and small negative shocks have similar effects on domestic price volatility), α_3 focuses on the hull hypothesis that large and small positive have the same implication for domestic price volatility (positive bias). Further to the sign-bias, negative size-bias, and positive size-bias tests, a joint test is conducted to assess the null hypothesis of no sign-bias and size-bias in the volatility response of domestic price ($H_0: \alpha_1 = \alpha_2 = \alpha_3 = 0$). The test is carried out through the application of the Lagrange Multiplier (LM) test and the condition $TR^2 \sim \chi^2(3)$ where T is the number of observations and R^2 the squared multiple correlation (Engle and Ng, 1993).

4. Results and interpretations

Table 4 reports the parameters of the free elements in the variance equation specified in the VAR GARCH-M model, as the first step of the estimation procedure. The estimation of the parameters in the variance equations helps to identify the presence of ARCH and GARCH effects in the data generating process, although the graphs of the conditional variance provide an overview of the volatility. The ARCH effect is given by the coefficient on $\varepsilon_i(t-1)^2$ and the GARCH effect by the coefficient on $H_{i,i}(t-1)$. As depicted in the table, all five of the selected developing countries display ARCH effect in both oil prices and CPI. This implies that news about domestic prices volatility (respectively oil price volatility) from previous periods have a significant role in explaining the current volatility of domestic prices (respectively oil prices). In addition, the coefficient on $H_{i,i}(t-1)$ indicates a presence of GARCH effect in oil prices and CPI series. There are only two exceptions in these results, which are related to the CPI equations of Ghana and Niger. Firstly, in Ghana, because of the non-negativity restriction, the co-efficient is null, and secondly, in Niger, the coefficient is insignificant. The significance of the GARCH term in the majority of the countries infers that the previous periods' forecast variance of oil prices and CPI explain the current volatility of the two variables. The last column of the table represents the persistence of volatility of both oil prices and CPI. The persistency of volatility, given by the sum of the parameters on the ARCH and GARCH terms, measures the rate at which volatility dies out over time (Campbell et al., 1996; Chan, 2010). A number equal to or greater than 1 indicates a persistent volatility (volatility does not die out) and a non-stationary process. The GARCH specification should therefore be transformed into an integrated one (Integrated GARCH or IGARCH). From the table, it appears that oil and CPI volatility are not persistent and reduce over time. In general, domestic price volatility stabilises faster than oil prices, perhaps due to the relative lesser number of factors interacting with domestic price than with oil price.

Table 4. GARCH-M model: Estimation of the parameters in the variance equation

Country	Equation	Conditional Variance	Constant	$\varepsilon_i(t-1)^2$	$H_{i,i}(t-1)$	Persistency of volatility
Burkina Faso	$\Delta ln\ oil$	$H_{1,1}(t)$	0.034 (0.026)	0.177*** (0.056)	0.782*** (0.056)	0.959
	$\Delta ln\ cpi$	$H_{2,2}(t)$	0.038** (0.002)	0.140*** (0.037)	0.696*** (0.095)	0.836
Cote D'Ivoire	$\Delta ln\ oil$	$H_{1,1}(t)$	0.033 (0.003)	0.186*** (0.059)	0.777*** (0.056)	0.963
	$\Delta ln\ cpi$	$H_{2,2}(t)$	0.007*** (0.002)	0.216*** (0.049)	0.754*** (0.030)	0.97
Ghana	$\Delta ln\ oil$	$H_{1,1}(t)$	0.035 (0.026)	0.180*** (0.058)	0.778*** (0.057)	0.958
	$\Delta ln\ cpi$	$H_{2,2}(t)$	0.019*** (0.002)	0.349*** (0.095)	0.000	0.344
Niger	$\Delta ln\ oil$	$H_{1,1}(t)$	0.034 (0.026)	0.180*** (0.057)	0.779*** (0.057)	0.959
	$\Delta ln\ cpi$	$H_{2,2}(t)$	0.015*** (0.002)	0.595*** (0.076)	0.043 (0.051)	0.638
Nigeria	$\Delta ln\ oil$	$H_{1,1}(t)$	0.036 (0.027)	0.180*** (0.057)	0.778*** (0.057)	0.958
	$\Delta ln\ cpi$	$H_{2,2}(t)$	0.003* (0.002)	0.088*** (0.016)	0.906*** (0.012)	0.994

