Macroeconomic determinants of crude oil demand in Ghana

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Macroeconomic Determinants of Crude Oil Demand in Ghana

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Abstract

This paper investigates the macroeconomic determinants of crude oil demand (consumption) in Ghana with annual data from 1980 to 2013. The study applied the vector error correction model (VECM) to estimate the long-run and short-run determinants of crude oil demand in Ghana within the study period. The long run estimates reveal that price of crude oil, real GDP per capita, real effective exchange rate, and energy saving technical progress are significant long run determinants of crude oil demand. The results also indicate that crude oil demand in Ghana is income and price inelastic. Crude oil price has a positive long run effect indicating the virtual lack of substitutes and overdependence on crude oil for energy generation and economic activities in Ghana. Based on the variance decomposition and impulse response analyses, the study also found that positive shocks from real effective exchange rate had a dominant and positive impact on crude oil demand in Ghana. We suggest among others that Ghana vigorously explore alternative and sustainable and energy sources to curtail the overdependence on crude oil, strategically hedge against volatilities in the exchange rate market, and revive the country's oil refinery to refine her own crude oil to reduce importation.

Keywords: crude oil demand, GDP per capita, crude oil price, VECM, Ghana

Introduction

Crude oil is an important input in the productive sectors of any economy – manufacturing, agriculture, and services. The neoclassical growth model with oil (Solow 1974, 1986) emphasized the importance of oil resources in production. The model includes crude oil as an input in the production function together with capital and labour. It explains how crude oil complements labour and capital in aggregate production. Crude oil supports many sectors of an economy because it is a multi-purpose energy source, which is highly consumed in most countries (Stambuli, 2014). As a very important energy source for all economies, crude oil production and consumption have been found to be inseparably linked with industrialisation, economic growth and sustainable development (Cantah and Asmah, 2015; Adom and Kwakwa, 2014).

In Ghana substantial amount of crude oil is used for electricity generation, manufacturing, transportation among other production activities. In the energy sector for instance, apart from natural gas, light crude oil is the main energy source that powers Ghana's thermal plants to produce electricity (Energy Commission, 2016). Between 2012 and 2015, imported light crude oil constituted between 58 percent to 90 percent of the sources for electricity generation in Ghana (See Figure 1, National Energy Statistics, 2016). In addition, as at 2013, about 72 percent of imported light crude oil was used principally for electricity generation while the remainder 28 percent was refined into other petroleum products such as gasoline, petrol, kerosene, and liquefied petroleum gas (LPG) (National Energy Statistics, 2014). This means that Ghana largely depends on crude oil to meet her domestic petroleum needs – crucial for driving the wheels of industrial production and general economic activities in the country.

The recent power crisis in Ghana – attributed to the limited supply of Liquefied Petroleum Gas (LPG) from Nigeria and from the local oil fields – has necessitated a surge in the reliance and demand for light crude oil in the country to generate the extra megawatts of electricity needed for domestic and industrial use. The expected consequences of the power situation, similar to that of Nigeria and other sub-Saharan African countries, are soaring industrial production costs, and increasing industrial job losses, with significant loss of productive man-hours (Adom, 2015).

Ghana has witnessed an increasing trend in the consumption of crude oil since the 1980s (see Figure 2). In the 1980s crude oil demand (consumption) in Ghana averaged 21,000 barrels per day (bbls), which increased to an average of 53,870 bbls between 1990 and 2009 and further increased from 64,730 to 66,570 bbls in 2010 and 2013 respectively (US-Economic Intelligence Agency, 2014). This continuous ascendency of demand is attributed to increased energy and power requirements of the country due to the emerging middle class, increased urbanization, expansion in household energy use, and industrial productive capacity over the years (Eshun and Amoako-Tuffour, 2016). Figure 2 shows an increasing trend in crude oil consumption in Ghana.

