State-Space Analysis of Oil Prices and Consumer Price Index in Nigeria

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ABSTRACT
Nigerian economy has regularly been buffeted by international oil price fluctuations. This is largely due to the economy’s overdependence on crude oil as a major source of foreign exchange. Oil price shocks usually pass through to the domestic economy to the extent that prices of consumer products experience the effects of such shocks which dislodges the CPI from equilibrium. In this study, it is hypothesized that oil price was a latent component in CPI changes in Nigeria. Therefore, we fit a state-space model with oil price as a latent variable to estimate the relationship between oil price movements and CPI in Nigeria while utilizing monthly data set on the two selected variables between 1986 and 2015. The results show that the state space model traced the evolution of the two variables very closely. This suggest that domestic prices are indirectly dictated by movements in the international price of crude oil. Therefore, we recommend that expectations of oil price movements should be incorporated in the process of fiscal and monetary policy-making in Nigeria beyond just national budgets. Inflation control policies should equally incorporate oil price changes while a forward-looking inflation forecast should be conducted within allowable confidence interval to accommodate the likelihood of oil price changes. This will serve as a buffer on the economy during periods of oil price shocks.

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1. INTRODUCTION
The link between oil price swings and general prices are well documented in literature. Most researchers found a positive relationship between oil price and inflation (Nwosu,2009; Eregha, Mesagan and Olawale,2016; Razmi et al , 2016; Orlu,2017; Umar and 2018). The key channel of transmission had been through prices of productive factors or inputs which in turn raises the cost of production. This is apparent as there is a reverse effect of oil price instability for import dependent economies like Nigeria which suffer the effect of price increases that raises production cost of foreign firms which is in turn transmitted to domestic prices. This leads to price adjustments on final goods as a result of change in oil price. As an oil exporter, Nigeria earns huge foreign exchange from crude oil export. Given the link between petroleum and foreign exchange earnings, the connection between Nigeria and the rest of the world can easily be deduced. The petro-dollar accruing from crude export is usually monetized in the local currency which bloats the money stock. Consequently, this affects money supply which has direct bearing on the inflationary pressure in the economy (Sikkam,1999). Inflationary pressure in Nigeria has also been exacerbated by incessant adjustments of domestic price of petroleum products. Evidence shows that between 1978 and 2016, prices of petroleum products have been adjusted 21 times. This adjustment is mostly upward which usually cause rise in transportation cost and other consumer goods. This eventually induces high cost of living (Nwosu,2009). Theoretically, oil price shocks affect the economy via the supply-side and demand-side effects. On the supply-side, oil price increase result in reduction in input for production which leads to higher production costs, thus leading to a slowdown of output and productivity. On the
demand-side, higher oil prices increase the general level of prices and with a reduction in real income available for consumption, demand falls (Farzanegan and Markwardt, 2009). Furthermore, there is a fiscal transmission of oil proceeds to the domestic economy via revenue sharing arrangement of the government. In Nigeria, huge revenue accruing from crude oil transactions indirectly induce increase in general price level through unsterilized money supply. On a regular basis, the respective tiers of government converge in the Federal Accounts allocation Committee (FAAC) meeting to share revenue from crude oil. This constantly affects money supply in the economy. As a result, this unsterilized money supply distorts monetary policy due to the over-dependence of proceeds from crude oil for fiscal activities of the government. This affects inflationary trend in Nigeria. More so, other exogenous shocks in the international oil price pervade the entire economy via the terms of trade effect. The evolution of oil price and the consumer price index in Nigeria is depicted in Figure 1. Plotting oil price and the consumer price index in Figure 1, shows the trend of monthly consumer price index and oil price in Nigeria (IFS,IMF). It is easily observed that the CPI move in the same direction with the oil price. Even though there appears to be a disproportionate percentage change in the data which we attributed to other exogenous factors, a cursory inspection reveal that oil price movement may be a determinant factor of the consumer prices in Nigeria.