The Persistency of volatility is given by the sum of the parameters on $\varepsilon_i(t-1)^2$ and $H_{i,i}(t-1)$. The 0.000 in the table refers to the non-negativity constraint imposed in the parameterization. * significance at 10% ** significance at 5% ***significance at 1%

The tests of asymmetry (table 5) investigate the hypothesis of asymmetries in the volatility response of domestic prices to news, as described in the previous section. It appears from the table that the bias in the volatility response is driven by the positive size of the shocks rather than the negative size or the sign of the shocks. In each of the countries, the null hypothesis of no positive size-bias is strongly rejected at all percentage levels. This suggests that large and small positive shocks have different implications for domestic price volatility. In fact, in most developing countries such as sub-Saharan Africa, inflation tends to rise when the price of oil products (such as gasoline) increases due to the opportunity for profit maximisation for the sellers. Conversely, due to government interventions in the form of subsidies, tax exemptions and price regulations which protect both consumers and producers, it is not preordained that an unexpected and substantial oil price hike will result in a similar rise to the domestic price rate. The negative size-bias test shows that only Ghana and Nigeria display a minimally significant result (10%). Overall, the LM joint test shows a strong evidence of asymmetry in the response of domestic prices to news. This finding, combined with the sign-bias test produces an interesting insight into the interpretation as it shows that asymmetry in domestic price volatility responses to news does not solely depend on the sign of the shocks, but is a combination of both the sign and size of the shock. The result from the oil price equation is added to capture the response of oil price to news. The test shows similar results to the CPI equation, with the exception that both negative size-bias and positive size-bias present comparable magnitude and significance levels. The LM joint test shows that the asymmetrical response of oil price volatility to news is a combination of sign-bias and size-bias.

Table 5. Tests of asymmetry of the volatility response to news

	Variables	Sign-bias	Size-bias (Negative)	Size-bias (Positive)	LM joint test (Sign-and-size-bias)
Country	$\Delta ln\ oil$	0.0004 (0.0028)	-0.0990*** (0.0029)	0.0813*** (0.0245)	29.8744***
Burkina Faso	$\Delta ln\ cpi$	0.0001 (0.0008)	-0.0027 (0.0045)	0.0156*** (0.0034)	20.1016***
Cote d'Ivoire	$\Delta ln\ cpi$	0.0002 (0.0006)	-0.0039 (0.0067)	0.0220*** (0.0033)	45.6737***
Ghana	$\Delta ln\ cpi$	-0.0007 (0.0001)	-0.0129* (0.0070)	0.0112** (0.0047)	9.5399**
Niger	$\Delta ln\ cpi$	0.0004* (0.0002)	0.0040 (0.0109)	0.0457*** (0.0054)	47.1631***
Nigeria	$\Delta ln\ cpi$	0.0001 (0.0001)	-0.0090* (0.0052)	0.0215*** (0.0038)	33.4942***

