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Structural Vector Autoregressive Analysis of Crude Oil Price Shocks on Ghana's Economy

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Abstract: The paper analyses the extent to which crude oil price shocks impact GDP growth, exchange rate, interest rate and inflation of an emerging oil exporting economy, Ghana. The Structural Vector Autoregressive model is used to analyse the quarterly data from 2009q1 – 2020q4. The results showed that exchange rate and GDP growth respond positively but temporal to the impulse of crude oil price. In contrast, inflation and interest rate respond negatively to crude oil price shock. Specifically, the exchange rate appreciates in the initial quarter and begins to depreciate, whereas GDP growth experiences an increase in the first two quarters and also reduces afterwards. Crude oil price shocks to the Ghanaian economy follow the conventional behaviour of the impact of crude oil on macroeconomic indicators. The positive impact of the price shock on GDP growth and exchange rate is not much reflecting the fact that Ghana is an emerging oil-producing country with low production and export level. Ghana's prospects in the oil and gas sector should not just be a mere hoax. Policies should be directed toward petroleum exploration and production efforts since the energy transition endanger benefits for future exploitation. Policies should be implemented to attract competitive players locally and internationally in the oil industry. The shock of crude oil prices is beginning to show evidence based on this study. Therefore government must consider recognising the importance of other economic sectors in order not be become heavily dependent on oil.

Keywords: Structural Vector Autoregressive, Crude Oil Price, Macroeconomic Indicators

JEL Classification: C22, Q47, E32, O40

1. Introduction

Crude oil price shocks have been demonstrated to impact economies tremendously. However, according to literature, the impact comes at different forms and levels for oil and non-oil producing economies. Crude oil price shocks refer to fluctuations resulting from changes in the international oil market's demand or supply side (Wakeford, 2006)[1]. The supply-side disruptions emanate from policies on supply quotas from Organisation of Petroleum Producing Countries (OPEC), and international energy politics in the rich oil-producing countries in the Middle East.

In Ghana, an emerging oil-producing country, oil is beginning to play a major role in the conduct of fiscal and monetary policies. However, crude oil accounts for less than 5% of Ghana's annual revenue and Gross Domestic Product (GDP). Progress is being made in Ghana in crude oil exploration and production with anticipation of Ghana becoming a net exporter of crude oil. This negatively and positively impacts macroeconomic indicators for sustainable growth and development. In that respect, efforts have been to

increase petroleum exploration and production activities by attracting International Oil Companies (IOCs) and local competitive players into the upstream petroleum industry to tap the rich natural resources adequately. Between 2006 to 2019, the government of Ghana signed 18 petroleum agreements with independent companies to explore and produce crude oil in the country (CBOD, 2020). In addition to offshore oil exploration, the Ghana National Petroleum Corporation (GNPC) has announced the existence of large quantities of petroleum resources in the Voltaian Basin, which presents a good opportunity for the country to engage in onshore petroleum production. The number of barrels of crude oil explored daily has been increasing over the years, with average daily oil production increasing from 104 thousand in 2014 to 195 thousand barrels by June 2019. By the close of December 2019, GNPC announced that daily exploration in barrels of crude oil averaged 200 thousand. As shown in Figure 1, crude oil production is projected to upturn from 196 thousand barrels/day (below the projection of 240,000 barrels per day) in 2019 to 420 thousand barrels/day in 2023.

In terms of domestic gas production in Ghana, total gas production from domestic gas fields in 2019 amounts to 169.5 bcf in 2019. The local gas market, particularly for power generation and non-power uses, consumed 54 bcf whiles 94.4 bcf, 12.3 bcf, and 5.9 bcf were reinjected, used as fuel on Floating Production Storage and Overloading (FPSO) and flared, respectively. Local gas production has therefore relieved Ghana from heavy dependence on Nigeria. Nigeria gas supplied to Ghana only constituted 37 percent, with Sankofa, Jubilee and TEN fields delivering the difference.
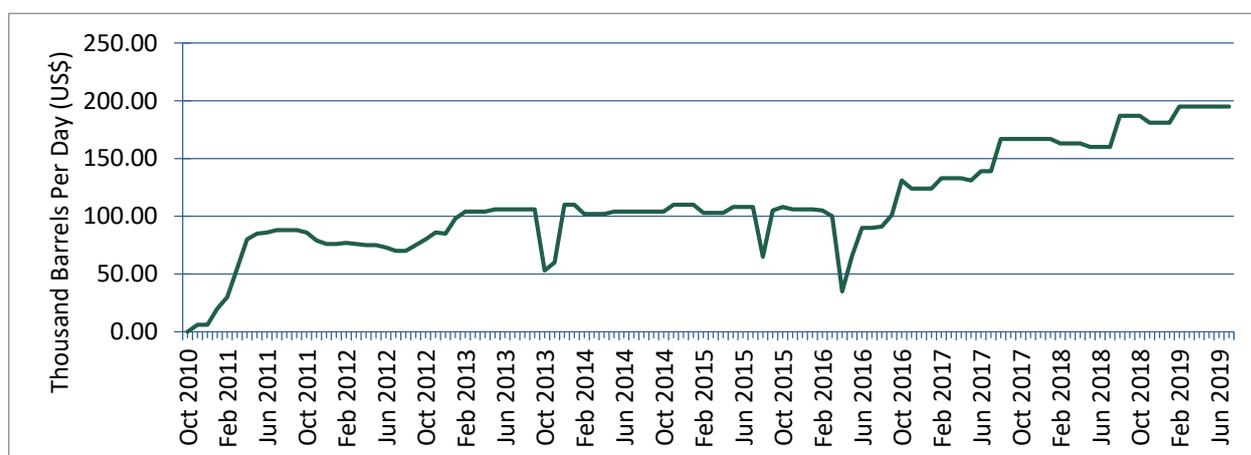

Figure 1. Trend in Crude Oil Production in Ghana for the period; Source: International Energy Data, Monthly Update, 2019

As a primary energy source, crude oil continues to play a critical role in the economy. In Ghana, it accounts for 97% of energy consumption in the agricultural sector. About fifty-two percent of consumption in the manufacturing sector is sourced from crude oil. The transport sector, fuelled largely by oil, requires 92% of its energy consumption requirement from crude oil. High dependence on the importation of crude oil has made Ghana more prone to the shocks of fluctuating crude oil prices. According to Ghana's Ministry of Finance, in 2018, although the country is raking in some gains from the export of oil via offshore exploration, it imports more oil than it exports. Ghana began production in commercial quantities of crude oil in the year 2010. However, on average, Ghana is yet to be a net oil exporter of petroleum.