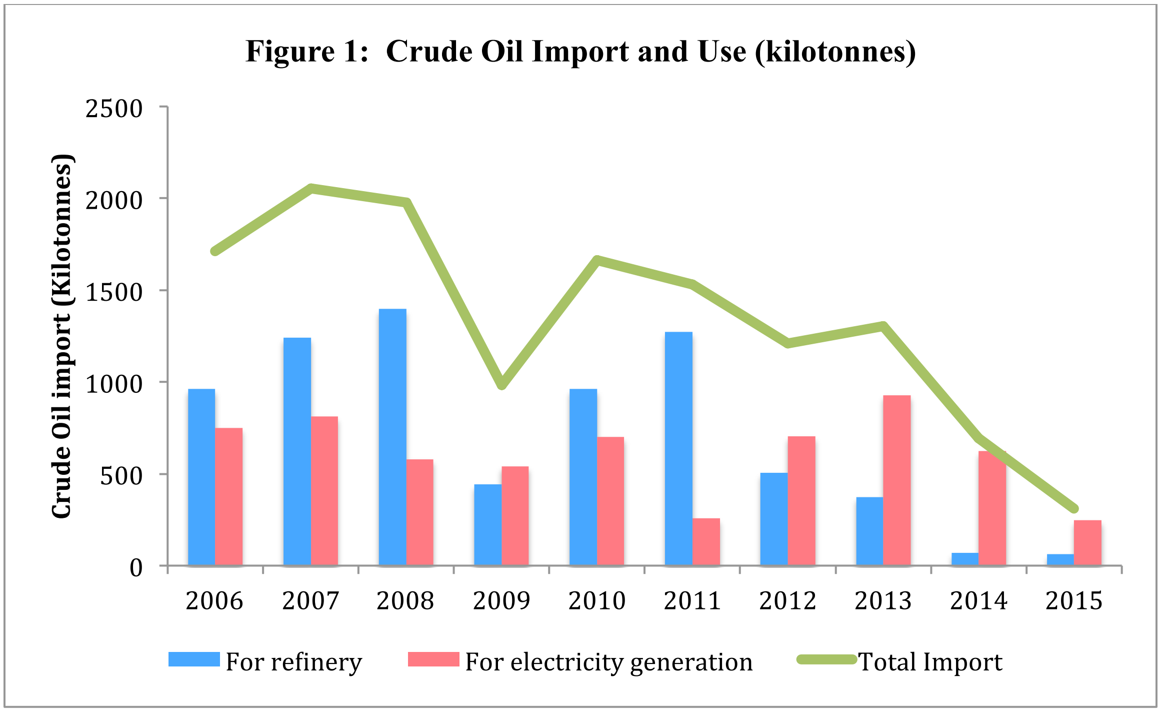

Figure 1: Crude Oil Import and Use (kilotonnes)

Source: National Energy Statistics, Energy Commission of Ghana, April 2016

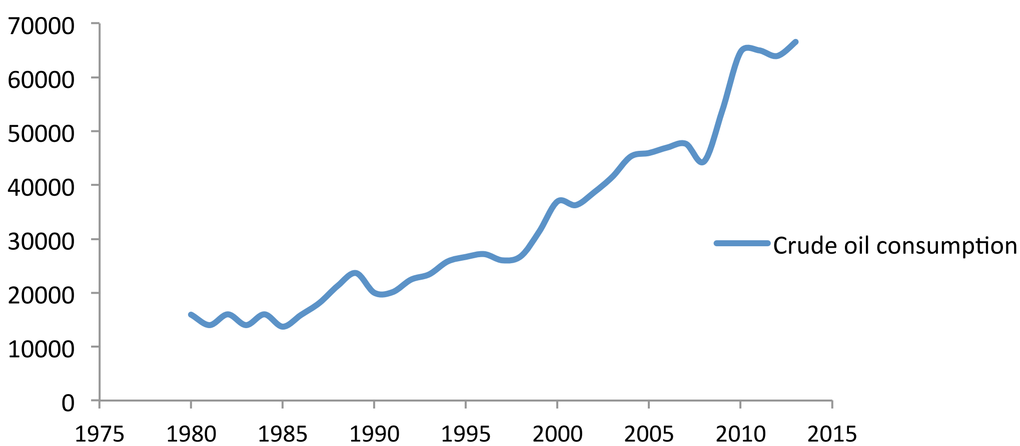

Figure 2: Trends in crude oil consumption in Ghana (thousand barrels per day)

Source: United States Energy Information Agency, 2014

Though Ghana has become a net-exporter of crude oil with significant production from its Saltpond and Jubilee Oil fields since 2011 (Energy Commission of Ghana, 2016), the country still over relies on imported crude oil to cater for its energy requirements. The domestic economy is therefore vulnerable to the negative impulses of changes in international crude oil prices, exchange rate volatilities, and other macroeconomic shocks (Marbuah, 2014; Cantah and Asmah, 2015).

Review of Related Literature

Energy demand is a well-researched topic and continues to grow in the literature. Studies on the determinants of demand for various energy sources show that real energy price, real income (or per capita income), industrial output, technological progress, urbanisation, and structural changes in the economy are some of the important drivers of demand. Ableku, et al (2013), for example, attributes the high demand for crude oil and refined petroleum products in Ghana to socioeconomic and technical factors such as growth in economic output and incomes, population shifts from rural to urban, growth in industrial output, and growth in the transportation sector. Most studies on energy demand have focused more on the price and income elements and used other variables as policy, structural, and technological control factors (Ziramba, 2010; Cantah and Asmah, 2015; Breitenfellner et al., 2009; Ozcan, 2015).