* significance at 10% ** significance at 5% ***significance at 1%

The impact of oil price uncertainty on domestic prices is captured by the coefficient on the standard deviation in the CPI equation. The coefficient is estimated for each country selected and is reported in the first column of table 6. The measurement of uncertainty is a test of exclusion restriction on Ψ in equation (1). The null hypothesis is that uncertainty about oil price does not affect domestic prices ($\psi_{21} = 0$), irrespective of the country's oil resources. The result indicates positive significance point estimates of the coefficient in almost all countries. This denotes that a consequence of oil price uncertainty in all but one of the countries is inflation. The exception is Niger, where the coefficient is insignificant. Furthermore, the impact of oil price uncertainty on domestic price is higher in resource abundant countries. As can be seen from the table, in Nigeria and Ghana, the impact is 0.67% and 0.80%, respectively. Although Cote d'Ivoire is an oil producer, the impact of oil price uncertainty on the country's domestic prices is relatively lower than in Ghana, which could potentially be explained by their different oil rent levels. For example, oil rent in Cote d'Ivoire was estimated to be 4% of GDP in 2015 whereas in Ghana, this figure was approximatively 1.7% of GDP (World Bank, 2015). In fact, at fixed prices, higher oil rent is an indicator of dynamism in the country's oil sector. The dynamism of oil sector has a knock-on effect on the economic activity, and higher risk or uncertainty on oil price can have a harmful effect. Although Nigeria is a big oil producer in Africa, the impact of oil price uncertainty on domestic prices is lower than in Ghana. Reasons for this difference can be found in the structure of the two economies. Ghana is known to have a high inflation rate, as the depreciation of Cedi upturned the import cost of goods. Also, the government of Ghana has maintained an expansionary policy over time, creating more pressure on domestic prices. The combination of these effects negatively impacts producers supply price and consequently, households' purchase decisions. Therefore, uncertainty on the condition of the international market (including oil market) can lead to higher pressure on domestic prices. As posited by Christiano and Fitzgerald (2003) usually, households and businesses do not take inflation into account in their decision making when the inflation rate is relatively low. From this perceptive, it can be postulated that increasing inflation leads to more uncertainty in households and businesses' decisions. An important aspect of the differences between Nigeria and Ghana is their choice of oil price benchmark. Nigeria is a member of OPEC and uses the OPEC basket reference as benchmark, along with Brent price. In the robustness check, Brent oil price is replaced by OPEC reference basket price to evaluate the possible stability of the points estimates.

The increasing uncertainty pushes producers to increase prices and can prompt households to rush purchases of non-durables as future price can inflate. Subsequently, due to these actions, domestic prices also increase. A noteworthy point is that, despite its exclusion from the analysis, an exchange regime can partially explain the results. As a fixed exchange regime has the advantage of providing better precision in terms of forecast of macroeconomic variables, partly due to the exclusion of the central bank's intervention compared with the flexible exchange regime, it can be predicted that the effect of oil price uncertainty on domestic prices is higher in counties adopting a flexible regime (such as in Ghana and Nigeria) than countries using a fixed exchange rate (such as in Burkina Faso, Cote D'Ivoire and Niger). The reason for that is that economic agents in countries with flexible exchange regimes incorporate the risk due to currency parity into their decision-making process (Peter, 2000).

The last three columns of table 6 are related to the robustness check of the estimation. The major financial crisis that has led to a plunge in oil price is excluded from the analysis, and the model is estimated until June 2008, which marked the beginning of the oil crisis. The coefficients of the point estimates for every country do not significantly deviate from the main result (column 2). Also, the nominal price rather than the real price of oil is employed to assess Hamilton's (2008) argument regarding using nominal or real oil price. Hamilton (2008) asserts that it does not make much difference in summarizing the size of any given shock whether using the nominal price or the real price of oil, as in most of these shocks, the change in nominal prices is an order of magnitude larger than the change in overall prices. The result remains robust and concurs with Hamilton (2008). Finally, the OPEC reference basket (a weighted average of petroleum blends prices produced by OPEC members, including Bonny Light of Nigeria) is used as an alternative benchmark. The coefficient in Niger becomes positive and significant, whereas that of Burkina Faso, although positive, becomes insignificant. For Cote d'Ivoire and Ghana, the coefficient does not substantially deviate and the significance level remains unchanged. However, the estimate for Nigeria increases significantly and outpaces that of Ghana. The coefficient moves from 0.67% to 0.83%. From the robustness check, it can be argued that the impact of oil price uncertainty on domestic prices is robust to the period of analysis and the type of price used, but depends on the oil benchmark used, whether Brent or OPEC basket.

The post estimation tests reported in table 8 show no additional residual ARCH effect. Also, Ljung-Box Q and Q^2 statistics provide good results for almost all countries. This confirms the acceptable results in the study.

Table 6. Results and Robustness

Country	Coef. on $H_{1,1}(t)^{1/2}$, oil volatility	Alternatives		
		Pre-2008 major oil crisis	Brent (nominal)	OPEC reference basket oil price
Burkina Faso	0.155***	0.173***	0.153***	0.145
	(0.060)	(0.070)	(0.060)	(0.099)
Cote d'Ivoire	0.292***	0.389***	0.290***	0.208***
	(0.062)	(0.075)	(0.063)	(0.080)
Ghana	0.802**	0.854***	0.802**	0.827***
	(0.064)	(0.073)	(0.065)	(0.106)
Niger	-0.023	-0.070	-0.025	0.233**
	(0.055)	(0.064)	(0.055)	(0.101)
Nigeria	0.671***	0.573***	0.671***	0.834***
	(0.065)	(0.082)	(0.065)	(0.011)

* significance at 10% ** significance at 5% ***significance at 1%. Sample size for OPEC reference basket: 2003m01-2013m12. A post-2008 crisis could not be estimated as the sample period was short.