The energy sector is a critical source of input for industrial production and socio-economic development. Ghana and many developing countries' quest to industrialise their economies has increased the demand for crude oil as a vital primary input in production. This has led to heavy reliance on crude oil, making them more susceptible to

the shocks of crude oil price fluctuations. The shortage of this energy resource poses untold consequences or threats to the successful management of these economies.

Successful governments, especially in developing counties, seem not to be taking the right combinations of policies to mitigate the shocks from the price fluctuations of crude oil. These governments' inability to deal with the unremitting adverse impacts of the price of crude oil and its associated negative effect on the performance of the economies has raised serious anxieties among scholars. Over the years, most policies targeting the arrest of the adverse impact of crude oil price and macroeconomic nexus have not been sustainable and have often yielded inefficacious results.

The literature points to a significantly negative relationship between the shocks in crude oil prices and the macroeconomic performance in developing countries. The level of importation and exportation of crude oil has a tremendous influence on the direction (positive or negative) of the shock of crude oil prices. As a net importer of crude oil experienced a negative impact on its economic progress due to high crude oil prices, resulting in electricity rationing. Kumi (2017)[2] attributed this period of load shedding (power rationing) in Ghana in 2006, 2007 and 2011 to fuel and natural gas supply challenges as well as low levels of water in the Akosombo dam. The sudden shock resulted in an increased Government of Ghana's expenditure to afford crude oil necessary to fuel power plants to produce electricity for domestic and industrial use. This challenge and other energy sector problems caused the government to remedy the situation with load shedding. The interruption of power supply to local and multinational corporations and companies, especially the manufacturing sector, resulted in the shutdown of some corporations, adversely affecting economic activities. Revenues earned by the government from these companies in the form of taxes reduced, investments reduced, provision of infrastructural facilities declined, and some active workforce lost their jobs and thus increasing unemployment. The situation is much better for oil-exporting countries that directly benefit from foreign earnings from petroleum exports.

Most oil-producing countries, especially in Africa, export crude oil for revenue to improve foreign exchange. This results in severe consequences for the host country's economy when there are changes in crude oil prices. The relationship between crude oil price shock and macroeconomic indicators has triggered many scholarly investigations on the possible impact of the shock on economic activities. Researchers attempt to explore the nexus between oil price and macroeconomic performance reveals a negative correlation. Hamilton (1983)[3], an early writer on the nexus, whipped a lot of early researchers' interest in this relationship. They mainly emphasised establishing the causal relationship between the crude oil price shocks and the world depression. All their toils confirmed the findings by Hamilton that unforeseen rises in crude oil prices negatively affect output (Hamilton, 1985 &1996; Barsky & Kilian, 2001)[4-6].

Specifically for Ghana, scholars such as Cantah & Asmah (2015), Etornam (2015), Emmanuel (2016), and Malik, Ajmal & Zahid (2017)[7-10] also examined this nexus. All these studie were conducted without focus on the period of Ghana exploration and production of petroleum. The impact of crude oil price shock is likely to have different dimensions of shock on oil exporting countries. The academic novelty of this current study is to specifically investigate the impact of crude oil price shock on Ghana's economy as an emerging oil exporting country during the period 2009q1 to 2010q4. Specifically, the study examines the impact of crude oil price shocks on some key macroeconomic indicators such as inflation, interest rate, exchange rate and economic growth using the structural vector autoregressive with the aid of impulse response functions (IRF) technique to control for the reverse causality between crude oil price changes and the rest of the macroeconomic variables.

2. Literature Review

2.1. Theoretical: Oil price shock transmission channels

According to theory, understanding the effects of crude oil prices on macroeconomic indications has been delineated through a transmission mechanism. Following Tang, Wu, & Zhang (2009)[11], the transmission channel of this relationship is discussed below. Looking at the transmission of the shocks from the supply-side effect, the focus is on the direct impact on output (GDP). Increased crude oil price results in increased marginal production, which decreases the output of operating industries. Output reduces due to a cut in capacity utilisation. This has an untold consequence on how much goods are imported due to the oil price shock. Consequently, an increase in the general price of goods and service (i.e. inflation effect) become prevalent. This establishes the connection between domestic inflationary pressures from crude oil price shocks.

The trickle-down effect on the exchange rate market is that the domestic importers require one more petrodollar to import crude oil, and the exchange rate is directly affected by the real quantity of goods imported into the country. According to Basnet and Upadhyaya (2015)[12], the conventional theory of exchange rate on the shocks opines that price increase in crude oil depreciates the importing country's currency (receiving economy). Price increases in crude oil create excesses of the domestic country's currency in the exchange market and hence depreciation of the domestic currency. Conversely, a positive crude oil price shock appreciates the importing economy's currency. Nchor et al. (2016)[13] found that crude oil price shocks increase inflation and depreciate the exchange rate.

Increasing inflation and depreciation of domestic currency do not fare well for economic growth. It results in low outputs and hence hampering GDP growth. The story in Ghana might be different due to regulation and deregulation policies in the oil price over the years. The deregulated regime paced subsidies on petroleum prices which interfered with the direct impact of crude oil price shock on general price increases in Ghana. In 2012, Ghana switched to operating a free-market sytem by deregulating oil prices. Hence, the oil price shock passes through the economy directly. High interest rate in an economy can give investors more returns compared to other countries and thus attract more foreign direct investments, which weakens the domestic currency; consequently, as the domestic currency weakens exchange rate increases.

2.2. Empirical Review

Studies on the relationship between oil price shocks on economic activities in recent years have shown a less significant impact of oil price shocks on the economy, especially in developed economies. Most studies on this relationship have dwelled mainly in developed economies. Also, very little literature exists for developing oil-exporting economies like Ghana. Studies in Ghana include Cantah & Asmah (2015), Etornam (2015) and Emmanuel (2016) [7-9], and they posit an enormous impact of COP shocks on the Ghanaian economy. These studies foused in Ghana wer conducted without consciously establishing how diffeent the impact of crude oil price shock is on an emerging oil-exporting country. It already been established that there exists a different level of impact of the shock on economies of oil-exporting and non-oil-exporting countries.

Cantah & Asmah (2015)[7] employed the ARDL (Autoregressive Distributed Lag) approach to cointegration to study the relationship between crude oil price and Ghana's economic growth using annual data sets from 1967 to 2011. They found that both short- and long-run association exists between crude oil price and Ghana's economic growth. The paper posits that the shocks in crude oil price results in increases in government expenditure on the importation of crude oil, consequently hindering economic growth. Similarly, Etornam (2015)[8] found a significant adverse impact of COP shocks on the macroeconomy of Ghana. The studies examined the impact of the COP shocks on Ghana's

economy using a restricted vector autoregressive model and test of Johansen Cointegration. The study used annual data whose frequency is not high enough to deict the impact of the volatile prices of crude oil. The study also found that negative shocks of COP negatively influence economic growth though the level of impact is not great.