Figure 1: Trend of Monthly Consumer Price Index and Oil Price in Nigeria (1986 – 2015)

Several studies have been carried out to assess the linkage between oil prices and economic activities. Majority of these studies concentrated on the effect of oil price shocks on the aggregate macroeconomy (Abel and Bernanke,2001; Hamilton,2005; Olomola and Adejumo,2006; Ayadi 2005, Aliyu,2009; Iwayemi and Fowowe,2011; Aremo, Orisadare and Ekperiware,2012; Musa 2015). However, studies that assessed the linkage between oil price shocks and prices have been sparse in Nigeria. The few studies available utilized prices of domestic petroleum products (Eregha, Mesagan and Olawale,2016; Orlu,2017; Umar and Lee,2018). None of these studies have tried to explore the evolution of inflationary trend in Nigeria by including international oil price fluctuation as a likely determinant of general price level. This may affect policies targeted at inflation control. The objective of this study, therefore is to analyze the evolution of inflationary trend in Nigeria by incorporating international oil price movements as a key determinant in a bivariate state-space model. The rest of the paper is organized as follows: following the introduction, section 2 is devoted to theoretical and empirical literature review, source of data and model specification is presented in section 3 while section 4 is devoted to result and interpretation. Section 5 presents conclusion and recommendations.
2. Theoretical and Empirical Literature Review
The linkage between oil prices and inflation takes several routes. This may depend on whether the economy is an oil importer or exporter. Income transfers from oil-importing to oil-exporting countries depress global demand in the oil-importing nations which outweighs the demand increase in the oil-exporting countries because of an assumption of low propensity to consume in the oil-exporting countries. Given constant level of capital stock and the assumption that wages are relatively inflexible in the short run, an increase in input costs of production via oil price increase will result in decrease of non-oil output. This idea follows from the understanding that crude oil is a basic input in production. Therefore, an increase in oil price leads to an increase in production costs. Depending on the definition of core inflation, positive oil price change affects consumer prices. Furthermore, increase in energy prices raise the consumer price index, leading to policy interventions from the central bank. Policy response in the face of increased prices takes the contractionary route. Therefore a tightened monetary policy portend dire consequences on economic output since oil demand is inelastic (Finn, 2001; Abel and Bernanke, 2001). Tang et al (2010) argues that crude oil is a fundamental and crucial raw material for industrial production and the change in its price can affect the output directly. Oil-price shocks raises the marginal cost of production in many industries, and thus reduce the production. This is referred to as the supply-side shock effect which induces reduction of output due to the cut in capacity utilization. Cost shocks in the upstream industry can be transmitted from producers to end-users. Given a well-developed industrial chain, inflationary shock can be transmitted from upstream to down-stream which leaves the producers’ profit rate slightly affected. This raises the overall cost for consumers and producers, thus reducing the consumers’ real balance. This transmission ends up with the reduction of consumption and the real output as well. As mentioned earlier, studies on oil price and inflationary trend in Nigeria are scanty.
Bobai (2012) studied the nexus between petroleum prices and inflation in Nigeria and found the existence of a positive relationship between PMS, AGO and inflation. However, PMS was found to exert higher impact on inflation than AGO. Edame et al (2014) studied the relationship between energy prices, finance and investment in Nigeria and found that energy price exert a positive influence on investment and finance. Eregha, Mesagan and Olawale (2016) studied petroleum products prices and inflationary dynamics in Nigeria and found that there is high positive relationship between the prices of PMS and AGO and inflation in Nigeria. Orlu (2017) investigated the impact of premium motor spirit (PMS) price on the growth of Nigerian economy. The result of this study shows a negative and significant impact on the Nigerian economy due to increase in PMS Price. Umar and Lee (2018) investigated the asymmetric impact of oil price changes on inflation in selected African OPEC countries (Algeria, Angola, Libya, and Nigeria) using three different kinds of oil price data. Overall, they found that both positive and negative oil price changes have a positive influence on inflation. From the studies reviewed, none tried to ascertain the concomitant evolution of oil price and consumer price index in Nigeria. This study aims to bridge this gap.

RESEARCH METHODS
3. Data Sources and Model Specification
The data set utilized for this study was sourced from the International Financial Statistics of the International Monetary Fund (IMF, 2015). The source of this data set was informed by the need to utilize a high frequency data which is difficult to assess locally. The data include monthly data on Nigeria’s Consumer Price index (CPI) and International Oil Price (OILP) ranging from 1986M01 to 2015M12. The choice of data starting from 1986 was motivated by the findings that prior to 1986, oil price shocks were predominantly positive but a large fall was observed in 1986 and periods of oscillations followed thereafter (Mork, 1989). The two variables have been transformed in their natural logarithm. Figures 2 and 3 shows the log of monthly CPI and log of monthly OILP as utilized in this study.
Bivariate State Space Model Specification
Following Bossche (2011), we developed a bivariate state space model of the dynamics of consumer price index (CPI) and international oil price (OILP). In this application of state space model, an attempt is made to ascertain the existence of a concomitant evolution of the two variables in the model. This was necessitated by the understanding that movements in oil prices remains a significant determinant of global economic activities. Kilian (2009) showed that it is inappropriate to assume that oil price is an exogenous driver to economic fundamentals. In Nigeria, as espoused previously, cost of transportation and general prices depend on the prices of petroleum products which in turn depends on fluctuations in the international oil prices (oru, 2017). Therefore, we hypothesized that oil prices may be a latent variable in the evolution of consumer prices in Nigeria. The bivariate model of this study falls within the general Gaussian state space model presented as follows:

\[ y_t = Za_t + \epsilon_t \quad \epsilon_t \sim NID(0, H) \]  
(1)

\[ a_{t+1} = Ta_t + R\eta_t \quad \eta_t \sim NID(0, Q) \]  
(2)