Table 7. Residual diagnostic

Country	LM test of Arch effect in the residual		Autocorrelation (Ljung-Box Q-stat)			
	F-statistic	Prob.	Q-Stat	Prob.	Q^2-Stat	Prob.
Burkina Faso	0.714	0.398	2.955	0.565	1.533	0.821
Cote d'Ivoire	0.041	0.838	6.232	0.182	0.321	0.988
Ghana	0.655	0.418	1.460	0.834	1.016	0.907
Niger	0.0125	0.910	2.987	0.560	1.096	0.895
Nigeria	0.344	0.557	24.13	0.000	0.984	0.912

5. Conclusion and discussions

A broad literature on oil price volatility attempts to capture the macroeconomic or financial spillover effect of oil price movements using different econometric techniques. Only a few studies have highlighted the role of uncertainty as well as asymmetries in oil price movements in developing countries. This study fills this gap by focusing on domestic prices in five developing African economies. The approach follows Engle and Ng's asymmetry tests (1993), and the Elder (1995, 2004), Elder and Serletis (2009, 2010) Bivariate VAR GARCH-M model used to analyse oil price uncertainty, where uncertainty is measured as the conditional standard deviation of the one-period-ahead forecast error of the change in the price of oil. The results indicate evidence of asymmetry in the response of domestic prices to shocks. The bias in the volatility response of domestic price is driven by the positive size of the shocks rather than the negative size or the sign of the shocks. In all five countries, the null hypothesis of no positive size-bias is strongly rejected at all percentage levels, indicating that large and small positive shocks have different implications for domestic price volatility. The investigation into the effect of oil price uncertainty on domestic price shows a positive, large and significant coefficient. There is a strong correlation between uncertainty of oil price and increasing domestic prices. The point estimates seem to be highly associated with the country's oil endowment. Oil producing developing countries are more sensitive to oil price uncertainty than non-oil producing developing economies. The robustness tests indicate that the results are robust to the period used or the measurement of oil price, whether nominal or real. However, changing from Brent oil price to OPEC basket reference generates challenging results, which could be explained by the countries' choice of benchmark. Combining the findings from the tests of asymmetry with that of the impact of oil price uncertainty (see Bernanke, 1983 and Pindyck, 1991), it is apparent that economic agents are oil risk adverse. Uncertainty about oil price creates biases in both producers and consumers' behaviours, leading to more asymmetries in the response of domestic prices.

The study has the following caveats. First, the measurement of oil price uncertainty is based on the conditional standard deviation of oil price around the mean, which is the dispersion in the forecast error generated by historical data. The model does not incorporate future components in the parametrization. However, the extensive application of ARCH-types models in the measurement of uncertainty in the literature (such as Engle, 1982; Greir and Perry, 1998; Elder 1995, 2004; Elder and Serletis, 2009, 2010) provides a strong background and justification for this study. Second, is the measurement of domestic prices. The indicator used is the consumer price index of all goods. The effort to disaggregate this data (and use indices such as food price index, or non-food price index) or use the producer price index faced data availability challenges. The third caveat is that the paper does not cover issues like states switching or the probability of transition between states in the interaction between oil prices and domestic prices. In this regards, modeling the relationship using the Markov-switching model can provide interesting insights. The advantage of Markov-switching is that, in addition to dealing with regime switching, the model captures possible asymmetries or nonlinearity in the adjustment processes of variables, including when the adjustments are driven by exogenous shocks (basher et al.,2016). The MCMC has been applied in many issues including marketing research (The study can therefore be extended by incorporating for example domestic fuel prices and domestic food prices to the model into a Bayesian Monte Carlo Markov Chain (MCMC) framework, as in Managi et Okimoto (2013). This choice can be justified by the numerous flexibilities the MCMC offers (Kim and Nelson, 1999; Chib, 1996) as well as the advantages mentioned above. Besides, the analysis of oil price spillover should remain broad, involving numerous variables. The reasons is that oil price fluctuates at a high frequency, and its denomination is US dollar increases its interaction with financial variables at both international and national levels.