Moreover, from the accessible literature, most of the energy demand studies in sub-Saharan Africa and particularly on Ghana have mainly focused on demand for specific types of energy sources such as petroleum, gas oil/diesel, kerosene, LPG, and biofuels (See Adom et al, 2012, Adom et al, 2013, Ackah, 2014, Mensah, 2014, Mensah et al, 2016). Marbuah (2014) is the only known study on demand for crude oil in Ghana but the study focused on crude oil import demand behaviour. Specifically, Marbuah (2014) investigated how crude oil imports respond to price and income changes in Ghana while controlling for other macroeconomic variables such as population growth, real effective exchange rate, and crude oil production.

The studies on crude oil consumption identified in the extant literature were mostly from outside sub-Saharan Africa (See Table 1). These studies have employed various econometric methods to estimate the determinants of crude oil demand in both single time series and cross-country panel cases respectively. Among them are time series and panel data models, partial adjustment and lagged models, ARDL and other cointegration models. To a larger extent, the studies do not always report unanimous findings on the effect of the macroeconomic determinants of demand for energy, though most confirmed the expected signs of real price and real income effects based on demand theory (Ozcan, 2015). Table 1 provides a summary of empirical studies that focused specifically on the demand for oil consumption.

Tables

Table 1: A Summary of Literature specific on Crude oil consumption (demand)

Study	Country	Period	Method	LR-price elasticity	SR-price elasticity	LR-income elasticity	SR-income elasticity
Ozcan (2015)	20 selected OECD countries	1980-2011	Panel cointegration tests and FMOLS	-0.16		0.72	
Fawcett and Price (2012)	*G7, Remaining OECD, Developing Asia, Latin America		Panel unit root and cointegration tests	-0.15 to -0.06	-0.04 to 0.008	0.26 to 1.31	0.61 to 0.90
Cho et al. (2011)	51 countries	1971-2005	Panel cointegration tests and FMOLS	-0.01(all) -0.03(Asia) -0.02 (OECD)	-----	0.37(all) 0.44(Asia) 0.06(OECD)	----
Narayan and Wong (2009)	6 Australian States and one territory	1985-2006	Panel cointegration tests and FMOLS	0.02ns	-----	0.17	-----
Narayan and Smyth (2007)	12 Middle East countries	1971- 2002	Panel cointegration tests and DOLS	-0. 015	-0.0008ns	1.014	0.1715
Stambuli (2013)	Tanzania	1972-2010	Nerlove's Partial	-0.012	–0.005	1.75	0.747

			Adjustment Model (PAM)				
Tsirimokos (2011)	10 IEA member-countries	1980-2009	Nerlove's PAM	-0.275 to -0.066	-0.104 to -0.036	0.726 to 2.473	0.355 to 0.66
Cooper (2003)	23 OECD countries Norway France Iceland	1971-2000	OLS Nerlove's PAM	-0.005 to -0.568 -0.036 -0.568 ---	-0.001 to -0.109 -0.026 --- -0.19	----	---
Sillah and Al-Sheikh (2012)	6 GCC	1980-2010	Cointegration and VECM	-0.30 to 2.51	------	-2.20 to +0.28	----
Dees et al. (2007)	10 main trading partners of the euro area	1984- 2002	DOLS and VECM	-----	-0.07 to -0.03	0.17 to 0.98	0.01 to 0.82
Krichene (2005)	World market	1918-2004 1918-1973 1974-2004	Cointegration and two-stage least squares	-1.59 -2.73 -012	-0.05 -0.05 -0.003	3.48 3.43 0.62	0.54 0.43 1.49
Moore (2011)	Barbados	1998- 2009	ARDL	-0.55	-----	0.91	----
De vita et al. (2006)	Namibia	1980-2002 1990-2002	ARDL	-0.85 -0.79	-----	1.08 0.95	-----
Gately and Huntington (2002)	96 OECD non-OECD	1971-1997	Panel fixed effects model	-0.60 -0.12	----	0.55 0.95	---
Ghouri (2001)	US Canada Mexico	1980-1999	Almon polynomial distributed lag model	-0.045 -0.06 -0.13	-0.029 -0.007 -0.015	0.98 1.08 0.84	---

Notes: VECM represents Vector error correction model; n denotes insignificance; LR and SR indicate long-run and short-run, respectively; ARDL is the autoregressive distributed lag model; FMOLS is the fully modified ordinary least squares; DOLS is the dynamic ordinary least squares.