Nchor et al. (2016)[13], with the aid of the VAR and Vector Error Correction model and data from the United States Energy Information Administration and the World Bank's World Development Indicators for Ghana, examined the dynamic line amongst the shocks of crude oil price and some economic indicators of Ghana. The paper found that crude oil price shocks have a negative effect on Ghana's macroeconomic indicators. Exchange rate, inflation, and government expenditure were found to have a strong positive impact on the shocks of crude oil prices.

Cantavella (2020)[14] used data spanning from 1945 to 2018 to investigate the asymmetric effects of COP on GDP in Spain. The study employed a nonlinear autoregressive distributed lag model and found that long-run decreases in COP significantly affect per capita GDP more than COP increases. The findings corroborate the conventional behaviour of the COP-macroeconomy relationship for the case of Ghana. Similarly, Emmanuel (2016)[9] used SVAR with yearly data from 1980 to 2014 to investigate the impact of COP shocks on the macro-economic variables of Sub-Sahara Africa countries that are net crude oil-exporters.. The study found an indirect effect of COP on GDP through an increase in cash incomes which affects every component of GDP. Findings also revealed that corruption and unemployment correlated with COP shocks. SVAR does not adequately present the impact of COP on the indicators when yearly data used

The impact of COP changes on the US GDP growth has been analysed by Charfeddinea, Kleinb, and Walther (2018)[15] and found an adverse impact of COP on GDP growth. The study used recent data and replicated the findings of Hamilton (2003)[16] and other prominent studies by employing several measures of COP found that COP has an insignificant impact on GDP growth. The paper opines that aggregated COP measures having dissipating impact on quarterly data are becoming more useful in describing GDP growth levels when mixed data sampling is applied monthly.

The studies mentioned above present quite a serious gap in research in terms of the methodology applied and the period of the study for the up-to-date policy focus of Ghana. This current study uses quarterly data of Ghana and focuses on the period when Ghana became an exporter of crude oil to establish whether the conventional pattern of impact still holds for Ghana. Unlike the studies mentioned above, which used yearly data, the paper used quarterly data since crude oil prices are highly volatile, and the impact of the price shock might not be persistent throughout the months and quarters with the year of the shock.

3. Materials and Methods

The study is a quantitative research using quarterly data covering the period 2009q1 to 2020q4 for Ghana. This period falls within the oil-production age of Ghana in commercial quantities. Variables considered in the study include Crude Oil Price (COP), Inflation (INFL) Interest Rate (IR). Exchange Rate (EXCH) and GDP growth (GDPgr). The data on these economic variables were gathered from the Bank of Ghana and World Bank's World Development Indicators, and International Financial Statistics (IFS). The quarterly West Texas Intermediate Crude Oil (WTI) Price data were obtained from the Statistical Review of World Energy. The limited period for the study comes as a result of the fact that the study focuses on investigating the impact of oil price shocks during the period of crude oil production in Ghana. Secondly, the study was also influenced by the fact that quarterly GDP data retrieved from the Bank of Ghana's website started in 2009. The COP is in U.S. dollars per barrel, while the exchange rate is proxied by national currency (Ghanaian Cedi) per U.S. dollar. The inflation rate is measured by the annual

growth rate of the GDP implicit deflator shows the rate of price change in the economy as a whole. The graphs of variables are given in Figure 2 for the period of 46 quarters which span 2009q1 to 2020q4.

3.1. Tests for Unit Root with Structural Breaks

The variables under consideration in the study are time series and might exhibit some structural breaks. In order to treat problems of structural breaks in the series, the Zivot-Andrews unit root test. Not considering the possible existence of breaks in the series could result in biases that can reduce the ability to reject the false unit root null hypothesis (Glynn et al., 2007)[17]. However, the Zivot-Andrew unit root test is criticised on the ground that it does not allow for gradual or multiple breaks under the null hypothesis (Perman and Byrne, 2006)[18]. As a result, the series were futher visualised in graphs to detect the presence of any structural breaks. The stationary time series process exhibits a property of constant first and second moments whose probability distribution is stable over time. The study tests for the unit root to analyse the stationary properties in the dataset. This allowed the opportunity to avoid spurious results (ie. false regressions) and ensure that the variables fit into the estimation technique. To determine the stationarity, the Augmented Dickey-Fuller (ADF) test is employed under the null hypothesis of the presence of unit and the alternative hypothesis that the variable does not contain a unit root. The study includes trends and intercepts in the test equation. The variables are differenced for a different stationary process until they become stationary.
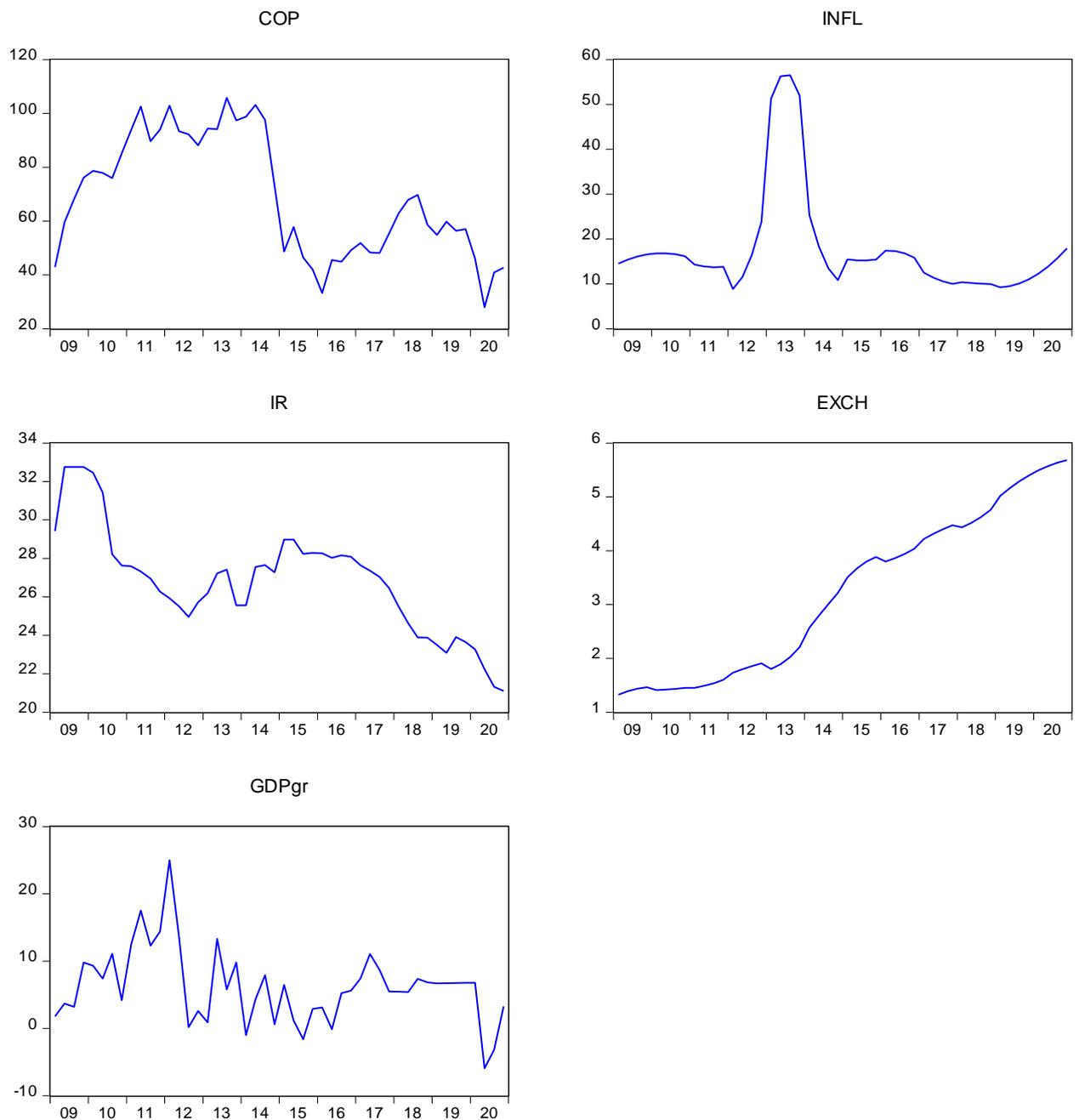
Figure 2. Plots of variables of interest; COP = Crude Oil prices (dollars per barrel), INFL = Inflation (GDP deflator), IR = Interest Rate, EXCH = Exchange rate (Ghanaian Cedi per U.S. dollar), GDPgr = GDP growth rate; Source: BoG (2021); World Bank (2021), and IFS (2021)