References

Barlett, M.S., (1963) "Statistical Estimation of Density Function, Sankhya" *Ser*. A, 25, 245-54

Barsky, Robert B., & Lutz Kilian. (2004) "Oil and the Macroeconomy since the 1970s" *Journal of Economic Perspectives*, 18(4), 115–34.

Basher, S. A., Haug, A. A., & Sadorsky, P., (2016) "The impact of oil shocks on exchange rates: A Markov-switching approach". *Energy Economics*, *54*, 11–23.

Bernanke, B.S., Mark G., & Mark, W.W., (1997) "Systematic Monetary Policy and the Effects of Oil Price Shocks" *Brookings Papers on Economic Activity*, 1,91–142.

Beckmann, J., & Czudaj, R., (2013). Is there a homogenous causality pattern between oil prices and currencies of oil importers and exporters? *Energy Econ*. 40, 665–678.

Bollerslev, T., Engle, R.F., & Wooldridge, J.M., (1988) "A capital asset pricing model with time varying co-variances" *Journal of Political Economy*, 96, 116-131.

Bollerslev, T., (1986) "Generalized Autoregressive Conditional Heteroskedasticity" *Journal of Econometrics*, 31, 307-327.

Borenstein, S., Cameron, A. C., & Gilbert R., (1997). "Do Gasoline Prices Respond Asymmetrically to Crude Oil Price Changes?" *Quarterly Journal of Economics*, 112 (1), 305–39.

Brown, S., & Yucel, M., (1999) "Oil prices and U.S. aggregate economic activity: a question of neutrality" *Economic and Financial Review*, Federal Reserve Bank of Dallas Second Quarter, 16-23.

Brown, S., & Yucel, M., (2002) "Energy prices and aggregate economic activity: an interpretative survey" *Quarterly Review of Economics and Finance*, 42 (2), 193–208.

Campbell, J. Y., Lo, A. W., MacKinlay, A. C., Adamek, P., & Viceira, L. M. (1997) "The *Econometrics of Financial Markets"* Princeton, NJ: Princeton University Press.

Chib, S.,(1996). "Calculating posterior distributions and model estimates in Markov mixture models". *Journal of Econometrics,* 75, 79–98.

Christiano, L.J., & Fitzgerald, T. J., (2003) “The band pass filter” *International Economic Review*, 44,435-465.

Davis, S.J., (1987) “Allocative Disturbances and Specific Capital in Real Business Cycle Theories” *American Economic Review Papers and Proceedings*, 77, 738–51.

Davis, S.J., & Haltiwanger J., (2001) “Sectoral Job Creation and Destruction Responses to Oil Price Changes” *Journal of Monetary Economics*, 48, 465–512.

Dickey, D.A., & Fuller, W.A., (1981) “Likelihood ratio statistics for autoregressive time series with a unit root” *Econometrica,* 49, 1057–1072.

Ding, Z., Granger, C. W. J., & Engle, R. F., (1993) “A Long Memory Property of Stock Market Returns and a New Model” *Journal of Empirical Finance*, 1, 83–106.

Edelstein, P., & Kilian L., (2007a) “The Response of Business Fixed Investment to Changes in Energy Prices: A Test of Some Hypotheses about the Transmission of Energy Price Shocks” *B.E. Journal of Macroeconomics*, 7(1).

Edelstein, P., & Kilian L., (2007b) “Retail Energy Prices and Consumer Expenditures” Unpublished.

Elder, J., (2003) “An impulse-response function for a vector auto-regression with multivariate GARCH-in-mean” *Economics Letters*, 79 (1), 21–26.

Elder, J., (1995) “Macroeconomic and Financial Effects of Monetary Policy and Monetary Policy Uncertainty” *(Ph.D. Dissertation) University of Virginia*.

Elder, J., (2004) “Another perspective on the effects of inflation volatility. *Journal of Money” Credit and Banking*, 36, 911–928.