Objectives

As acknowledged above, though a plethora of studies exist on determinants of energy demand, the literature reveals there is no study specifically on the determinants of crude oil consumption in Ghana. Given this background and context, this paper examined the long and short run determinants of crude oil demand in Ghana using the vector error correction model (VECM). In addition, we examined through the variance decomposition functions (VDFs) and impulse response functions (IRFs) how shocks and innovations from crude oil price (*OilP*), real per capita GDP (*rGDPPC*), real effective exchange rates (*REEX*) and exogenous technical progress (*T*) affect crude oil consumption (*OilC*) in Ghana.

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Rationale of the study

With the growth in the productive sectors of the economy of Ghana, comes along the increase in demand for all types of energy. Ghana's huge dependence on crude oil as the main energy source has ramifications for its external balances (Marbuah, 2014) coupled with the environmental effects from Carbon emissions. Moreover, the increasing levels of crude oil consumption in Ghana have implications for the sustainability of climate change initiatives and policies in Ghana. Therefore, knowing what drives crude oil demand in Ghana has important economic implications for the strengthening of crude oil demand-side management policies and effective investment decisions (Adom and Bekoe, 2012) that is in tandem with Ghana's growth aspirations.

Methodology and Data

Crude Oil Demand Model

Following Jiping and Ping (2008), crude oil demand in this study is synonymous with total crude oil consumption due to the absence of statistical information for actual oil demand. The existing literature posits that aggregate oil consumption is determined by factors such as prices, income, and the economic structure of the country (Howard et al., 1993, cited in Narayan and Smyth, 2007). The crude oil demand model used in this study is based on the general energy demand model, which is specified as a function of price of crude oil, per capita income (GDP) and other macroeconomics control variables (Ozcan 2015; Marbuah, 2014). This is expressed in functional form as:

$$OilC_t = f(rGDPPC_t, OilP_t, REEX_t,\ T) \tag{1}$$

where OilC represents oil consumption, rGDPPC represents real per capita GDP in US$, OilP is the real oil price (calculated from Brent crude prices in US$), REEX represents real effective US$ to Ghana cedi exchange rates, and T is the time variable as a proxy for energy saving technical progress (Beenstock and Willcocks,1983).

The estimable logarithmic form of the crude oil demand model from equation (1) is written as:

$$lnOilC_t = \beta_1 + \beta_2 lnrGDPPC_t + \beta_3 lnOilP_t + \beta_4 lnREEX_t + \beta_5 lnT_t + \varepsilon_t \quad (2)$$

Oil consumption and Brent crude oil prices were sourced from British Petroleum and the United States Energy Information Administration. The real GDP per capita and the real effective US$ exchange rate data were sourced from the World Bank's World Development Indicators. The data used constituted annual time series covering the period from1980 to 2013.

Econometric Methods

Prior to estimating the demand function for crude oil, we followed the standard econometric procedure by first checking the stationarity and order of integration of the time series data and then proceeding to conduct the cointegration analysis. We used the Augmented Dickey Fuller (ADF) and the Phillip-Perron (PP) unit root tests in this case (See Maitra, 2016 for more on ADF unit root test). We also used the alternative unit root test for structural breaks in the series by Perron and Vogelsang (1992) and Perron (1997). The null hypothesis of the ADF and PP unit test states a condition of non-stationarity against the alternative of stationarity in the series. PP is used as a check on the possible low power problem of ADF in rejecting the null hypothesis of stationarity in small sample data (Khatun, 2016).

The Johansen (1988) multivariate cointegration test was applied to test if the variables in the time series follow a common long run trend. The ARDL cointegration test (Pesaran et al. 2001) was applied as a robust check to the Johansen cointegration analysis. Though the Johansen (1988) cointegration analysis may suffer from finite sample problems, it reveals the number of cointegrating vectors that are used in the estimation through the vector error correction model (VECM) unlike the ARDL method[1].

According to Johansen (1988), for n (more than two) number of variables, there can only be up to n-1 cointegration vectors. The estimation equation is specified as:

$$\Delta V_t = (A_t - I)V_{t-1} + \varepsilon_t \tag{3}$$

where V_t represents a $n\times 1$ vector of variables, ε_t represents a $n\times 1$ vector of disturbances and A_t are $n\times n$ matrix of parameters, given that there are n variables. The mean of the $n\times 1$ vector of disturbances is zero and the covariance matrix is *iid*. This approach by Johansen employs the trace-statistic and maximum Eigenvalue criteria to test for cointegrating equations.