3.2. Maximum Lag Order Selection Criteria

Since the VAR model is sensitive to lag, an optimum number of lags is decided for the study using the Akaike Information Criteria (AIC) which is specified in equation (1).

$$AIC = 2\ln(u) + 2v \tag{1}$$

where v denotes the number of parameters. The maximum value of the likelihood function for the model is represented by u. If the Akaike Information Criteria minimised for order 1, then the VAR model with a lag length of 4 is used.

3.3. Model specification

3.3.1. Structural Autoregression model

The SVAR system provides a mixture of time series modelling and economic theory for identifying responses to independent shocks from macroeconomic variables (Effiong, 2014)[19]. Thus, it allows for the derivation of time profiles of the impact of shocks on specified variables included in the model (Hamilton, 1996)[5].

VAR is usually stated in a reduced form model, which means to express the dynamic properties of the data (Cooley & LeRoy, 1985)[20]. These reduced-form VAR models are hard to comprehend without regard to a particular economic framework. For example, the substantial number of coefficients calculated in a VAR model usually makes it hard to make meaningful inferences.

So long as such parameters are not linked to "strong" structural parameters that define expectations, technologies, and behaviour of optimization, the parameters have no economic significance and are subject to the so-called Lucas critique. Sims (1980)[21] presents that as a replacement for the identification of VAR coefficients, identification emphasises system residuals that are viewed as an exogenous shock. SVAR enables us to identify the short-run effects of COP on inflation, IR EXCH and GDP growth. Following Sim (1980)[21], the model is represented as follows;

$$y_t = A_0 + \sum_{i=1}^{\rho} A_1 y_{t-i} + A_2 X_t + \varepsilon_t \qquad (2)$$

where ε_t $(\varepsilon_t \sim N(0,1)$, is the residuals, y_t represents the vector of endogenous variables at period t, X_t represents exogenous variables, A_0 denotes the intercept, A_1 represents the coefficient of the matrix of endogenous variables and A_2 represents the coefficients of the vector of exogenous variables.

By assuming stability of the VAR model, we can transform equation (2) into moving average;

$$y_t = A_0 + \sum_{i=0}^{\infty} A_i y_{t-i} + \sum_{i=0}^{\infty} A_3 \varepsilon_{t-i} \qquad (3)$$

where A_2 denotes the dynamic multiplier functions and A_3 denotes impulse-response functions (IRFs) at horizon *i*. It is important to note that past values of the endogenous variables (y_t) are replaced. The VAR model can now be determined using Ordinary Least Squares (OLS) since it is unbiased and efficient (Enders (2003)[22] as cited in Beck, et al. (2019)[23].

The structural vector autoregressive model offers a dynamic examination of the transmission of shocks via impulse and variance decomposition.

Following Malik, Ajmal and Zahid, 2017, in equation (4), the SVAR model with the number of lags represented by 'ρ' is specified as:

$$AY_t = A_0 + A_1 Y_{t-1} + A_2 Y_{t-2} + \cdots + A_\rho Y_{t-\rho} + \varepsilon_t \qquad (4)$$

where A is the full-length matrix comprising of an nxn matrix of structural coefficients which takes care of the contemporaneous relationship on the endogenous variables, Y_t represents the matrix of endogenous variables, ε_t denotes the exogenous residual term in the matrix and it is not serially and mutually correlated structural shocks and ρ denotes the maximum lag order.

The model assumes that the errors are linearly linked to the structural shocks as; $\mu = (\gamma \varepsilon_t)$ the parameter γ represents the structural coefficient vector signifying the impact of structural shocks. To express the impact of the shocks independently, an assumption is laid on the residual to be orthogonal. The model can be written following the above assumptions by multiplying both sides of equation (4). In light of the above assumptions, the model can be written by multiplying A^{-1} to both sides of equation (4).

$$Y_t = A_t * Y_{t-1} + A_2 Y_{t-2} + A_\rho Y_{t-\rho} + \mu_t \qquad (5)$$

where $A_j^* = A^{-1}A_j$ (given $j = 1,2,...\rho$); the vector of residual becomes $\mu_t = A^{-1}\gamma\varepsilon_t$ and $E[\varepsilon\varepsilon'] = I$.

The model assumes that the vector of residuals or the structural shock follows a normal distribution of the form $\mu_t \sim N(0, \Omega)$, where $\Omega = (\mu_t, \mu_t)'$. The study also assumes orthogonality of μ_t and X_t and therefore, the estimate of μ_t can be used to estimate Ω. For this, using simple OLS will offer consistent estimates of A_t^*.