Elder, J., Serletis, A., (2009) “Oil price uncertainty in Canada”. *Energy Econ*. 31, 852–856.

Elder, J., Serletis, A., (2010) “Oil price uncertainty. J. Money Credit Bank”. 42, 1138–1159. Elder,

Elliot, G., Rothenberg, T.J., & Stock, J.H., (1996) “Efficient tests for an autoregressive unit root” *Econometrica*, 64, 813–836.

Engle, R.F., (1982) “Autoregressive conditional heteroskedasticity with estimates of the variance of United Kingdom inflation”. *Econometrica*, 50, 987-1007.

Engle, R.F., Granger, C.W.J &. Kraft, D.F., (1984) “Combining competing forecasts of inflation using a bivariate ARCH model”. *Journal of Economic Dynamics and Control*, 8, 151-165.

Engle R.F., Lilien, D.M., & Robins, R.P., (1987) “Estimating time varying risk premia in the term structure: The ARCH-M model”. *Econometrica*, 55 391–407.

Engle, R.F., & Kroner, K.F., (1995) “Multivariate simultaneous generalized ARCH”. *Econ. Theory*, 11, 122–150.

Engle, R.F., & Victor K. Ng., (1993) "Measuring and Testing the Impact of News on Volatility". *The Journal of Finance*, 5, 1749-1778.

Glosten, L., Jaganathan, R., & Runkle, D., (1993) "Relationship between the Expected Value and Volatility of the Nominal Excess Returns on Stocks", *Journal of Finance*, 48, 1779–1802.

Goldberg, P.K., (1998) "The Effects of the Corporate Average Fuel Efficiency Standards in the US". *Journal of Industrial Economics*, 46(1), 1–33.

Golub, S.S., (1983) "Oil prices and exchange rates". *Econ. J.* 93, 576–593.
Greir, K.B., & Perry, M.J., (1998) "Inflation and inflation uncertainty in the G-7 countries". *Journal of International Money and Finance*, 17 (4), 671–689.

Greir, K.B., & Perry, M.J., (2000) "The effects of real and nominal uncertainty of inflation and output growth: some GARCH-M evidence". *Journal of Applied Econometrics* 15 (1), 45–98.

Grier, K.B., Henry, Ó.T., Olekalns, N., Shields, K., (2004) "The asymmetric effects of uncertainty on inflation and output growth". *J. Appl. Econ*. 19, 551–565.

Hamilton, J.D., (2008) "Oil and the macroeconomy. In: Durlauf, S.N., Blume, L.E. (Eds.)", *The New Palgrave Dictionary of Economics. Palgrave Macmillan.*

Hamilton, J.D., (1988) "A Neoclassical Model of Unemployment and the Business Cycle". *Journal of Political Economy*, 96, 593–617.

Hamilton, J.D., (1996) "This Is What Happened to the Oil Price–Macroeconomy Relationship". *Journal of Monetary Economics*, 38(2), 215–20.

Hamilton, J.D., (2003) "What Is an Oil Shock?" *Journal of Econometrics*, 113(2), 363–98.

Hamilton, J.D., (2008) "Oil and the Macroeconomy". In the New Palgrave Dictionary of Economics, Second edition, ed. Steven N. Durlauf and Lawrence E. Blume. Houndmills, U.K. and New York: *Palgrave Macmillan*

Hooker, M.A., (1996a)T"his Is What Happened to the Oil Price–Macroeconomy Relationship: Reply." *Journal of Monetary Economics*, 38(2), 221–22.

Hooker, M.A., (1996b) "What Happened to the Oil Price–Macroeconomy Relationship?" *Journal of Monetary Economics*, 38(2), 195–213.

Hooker, M.A. (2002) "Are Oil Shocks Inflationary? Asymmetric and Nonlinear Specifications versus Changes in Regime". *Journal of Money, Credit, and Banking*, 34(2), 540–61.

Johansen, S., (1988) "Statistical analysis of cointegrating vectors". *Journal of Economic Dynamic and Control,* 12, 231–254.

Johansen, S., (1991) "Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models". *Econometrica*, 59, 1551–1580.

Keane L. S., Mignon, V., (2008) “Oil prices and economic activity: an asymmetric cointegration approach”. *Energy Economics* 30 (3), 847–855.