Equations (1) and (2) stand for the observation (signal) and state equations respectively for \( t = 1, \ldots, n \).

In the observation equation (1), \( y_t \) represents a \( p \times 1 \) vector which contains the observed values of...
\[ p \text{ dependent variables at time } t. \] The \( \varepsilon_t \) is a vector of dimension \( p \times 1 \) which contains the \( p \) corresponding observation disturbances. The observation disturbances are assumed to be normally and independently distributed with zero mean and an unknown variance-covariance structure contained in \( p \times p \) square matrix \( H_t \). If there are \( m \) state components in this model, \( a_t \) represents a state vector of order \( m \times 1 \) containing unobserved variables while \( Z_t \) is a matrix of order \( p \times m \) which links the unobservable components of the state vector with the observation vector. Matrix \( T_t \) is a transition matrix of order \( m \times m \). The vector \( \eta_t \) is an \( m \times 1 \) vector which contains the state disturbances with zero mean and an unknown variance-covariance collected in \( m \times m \) matrix \( Q_t \).

Finally, \( R_t \) is usually an identity matrix of order \( m \times m \). In some cases, \( R_t \) can be of order \( m \times r \) which serves as a selection matrix with \( r < m \) where \( r \) are columns in the identity matrix.

In this study, we tried to develop a local linear trend model a`la Bijleveld and Commandeur (2006) where two dependent variables (\( p = 2 \)) are modeled, that is, Consumer Price Index (CPI) as proxy for inflation and international oil price (OILP) and both variables are expressed in their natural logarithm. For each observation, there are two states describing the levels and slopes. Consequently, our bivariate model can be expressed as follows:

\[
y_t = \begin{pmatrix} y_{t(1)} \\ y_{t(2)} \end{pmatrix} = \begin{pmatrix} \text{Logcpi}_t \\ \text{Logoilp}_t \end{pmatrix}
\]

(3).

Following the state space model convention, we write out the signal or observation equations as follows:

\[
y_{t(1)} = \mu_{t(1)} + \varepsilon_{t(1)}
y_{t(2)} = \mu_{t(2)} + \varepsilon_{t(2)}
\]

(4)

The first signal equation in equation (4), \( y_{t(1)} \) is for the observed monthly Logcpi while the second equation , \( y_{t(2)} \) is for the observed monthly Logoilp. \( \mu_{t(1)} \) and \( \mu_{t(2)} \) are the local level and trend (slope) components respectively while \( \varepsilon_{t(1)} \) and \( \varepsilon_{t(2)} \) are the signal disturbances. The unobserved state equations given the signal equation (4) is written as follows:

\[
\mu_{t(1)} = \mu_{t-1} + v_{t-1}^{(1)} + \xi_{t(1)} \\
v_{t(1)} = v_{t-1}^{(1)} + \xi_{t-1}^{(1)} \\
\mu_{t(2)} = \mu_{t-1} + v_{t-1}^{(2)} + \xi_{t(2)} \\
v_{t(2)} = v_{t-1}^{(2)} + \xi_{t-1}^{(2)}
\]

(5)

Equations (5) represent the corresponding state equations which determine the dynamics (trend and slope) of the observation equations (4). Finally, the bivariate model of equations (1) and (2) can further be defined in matrix form. Vectors \( a_t \), \( \varepsilon_t \) and \( \eta_t \) as well as matrices \( T_t \), \( R_t \), \( Z_t \), \( H_t \) and \( Q_t \) are defined as follows:

\[
a_t = \begin{pmatrix} \mu_{t(1)} \\ v_{t(1)} \\ \mu_{t(2)} \\ v_{t(2)} \end{pmatrix}, \quad \varepsilon_t = \begin{pmatrix} \varepsilon_{t(1)} \\ \varepsilon_{t(2)} \end{pmatrix}, \quad T_t = \begin{bmatrix} 1 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \quad R_t = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix},
\]

\[
Z_t = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 \end{bmatrix}, \quad \eta_t = \begin{pmatrix} \xi_{t(1)} \\ \xi_{t(2)} \end{pmatrix}, \quad H_t = \begin{bmatrix} \sigma_{\varepsilon_{t(1)}^{(1)} \varepsilon_{t(2)}^{(1)}} & \text{cov}(\varepsilon_{t(1)}^{(1)}, \varepsilon_{t(2)}^{(2)}) \\ \text{cov}(\varepsilon_{t(1)}^{(2)}, \varepsilon_{t(1)}^{(2)}) & \sigma_{\varepsilon_{t(2)}^{(2)}} \end{bmatrix}
\]