The representation of all five variables in the crude oil consumption function in the vector error correction model (VECM) specification takes the form:

$$\begin{aligned}
&\Delta Z_t = \alpha + \Gamma_1 \Delta Z_{t-1} + \Gamma_2 \Delta Z_{t-2} + \Gamma_3 \Delta Z_{t-3} + \Gamma_4 \Delta Z_{t-4} + \Gamma_5 \Delta Z_{t-5} + \Pi Z_{t-1} + \mu_t \\
&\Gamma_i = -(A_1 + A_2 + A_3 + A_4 + A_5 - I) \\
&i = 1,2,3,4,5 \\
&\Pi = A_1 + A_2 + A_3 + A_4 + A_5 - I
\end{aligned} \tag{4}$$

[1] See Johansen (1988) for detail theoretical treatment on the cointegration analysis method and Pesaran et al. (2001) for more on ARDL cointegration.

Z_t is a vector of variables integrated of order one I(1) of dimension $n \times 1$. $\prod$ is the impact matrix and also a square coefficient matrix with dimension 5×5. It estimates the degree of cointegration in the system and has knowledge regarding the long-run relationships among the variables. The disturbance term (μ) is a representation for a vector of innovations with dimension $n \times 1$. If we impose the assumption that $\prod = \alpha\beta^I$ for matrix of dimension ($m \times r$), the speed at which the model will adjust to equilibrium after external shocks is denoted by α. The long-run matrix of coefficients is represented by β^I.

Analysis of Results

Table 2: Unit root results (constant with trend)

Variable	**ADF test**		**PP test**		
	LEVELS	1ST DIFFERENCE	LEVELS	1ST DIFFERENCE	Decision
LnC	-5.216015	-5.51440***	-7.228223	-15.1287***	I(1)
LnGDPPC	-2.006984	-4.927563***	-2.372341	-3.405053**	I(1)
LnOilP	-1.802041	-5.506144***	-1.627126	-8.592828***	I(1)
LnREEX	-2.205203	-6.7954***	-1.748826	-6.712282***	I(1)

***, ** indicates 1% and 5% significance levels respectively

Source: Authors' Computation.

Table 3: Cointegration results

Hypothesized No. of CE(s)	**Trace test** Test stat	**5% CV**	**Max- Eigen value** Test stat	**5% CV**	**Decision**
None	211.2154	69.81889**	160.4140	69.81889**	
At most 1	50.80139	47.85613**	25.46381	47.85613	Cointegration
At most 2	25.33758	29.79707	14.75949	29.79707	Present
At most 3	10.57808	15.49471	10.16484	15.49471	
At most 4	0.413244	3.841466	0.413244	3.841466	

**Reject the null hypothesis at 5% significance level

Source: Authors' Computation.

From Table 2, the ADF and PP tests significantly rejected the null hypothesis of non-stationarity after the first-difference of each of the series. The series employed in this study have an integrating order of one [I (1)]. Meaning shocks to each of the variables will not have a lasting effect since there is the presence of mean reversion after first difference.

The Johansen cointegration results presented in Table 3 show that a cointegration relationship exist and hence there is a stable long-run equilibrium relationship among the variables when crude oil consumption is considered the dependent variable. Both the trace test and maximum eigen results reject the null hypothesis of no cointegration. The ARDL bounds test used as a robust check for cointegration shows the presence of cointegration. From Table A3 in the appendix, the F-statistic of 10.87 clearly exceeds both the lower and upper bounds at the 1% significance level.

Table 4: VECM results for long-run estimates

Variable	Coefficient	Standard Error	t-value
LNGDPPC	0.206880**	0.24770	4.33710
LNOILP	0.300042**	0.05221	5.74646
LNREEX	0.418294**	0.09703	4.31112
LN_T	-2.897419**	0.26144	-11.0824

** – indicates significance at 5% level, respectively. Optimal lag length is determined by the AIC (See Table A1 in the appendix).

Source: Prepared by the authors.

Having confirmed the existence of cointegration among the variables, we estimated the VECM long run determinants of crude oil consumption in Ghana based on equation 2. From the results presented in Table 4, all the coefficients are inelastic except the time trend variable. From the results, the real GDP per capita has a positive and significant long run effect on crude oil consumption, indicating that an improvement in national income increases crude oil demand in Ghana. This supports the findings of Marbuah (2014) for crude oil import demand behaviour in Ghana that increases in national income stimulates demand for crude oil dependent economic activities and cause the demand for crude oil to also increase. Our estimate was however income inelastic showing a less sensitive effect compared to Marbuah (2014) perhaps due to the inclusion of domestically produced crude oil as part of the quantity of crude oil consumption.

Price of crude is also significant with an inelastic but positive long run effect. This can be explained partly by the fact that Ghana is overly dependent on crude oil for energy generation for almost all categories of economic activities, including manufacturing, transportations, electricity generation, agriculture, financial services provision, among others, with virtually no substitute. For instance, natural gas has been an unreliable source of energy generation and has constituted no more than 13% of total energy supply in Ghana (Energy Commission, 2016). Although expensive, an increase in prices of crude oil does not have much effect on the consumption of crude for the generation of energy to support economic activities in Ghana. This result is contrary to findings from most developed countries (See Table 1) and also that of Marbuah (2014) who found a negative price inelastic demand for crude oil.