The reduced-form VAR model specified in equation (4) is weak in tracing the contemporaneous relationship amongst the variables that offer the error terms a cross-correlation. The VAR equation has all the lagged terms on the right-hand side. The contemporaneous relationship is likely to affect the IRFs. Equation (6) presents the link between reduced form vector autoregressive and the SVAR.

$$A\mu_t = \gamma\varepsilon_t \text{ or } \mu_t = A^{-1}\gamma\varepsilon_t \tag{6}$$

This will offer us the room to perform an impulse response analysis by determining the impact of an impulse in one of the variables of interest within the model.

3.4. Empirical Framework

The SVAR system was employed to investigate the effect of COP on the economic performance of Ghana with the aid of IRF. SVAR allows for the imposition of restrictions on the model base on economic theory. Restrictions are imposed on the structural parameters. Zeros are placed as restrictions on the contemporaneous structural parameters, with the direct effect of exogenous variables on the endogenous variables (Gottschalk, 2001).

By constructing the SVAR model, the study seeks to find out how specifically inflation, interest rate, exchange and GDP growth respond to crude oil price shocks. Some variables were transformed to deal with the possible issues of heteroscedasticity.

Five structural shocks are considered for the study, and they include crude oil price shocks, ε_t^{COP}, inflation ε_t^{INFL}, interest rate ε_t^{IR}, exchange rate ε_t^{EXCH} and GDP ε_t^{GDPgr}. For the 5-component structural VAR model, y_t represented as follows;

$$y_t = (COP_t + INFL_t + IR_t + EXCH_t + GDPgr_t) \tag{7}$$

where $lnCOP_t$ represents the logarithm of COP, $INFL$ denotes consumer price index, IR denotes interest rate, $EXCH$ represents real exchange exchange rate, and $GDPgr$ denotes Gross domestic product at constant domestic currency.

There are $\frac{n(n-1)}{2}$ (where n represents the number of variables in the model) restrictions in this study and its imposed on the matrix n for the estimation of the SVAR system. For the case of the five variables, there are ten restrictions imposed $[5(5-1)/2] = 10$.

As an identification scheme, the study adopts a Cholesky factorization to get the vector of structural shocks (ε_t) from the reduced-form error (μ_t). The identification scheme can be written from the structural innovations based on the variables under consideration as;

$$\begin{bmatrix} \mu_{COP} \\ \mu_{INFL} \\ \mu_{IR} \\ \mu_{EXCH} \\ \mu_{GDPgr} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ b_{21} & 1 & 0 & 0 & 0 \\ b_{31} & b_{32} & 1 & 0 & 0 \\ b_{41} & b_{42} & b_{43} & 1 & 0 \\ b_{51} & b_{52} & b_{53} & b_{54} & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_{COP} \\ \varepsilon_{INFL} \\ \varepsilon_{IR} \\ \varepsilon_{EXCH} \\ \varepsilon_{GDPgr} \end{bmatrix} \tag{8}$$

From equation (8), the study will assume that the crude oil price is exogenous so COP will not contemporaneously be affected by other shocks in the system. This is because the international price of crude oil is not determined by one country since one economy

cannot significantly dominate in pricing crude oil. Thus, consumer price index, interest rate, exchange rate and GDPgr do not influence COP in the global market and do not help to predict COP (Chuku et al., 2011)[24] and hence the assumption that COP is exogenous is reasonable. Therefore, four restrictions are placed on the structural coefficient matrix (γ) and so the COP equation is modeled as; $\mu_{COP} = \varepsilon_{COP}$

Following Malik et al. (2017)[10], the consumer price index will be shocked by COP and itself, and hence three restrictions are placed on the structural coefficient matrix of the INFL estimation modelled as;

$$\mu_{INFL} = b_{21}\varepsilon_{COP} + \varepsilon_I$$

The interest rate is assumed to be affected by COP shocks, INFL shocks and itself. It is in agreement with the theory which supposes that an increase in crude oil price and inflationary pressures can increase interest rate. On row three, two restrictions is placed on the structural coefficients as modelled as;

$$\mu_{IR} = b_{31}\varepsilon_{COP} + b_{32}\varepsilon_{INFL} + \varepsilon_{IR}$$

The exchange rate is supposed to be contemporaneously influenced by COP shocks, INFL shocks, IR shocks and itself. It is in agreement with the theory which supposes that an increase in crude oil price, inflationary pressures, and interest rate can increase the exchange rate. On row four, one restriction is placed on the structural coefficients as modelled as;

$$\mu_{EXCH} = b_{41}\varepsilon_{COP} + b_{42}\varepsilon_{INFL} + b_{43}\varepsilon_{IR} + \varepsilon_{EXCH}$$

Lastly, in row five, shocks to the GDP are assumed to be affected by shocks to all other variables. Therefore, the GDP shocks can be modelled as;

$$\mu_{LNGDP} = b_{51}\varepsilon_{COP} + b_{52}\varepsilon_{INFL} + b_{53}\varepsilon_{IR} + b_{54}\varepsilon_{EXCH} + \varepsilon_{GDPgr}$$

The model is estimated using the maximum likelihood method with the optimal lag length.

Three SVAR diagnostic tests are done. Jarque-Bera test is done to know whether or not the disturbance terms are normally distributed. A test is also run to establish the existence of autocorrelation among the residuals using the Lagrange Multiplier test. There is also confirmation of whether the model meets the stability condition.

It is anticipated that COP will positively affect GDP growth, exchange rate, interest rate and inflation. The exchange rate is expressed in a nominal effective exchange rate and measured as a currency value against the United State Dollar. Specifically, for Ghana, the nominal exchange rate is expressed as Ghana Cedis per U.S. dollar. Since increases in crude oil price exert pressure on the domestic currency as more of the local currency will be required to import crude oil. Consequently, it is anticipated that, the shock will have an adverse effect on REER for oil importing countries and vice versa for oil-exporting countries. Due to the fragility of developing economies, it is easy for COP shocks to penetrate and worsen the volatile REER of Ghana since oil production has not yet occupied a large share in the country's GDP and exports and hence an expectation of the negative link. Inflation is defined in this context as the quarterly percentage change in the GDP deflator. All variables are log-transformed except the GDP growth rate and REER. Increase oil prices directly impact industry production cost which translates into increases in prices of the product. In effect, increases in general prices of goods and services due to the COP shock becomes unavoidable and hence an expectation of a negative nexus between crude oil price and inflation.

4. Results and Discussions

4.1. Data Issues

The data sampled for the study spans 48 quarters covering the period of Ghana's commercial production of crude oil. For the period under study, we found that COP averaged US$ 68.79 per barrel, selling as low as US$ 27.97   and as high as US$ 105.80. The standard deviation in COP of US$ 22.32 indicates a wide variation in the COP variable. Ghana's inflation rate and exchange rate looked quite good for businesses to thrive compared to 35% and US$ 10.07, respectively, in August 2022. The interest rates in Ghana averaged 26.83 with a standard deviation of 2.83% , as shown in Table 1.