Kenen, P. B., (2000)” Fixed Versus Floating Exchange Rates”. *Cato Journal*, 20(1), 109-113.

Kilian, L., (2009) “Not All Oil Price Shocks Are Alike: Disentangling Supply Shocks in the Crude Oil Market”. *The American Economic Review*, 99(3), 1053–1069.

Kilian, L., (2008) “The Economic Effects of Energy Price Shocks”. *Journal of Economic Literature*, 46(4), 871–909.

Kilian, L., (2008b) “Exogenous Oil Supply Shocks: How Big Are They and How Much Do They Matter for the U.S. Economy?” *Review of Economics and Statistics*, 90(2), 216–40.

Kim, C. J., & Nelson, C., (1999). “State-Space Models with Regime Switching: Classical and Gibbs-sampling Approaches with Applications”. *MIT Press, Cambridge.*

Kwiatkowski, D., Phillips, P.C.B., Schmidt, P., & Shin, Y., (1992) “Testing the null hypothesis of stationarity against the alternative of a unit root”. *J. Econ*. 54, 159–178.

Lee, K., Ni S., (2002) “On the Dynamic Effects of Oil Price Shocks: A Study Using Industry Level Data”. *Journal of Monetary Economics*, 49(4), 823–52

Lee, K., Ni S., & Ronald, A. R.,(1995) “Oil Shocks and the Macroeconomy: The Role of Price Variability”. *Energy Journal*, 16(4), 39–56.

Lee, N, W. K., & West, K. D., (1994) “Automatic lag selection in covariance matrix estimation”. *The Review of Economic Studies*, 61,631-653.

Managi, S., & Okimoto, T., (2013). Does the price of oil interact with clean energy prices in the stock market? *Japan and the World Economy*, *27*(1)–9.

Mork, K.,A., (1989) “Oil and Macroeconomy When Prices Go Up and Down: An Extension of Hamilton’s Results”. *Journal of Political Economy*, 97(3), 740–44.

Moschini, G., & Hennessy, D. A., (2001) “Uncertainty, Risk Aversion, and Risk Management for Agriculture Producers”. *Handbook of Agricultural Economics*, 1, 88–153.

Nelson, D. B., (1991) “Conditional Heteroskedasticity in Asset Pricing: A New Approach,” *Econometrica*, 59, 347-370.

Nelson, D. B. & Cao, C. Q., (1992) “Inequality Constraints in the Univariate GARCH Model”. *Journal of Business and Economic Statistics*, 10, 229–235.

Newey, W. K. & West, K, D., (1987) “A Simple, Positive Semi-definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix”. *Econometrica*, 55 (3): 703–708.

Ngai H, C, (2010) “Time Series: Applications to Finance with R and S-plus”. *2nd Edition, John Wiley*.

Phillips, P.C.B., & Perron, P., (1988) “Testing for a unit root in time series regressions”. *Biometrica,* 75, 335–346.

Pindyck, R. S. (1991) “Irreversibility, Uncertainty, and Investment”. *Journal of Economic Literature,* 29(3), 1110–48.

Sadorsky, P., (1999) “Oil price shocks and stock market activity”. *Energy Econ*. 21, 449–469

Savage, L., (1954) “The Foundations of Statistics”, *New York: Wiley*.

Schwarz, G., (1978) “Estimating the dimension of a model”. *Ann. Stat*. 6, 461–464.

Von Neumann, J. & Oscar M., (1944) “Theory of Games and Economic Behavior”. *Princeton*, *NJ*: Princeton University Press.

Zakoian, J. (1994) “Threshold heteroskedastic functions”. *Journal of Economic Dynamics and Control*, 18: 931-955.

Zakoian, J. M. (1991) “Threshold heteroskedastic models”, *Technical report*, INSEE.

Zakoian, J. M. (1994) “Threshold Heteroscedastic Models”. *Journal of Economic Dynamics and Control*, 18, 931–955.

Energy Information Administration
http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=RBRTE&f=M

National archive
(http://archives.assembleenationale.bf/20072012/Rapport/Rapportscommissionsadhoc/Rappor2.pdf)

The World Bank http://data.worldbank.org/indicator/NY.GDP.PETR.RT.ZS