The long run effect of real effective exchange rate is positive and inelastic and has a similar magnitude of 0.4 as in the case of Marbuah (2014). The results imply that a real depreciation of the US dollar against the Ghana cedi motivates economic activities with significant tradable components and causes consumption of crude dependent energy sources to also increase (Askari and Krichene, 2010), though with a small effect. Moreover, the results showed evidence that in the long run exogenous technical progress over time has a negative effect on crude consumption. That is, the country can benefit from technological advancement by way of using energy saving technology for production activities.

Table 5: VECM results for short-run estimates

Variable	Coefficient	Standard Error	t-value
ECM (-1)	-0.931115**	0.31589	-2.94762
D(LNGDPPC(-1))	-1.310033	0.81217	-1.67301
D(LNGDPPC(-2))	-1.564101**	0.82153	-1.99388
D(LNOILP(-1))	0.004272	0.07954	0.05370
D(LNOILP(-2))	0.017198	0.06942	0.24773
D(LNREEX(-1))	0.155602**	0.06471	2.40458
D(LNREEX(-2))	-0.109346**	0.05568	-1.96392
D(LNT(-1))	11.28944**	3.66435	3.08089
D(LNT(-2))	-5.111163**	1.72513	-2.96278
C	-0.375328	0.14946	-2.51130
R-squared	0.696711	F-statistic	3.445780
Adj. R-squared	0.494519		
Lags: 2 (AIC Criteria)			
** Significant at 5% significant level			

Source: Prepared by the authors

The short run results associated with the long run is presented in Table 5. From the VECM results, the short-run coefficients of oil price are statistically insignificant at 5% significance level, probably explained by the fact that with net oil importers like Ghana, the fluctuations in the price of oil does not significantly affect the amount of oil that is demanded since economic activities in such economies is highly dependent on oil. However, real GDP per capita, lagged two periods, yielded a negative sign in the short run contrary to positive expectation. The real exchange rate effect in the short run is consistent with the long run for a one-year lag but negative for the two-year lag. Thus exchange rate appreciations of the Ghana cedi in the past year could signal some subdued increase in level of crude oil consumption in Ghana. The ECM(1) coefficient, -0.93, collectively indicates a high speed of adjustment with which crude oil consumption responds to changes in its estimated determinants in the model before adjusting to long-run equilibrium. This implies that for every 1% deviation from long-run equilibrium, 93% of it is corrected yearly. About 69% of variation in oil consumption in Ghana is explained by all the independent variables in the short run. The estimated VECM model diagnostic tests indicate that the model is stable and has a good fit as indicated by the results in Table A2 in the appendix. There is the absence of serial autocorrelation and heteroskedasticity.

We further examined how the dynamic behaviour of crude oil consumption in Ghana responds to a one period shock and innovations from its determinants: crude oil price, real GDP per capita, real effective exchange rate, and exogenous technical progress. We conducted a variance decomposition and impulse response analysis based on the estimated VECM. The results for variance decomposition analysis and the impulse response analysis are shown in Table 6 and Figure 3 respectively.