Table 1. Descriptive Statistics of COP and Macroeconomic Indicators (2009q1 – 2020q4)

Variable	Unit of Measurement	Obs	Mean	Std. Dev.	Min	Max
COP	US$	48	68.79	22.32	27.97	105.80
INFL	Percentage	48	11.80	3.21	7.80	18.90
IR	Percentage	48	26.83	2.79	21.10	32.75
EXCH	1 US$ to GH₵	48	3.20	1.51	1.32	5.68
GDPgr	Percentage	48	6.22	5.50	-5.92	25.00

4.2. Test for Stationarity

The ADF test is used to verify whether variables were stationary over the period under study 2009q2 to 2020q4. As shown in Table 2, the test found all the variables such as COP, INFL EXCH, IR and GDPgr have unit roots at levels but were stationary after first difference (thus, integrated of order one, I(1)).

Table 2. Augmented Dickey-Fuller test

Variable	ADF Test		
	Level with trend	1st Difference	Order of integration
COP	-1.201	-5.368***	I(1)
INFL	-0.434	-3.623***	I(1)
EXCH	-1.386	-3.669***	I(1)
IR	-2.059	-3.623***	I(1)
GDPgr	-1.037	-7.080***	I(1)
Critical Value 1%	-3.577723	-3.581152	
Critical Value 5%	-2.925169	-2.926622	
Critical Value 10%	-2.600658	-2.601424	

*, ** and *** represent 1%, 5% and 10% levels of respectively; Source: Author's computation

4.3. Structural breaks with Unit Roots Test

Figure 3 represents plots of the variables of interest in normalized scale for comparison and visualization to establish the presents of structural breaks. It is found that GDP and inflation (represented by GDP deflator) and the price of crude oil have structural breaks. By this visual inspection, the study applied the Zivot–Andrew Unit tests to establish the presence of structural breaks since the Augmented Dickey-Fuller test above will not be able to detect the presence of structural breaks. However, the series has been found to be integrated of order one, I(1).
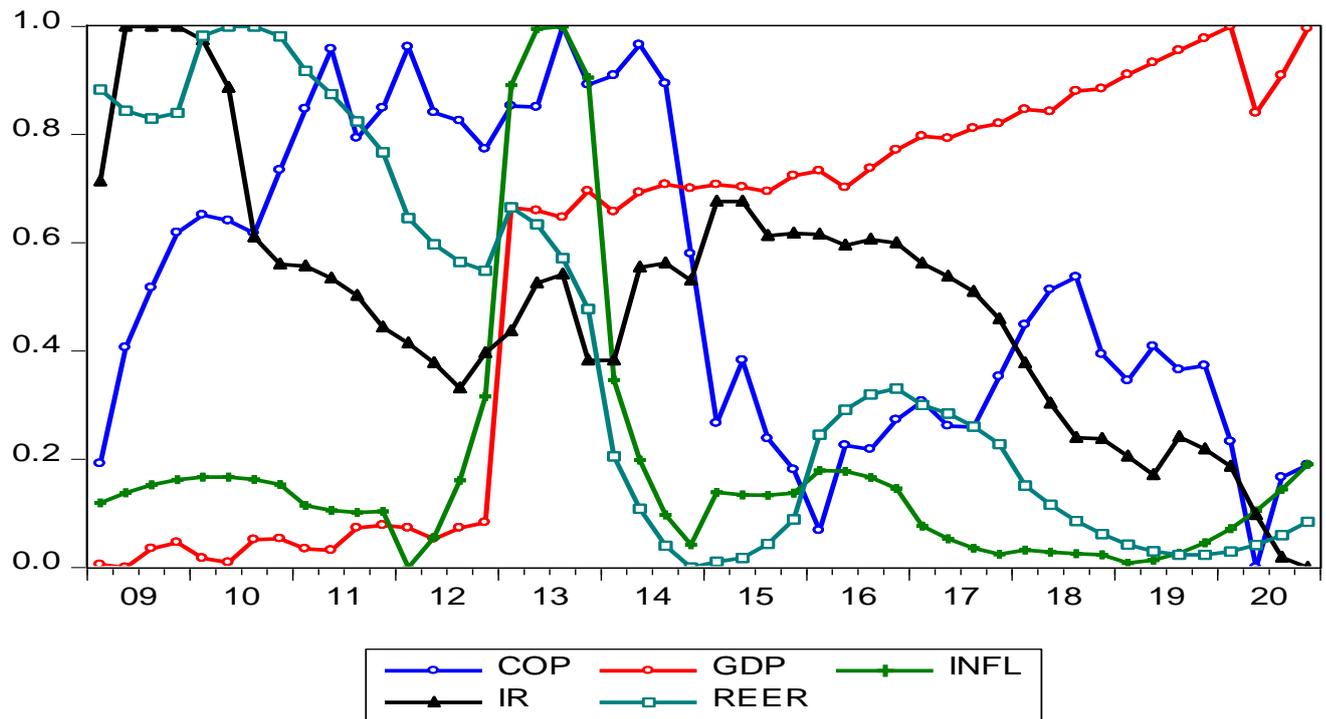
Figure 3. Trends in Normalised Series of COP, GDP, INFL, IR and REER

For the quarters under study, the structural breaks unit root test suggests the rejection of the null hypothesis that all the variables at levels have unit roots with structural breaks in the intercept, in trend, and intercept and trend, as shown in Table 3.

Table 3. Zivot–Andrew Unit tests for structural breaks

Variables	Both	Intercept	Trend
COP	-5.142***	-5.677***	-2.960*
INFL	-4.117***	-3.149**	-2.651**
EXCH	-4.474***	-4.447***	-2.973**
IR	-0.073*	-4.996***	-4.278***
GDP	-17.375***	-15.538***	-3.184***

Notes: intercept = break in intercept; trend = break in trend both = break in intercept and trend; *** = rejection of null at 1% significance level; ** = rejection of null at 5% significance level; null hypothesis of the test states unit root with a structural break in a specified part (intercept, trend, or both) of the variable.

4.4. Criteria for selection of Lag Length

It is imperative to determine the maximum lag for the SVAR system after satisfying the stationarity conditions of variables of interest in the data. Optimal lag order is determined for the SVAR model. Table 4 depicts the outcomes of the LR, AIC, SBIC and HQC criteria for determining the maximum lag length. A lag length of 2 is used for the SVAR model where all the criteria are minimized was chosen. The lag order 2 is sufficient enough for the estimates to reflect the effect of COP shocks on the specified macroeconomic variables. This is done to avoid too many lags that could result in a loss of degrees of freedom and insignificant statistical coefficients due to a possible presence of multicollinearity. Without the criterion, the paper could wrongly choose too few lags, leading to specification errors.