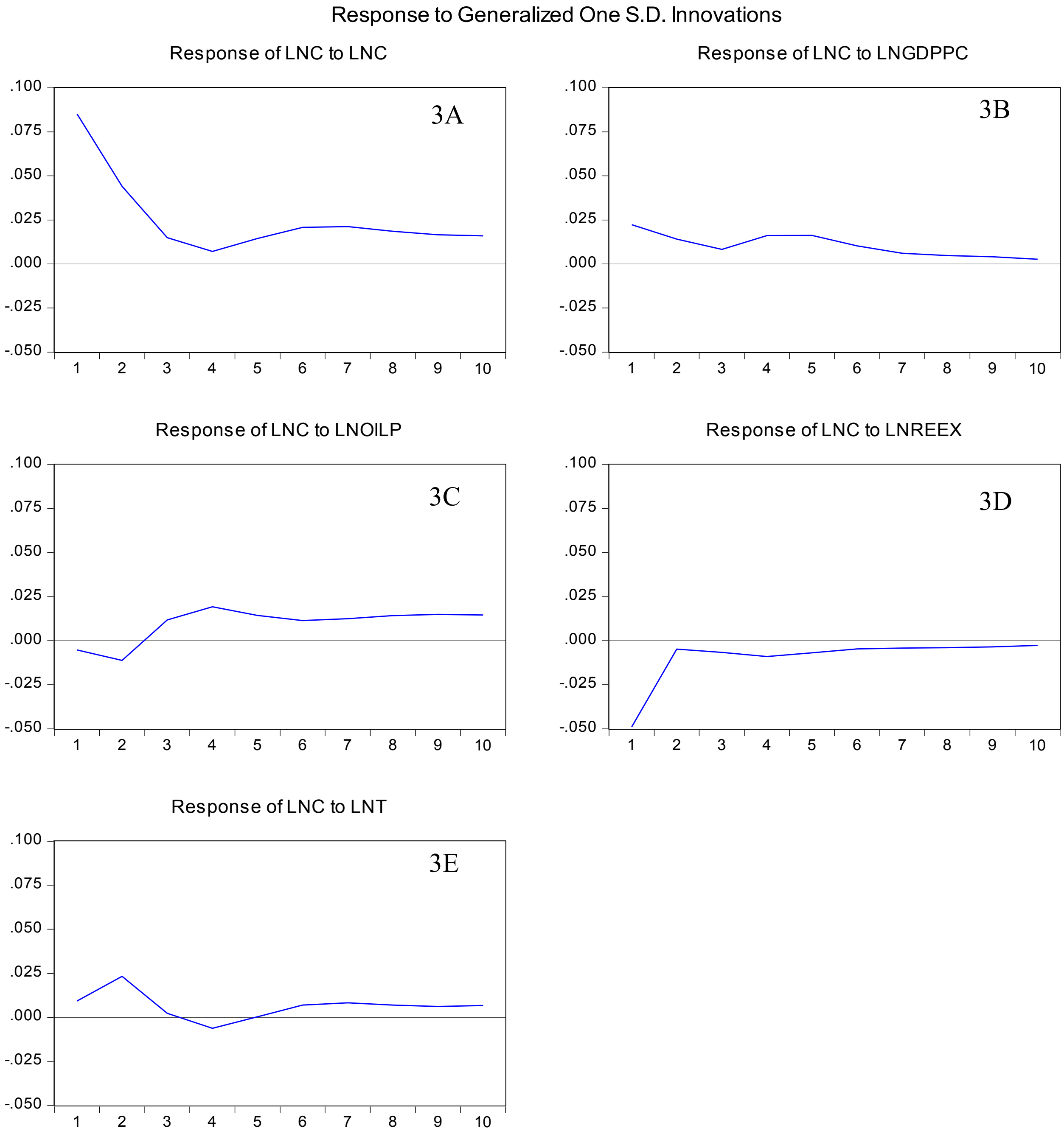
Table 6: Variance decomposition results

32 Observations, VAR=2					
% Generalized forecast error variance decomposition for Variable LnC					
% of forecast variance explained by shocks/innovations in included independent variables					
Horizon	LNC	LNGDPPC	LNOILP	LNREEX	LNT
1	90.827	6.8799	1.5289	23.865	6.2243
2	89.044	7.2343	2.7713	23.273	6.0117
3	84.650	9.1489	5.9181	22.731	6.0250
4	81.401	10.805	7.2998	21.786	5.6704
5	79.380	10.911	7.8450	20.515	5.6817
6	77.722	10.499	8.4887	19.363	5.8344
7	76.084	10.111	9.4603	18.473	5.8683
8	74.498	9.7681	10.520	17.728	5.8631
9	73.049	9.4123	11.435	17.045	5.9132
10	71.734	9.0533	12.173	16.408	6.0420

Source: Prepared by the authors

From Table 6, we infer that within a ten-year horizon, the forecast error variance in crude oil consumption (LNC) is primarily as a result of its own dynamics, ranging from 90.827% of the forecast error variance in the first horizon through to 71.73% in the tenth horizon. The dynamic changes in Ghana's crude oil demand within the sample period may be as a result of changes in the structure of the Ghanaian economy. The rest of the forecast error variance in crude oil consumption is mainly attributed to innovations in real effective exchange rate (LNREEX) with a forecasting power declining from 23.8% to 16.4% by the tenth horizon. Innovations in crude oil price is explosive as its forecasting error variance tended to rise over the time horizon from a low of 1.53% to 12.17% at the end of the forecast period. Thus, it is expected that crude oil price tends to influence the dynamics in crude oil consumption in the long run in Ghana.

Figure 3: Impulse response functions



Source: Prepared by the authors.

Figure 3 plots the generalized IRF of Ghana's crude oil consumption (LNC) with respect to the effect of one standard deviation shocks and innovations in each of the independent variables over a ten-year horizon. From panel B, shocks in real GDP per capita (LNGDPPC) caused a decline in crude oil demand in Ghana in the early time horizon. From period 1 to period 3, shocks in real GDP per capita caused a decline in LNC. Between period 4 and period 6, shocks in real GDP per capita caused crude oil demand in Ghana to peak slightly and thereafter declined after period 6 through to period 10. This confirms the speed of adjustment to long run equilibrium estimated in the VECM short run. From panel C, shocks from crude oil price caused deterioration in crude oil consumption in Ghana from period 1 to period 2. Crude oil price shocks however resulted in a sustained increase in crude oil demand from period 3 to period 5.