Table 4. Optimal Lag Length

Lag	Loglikelihood	LR	AIC	SBIC	HQC
0	-1058.076	NA	48.32163	48.52438	48.39682
1	-802.2318	441.9126	37.82872	39.04521*	38.27985*
2	-768.9891	49.86392*	37.45405*	39.68429	38.28113
3	-741.5952	34.86498	37.34524	40.58922	38.54826
4	-709.4705	33.58492	37.02139	41.27911	38.60036

*Optimal lag length; Source: Author's computation

4.5. Structural VAR Analysis

The objective of the study is to examine the effect of COP on consumer price index, exchange rate, interest rate and GDP using the SVAR model with the aid of impulse response analysis. The interest is to trace how domestic economic variables of Ghana respond to the shocks of COP.

Since the objective of the SVAR analysis is to examine the contemporaneous relationships amongst oil price and some macroeconomic indicators, but not to compute estimates of the parameters, the variables were used at levels since differencing the variables could lead to loss of important details about the co-movements in the variables (Ender, 2004)[25].

The optimal lag length was found to be 2 and so the SVAR was estimated with lag 2 (i.e. SVAR ($\rho = 2$)). Table 5 shows the diagnostic test of the SVAR model. Figure 4 is the graphical representation of the unit-roots which clearly shows that all roots lie inside the unit circle and therefore the condition for stability is satisfied. Also, in Table 5, the null hypothesis which states there is no autocorrelation is not rejected at a 10% significance level. The entire system did not also suffer any normality problem since in general the residuals are normally distributed.

Table 5. SVAR diagnosis tests

Test criterion	Results	P-value
Normality test - Jarque-Bera test (joint)	$\chi^2 = 18.08457$	0.0536
Autocorrelation test	LM-statistics = 52.33755	0.2227
Heteroscedasticity Test	White-statistics = 607.4711	0.4075

Source: Author's calculation

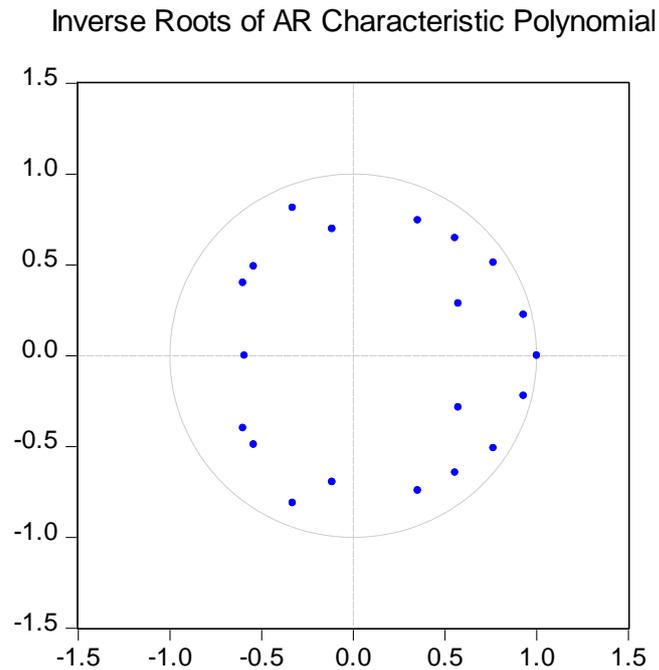### Inverse Roots of AR Characteristic Polynomial

Figure 4. Graph of the roots of the companion matrix; Source: Authors' Computation

4.6. Impulse responses Function

The responses of GDP per capita, total trade turnover, and exchange rate to one standard deviation shock to the price of oil for a 12-period forecast horizon are given in Figure 5. For a clear analysis of the effects of COP shocks on the macroeconomic indicators, the IRF of any shocks is presented graphically. The graph traces the impact of a variable's standard deviation (SD) shock on the rest of the variables in the model. Thus, structural shocks to each one of the variables to itself and the rest of the variables in the model is discussed with the help of the IRF. It must be noted that the vertical axis of the IRF shows the SD shock, and the horizontal axis represents the regimes (quarters).

4.7. Impact of Crude Oil Price

Figure 5 presents the IRF of the impact of crude oil price shock on key macroeconomic variables of Ghana. The blue line is the impulse response function, and the red line is the 95% confidence interval.

Response to Cholesky One S.D. (d.f. adjusted) Innovations ± 2 S.E.

Response of COP to COP

Response of Interest Rate to COP

Response of Exchange Rate to COP

Response of Inflation to COP

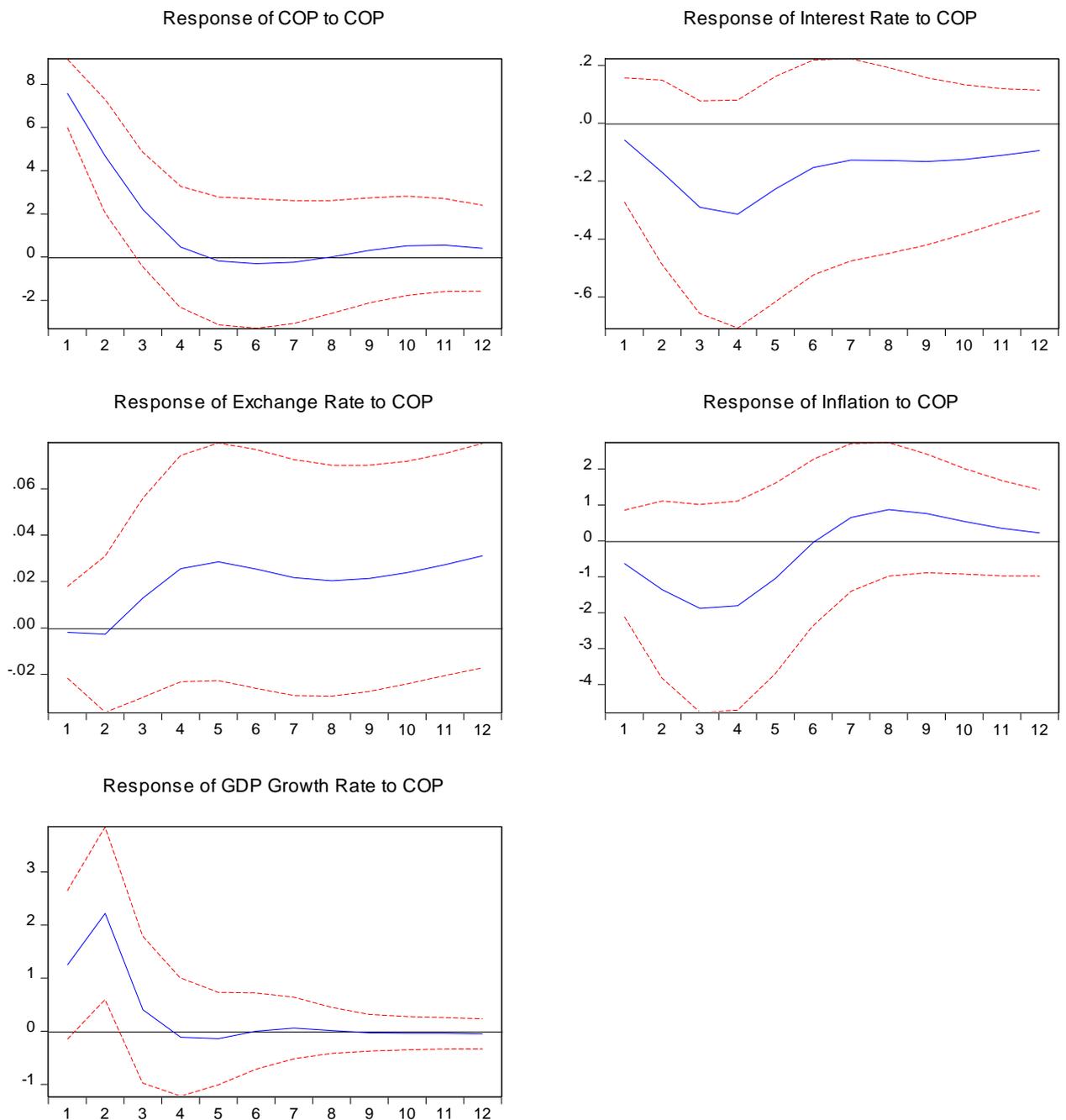Response of GDP Growth Rate to COP

Figure 5. Impulse responses to Crude Oil Price

   In the earlier stages, GDP growth increases become negative shortly, and the impact diminishes. Obviously, the response of GDP per capita to the oil price shock is positive during the first two quarters. However, it falls sharply from quarter three to quarter five and stabilizes. This implies that a rise in oil prices results in a temporal rise in GDP growth for two quarters, declines sharply and stabilizes. The results indicate that the exchange rate response to an oil price shock is as expected. The exchange rate response to oil price shocks during quarter one does not show many reactions from the exchange rate. Exchange rate decreased (appreciation of the national currency) in the second quarter. By the time the shocks impact the exchange rate in quarter three, it becomes significant and positive from periods three to five, thereby depreciating the local currency. The finding is

in corroboration with that of (Beck, et al., 2019)[23] The Ghanaian Cedis gains some appreciation over the dollar in quarter six to eight and depreciates slowly. This implies that higher oil prices increase the exchange rate (national currency depreciation) in four periods. The slight and unstained appreciation in the Ghanaian currency reflects the fact that though Ghana earns foreign exchange on the export of crude oil, revenues therefrom have not yet occupied a bigger portion of the country's total export.

The effect of crude oil price shock on the interest rate and inflation is significant and negative. Inflation, however, emerges from the negative impact of crude oil price shock to a positive effect from the 6th quarter onwards. The shock oil price causes inflation to decrease during the first three quarters, flattens in quarter three and begins to increase. The Interest rates continue to stay negative throughout the quarters. Following oil price shocks, interest rates decrease till the fourth quarter, increase slightly and flatten.

The estimation results concluded that the impact of oil prices on EXCH and GDP was positive while negatively affecting the interest rate and inflation. The positive shock is though not permanent, except for the first two quarters, the shock to oil prices results in depreciation of the local currency against the dollar. Though Ghana began commercial production of crude oil in 2010, the share of crude oil to the country's GDP is still below 5%. This implies that a rise in oil prices causes a rise in GDP and exchange rate. Studies in net oil-exporting countries such as Nigeria, Indonesia, Russia and Venezuela reveal the negative effect of oil price shock on exchange rate. Respectively, studies such as Nwani and Orie (2016), Sultan et al (2014), Balashova and Serletis (2020) and Mendoza and Vera (2010)[26-29] for these countries obtained a negative effect of oil price on the exchange rate and coincided with economic theory. The incipient negative effect of oil price on the exchange rate reflects that the increase in oil price slightly increased Ghana's oil revenue. However, foreign currency inflow in the first two quarters is increased but decreased the benefits in the subsequent quarters since the country was not a net oil-exporting country. Increased foreign currency inflows decrease the exchange rate (appreciation of the Ghana Cedis over the US Dollar) slightly.

5. Conclusion and Recommendation

This study investigates the impact of crude oil price shocks on GDP growth, exchange rate, inflation and interest rate for Ghana's economy, an emerging oil-producing country. The structural vector autoregressive method was applied to Ghana's quarterly data for the period 2009q1 to 2020q4. The structural VAR model allowed for the isolation of crude oil price shock on the macroeconomic variables. The paper also estimates IRFs on the variables of interest for the period understudy. The reaction of economic variables to COP shock, as depicted in the impulse response functions, follows the conventional pattern. There is enough evidence that international crude oil price positively impacts Ghana's GDP growth and exchange rate but negatively impacts inflation and interest rate. However, the positive impact on exchange rate (appreciating national currency) is little and temporal due to the smaller share of crude oil in the country's exports. As a result, the research makes the following recommendations.

As an emerging oil-producing country with large deposits of petroleum resources, Ghana should increase petroleum exploration and production efforts to increase petroleum revenue from a possible positive oil price shock. The study has presented evidence that a positive price shock appreciates the country's currency. The impact of the crude oil price shock on GDP growth was significant and positive during the immediate quarters. The impact is not stable, suggesting that emphasis should also be given to the more stable and sustainable economic sector to impact the economy, especially through appreciation of the national currency.

The study concludes that Ghana, as an emerging oil-exporting country, is sensitive to shocks in oil prices. This suggests that the Ghanaian economy is slowly becoming dependent on oil production and, therefore, the need to be conscious of the performance

of the other sectors for more sustainable growth. There is a need for Ghana to revive the Tema Oil Refinery (TOR) to enable it to operate at full capacity and also utilize the light and sweet crude produced offshore Ghana. This will inure to the development of crude oil system to control the over-dependence on refined oil import to absorb negative shocks of crude oil price on inflation. This will add meaning to Ghana's quest to become a net exporter of oil and subsequently wean off the threats of international crude oil price shocks. It is imperative to keep empirical studies on this relationship to keep abreast with the link between crude oil price shocks and the macroeconomic variables to inform policy direction.

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