From period 6 through to period 10, crude oil price shocks did not have any significant impact on crude oil consumption. This is consistent with the long-run inelastic coefficient for crude oil price reported in Table 5. From in panel D, shocks from real effective exchange rate also caused deterioration in crude oil consumption throughout the ten-year period. Shocks from technical progress however resulted in improvement in Ghana's crude oil demand from period 1 to period 3. Technical progress however caused a muted deterioration in crude oil consumption between the third and fifth period from period 6 through to period 10, it did not have any significant impact on crude oil consumption. Overall, the impulse response analysis in Figure 3 show that the effects of shocks from each independent variable on crude oil consumption were mostly transient with their effect fading out and converging to the long-run level from the 6th to the 10th forecast period.

Conclusion and Policy Implications

The macroeconomic determinants of crude oil demand (consumption) have not been exclusively studied in Ghana. All the existing studies focused on some disaggregate energy type such as demand for electricity, cooking fuels, LPG, kerosene, and petroleum. Adding to the existing studies on Ghana, this study examined the macroeconomic determinants of crude oil demand (consumption) in Ghana, in particular real GDP per capita, a measure of national income and crude price. The VECM technique was used to estimate the short-run and long run income and price elasticities of crude oil demand with annual time series data from 1980 to 2013. In addition, variance decomposition and impulse response analyses were used to examine the effect of shocks and innovations emanating from the independent variables on crude oil demand in Ghana.

The Johansen cointegration and ARDL cointegration both provide conclusive evidence of cointegration among the variable. The long run estimates reveal that price of crude oil, real GDP per capita, real effective exchange rate, and energy saving technical progress are significant long run determinants of crude oil demand. The results indicate that crude oil demand in Ghana is income and price inelastic. Crude oil price has a positive long run effect indicating the virtual lack of substitutes and overdependence on crude oil for energy generation and economic activities in Ghana.

As a demand side policy suggestion, continuous efforts at switching to the use of energy alternatives such as natural gas for the generation of energy must be sustained. Ghana must take advantage of the natural gas production from her Jubilee and TEN oil fields and also manage in an efficient way the financing of natural gas coming through the West African Gas pipelines to curtail the high dependence on crude. More renewable sources such as solar energy must also be developed at an incremental level to support industry and households. In the short run, though all variables are collectively determinants of crude oil demand, only price of crude appeared insignificant. This still supports the explanation for the long run price effect. It was also found that there is energy saving effect of technical progress in Ghana and that government with its stakeholders in energy conservation could take advantage to reduce the crude oil and overall energy bill of the country.

Finally, from the variance decomposition and impulse response analyses, shocks and innovations from real effective exchange rates had the dominant effect on crude oil demand in Ghana among the explanatory variables implying its fluctuations constitute a risk in the crude oil demand bill. Therefore responsible policy makers and actors in the energy sector can use the dynamics in crude oil consumption and real effective exchange rates to develop forward looking strategies aimed at hedging against the volatilities in the exchange rate market and its attendant effects on crude oil consumption in Ghana. Other suggestions include the development of a strategic oil demand security policy by implementing a planned crude oil reserve system to reduce the negative effects of disruptions in the international crude oil market. This suggestion will be easier if Ghana is able to revive the operations of the Tema Oil Refinery (TOR) to full capacity using crude oil produce from her Jubilee and TEN oil fields.

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Appendix Tables

Table A1: Lag length selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	8.935886	NA	5.38e-07	-0.245993	-0.016972	-0.170079
1	239.0389	373.9174	1.49e-12	-13.06493	-11.69081	-12.60945
2	341.6648	134.6965*	1.32e-14*	-17.91655*	-15.39732*	-17.08150*

* indicates lag order selected by the criterion, LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion, LogL: log likelihood

Table A2: Bounds test results (robust check for cointegration)

Test statistic	Value	*k*
F-statistic	10.870	4
Critical value bounds		
Significance	Lower bound	Upper bound
10%	2.45	3.52
5%	2.86	4.01
2.5%	3.25	4.49
1%	3.75	5.06

Source: Prepared by the authors.

Table A3: Model diagnosis tests

Test criteria	Results
Serial Correlation	0.5002
Heteroskedasticity	0.5635
Normality Tests	Residuals are multivariate normal
Stability Test	Stable

Source: Prepared by the authors

NOTE