(6)

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The bivariate model of this study is very restrictive as multivariate state space models are usually specified more elaborately with explicit definitions on the hyperparameters. However, our model is judged adequate for the purpose of this analysis. For further understanding of state space modeling, refer to Durbin and Koopman (2001), Hamilton (1994) and Harvey (1989).

4. RESULT AND INTERPRETATION

In this section, we present the result from the estimated bivariate model of the state space model using tables and graphs. Table 1 presents the output of state space bivariate model of Logcpi and Logoilp. We utilized the diffuse prior initialization to estimate the initial values of the state space model.

\[
Q_t = \begin{bmatrix}
\sigma_{\xi(1)}^2 & 0 & \text{cov}(\xi^{(1)}, \xi^{(2)}) & 0 \\
0 & \sigma_{\xi(1)}^2 & 0 & \text{cov}(\xi^{(1)}, \xi^{(2)}) \\
\text{cov}(\xi^{(1)}, \xi^{(2)}) & 0 & \sigma_{\xi(2)}^2 & 0 \\
0 & \text{cov}(\xi^{(1)}, \xi^{(2)}) & 0 & \sigma_{\xi(2)}^2 \\
\end{bmatrix}
\]

From Table 1, the coefficients of the estimated parameters and hyperparameters of the unobserved components of the state and signal equations are statistically significant at all conventional levels except C(8) with high p-value. The maximum of the log likelihood at convergence of the model is 1261.961 with final state vectors SV1-SV4 as reported in Table 1. Barring any other underlying misspecification errors, the result shows that the model is significant and suitable for this analysis.

Figures 4 and 5 shows the graph of actual data on Logoilp and Logcpi as well as their respective state space forecasted values from the estimated model. Figures 4 and 5 indicate that the estimated state space model of this study traced the actual data on Logoilp and Logcpi very closely. This indicate appropriateness and suitability of the selected model for both variables. Figure 6 shows the plot of the one step ahead forecast of Logoilp and Logcpi. There seems to be a direct comovement of the selected variables over time. In other words, activities in the price of international oil market may have a latent relationship with the consumer price index in Nigeria.
Figure 4: Actual Data on Logoilp and State Space Forecast of Logoilpf

Figure 5: Actual Data on Logcpi and State Space Forecast of LogcpiF
Figures 7 and 8 show the graph of one step ahead signal prediction together with two root mean squared errors (RMSE) bounds of Logoilp and Logcpi. From Figures 7 and 8, the estimated state space model for the signal equations shows that the actual variables can be predicted within two root mean squared error (RMSE) bound one step at a time. The implication of this result is that short term predictions of the evolution of the Logoilp and Logcpi can be performed using the selected state space model of this study. Even though it is possible to predict several periods ahead using a state space model, the accuracy of the predicted values from our model relies on its ability to perform one step prediction at a time within allowable confidence interval and prediction errors. This is further confirmed by the one step ahead signal residuals from the estimated state space model of Logoilp and Logcpi as shown in Figures 9 and 10.
Figure 7: One-step-ahead LOGCPI Signal Prediction

Figure 8: One-step-ahead LOGOILP Signal Prediction
Diagnostic test of the estimated state space model is further conducted to confirm the suitability and stability of the model. According Commandeur and Koopman (2007), there are three standard diagnostic tests for the residuals of state space models. These include test for independence, normality test and homoscedasticity test. These tests are applied to the standardized prediction error obtained from the combined descriptive and explanatory bivariate model of this study. Table 2 reports the results of the diagnostic tests of the estimated state space model of Logoilp and Logcpi.
Table 2: Diagnostic test of bivariate state space model

<table>
<thead>
<tr>
<th>Test</th>
<th>Statistics</th>
<th>Value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independence</td>
<td>Q(10)</td>
<td>7.8</td>
<td>0.66</td>
</tr>
<tr>
<td>Homoscedastic</td>
<td>H</td>
<td>73.9</td>
<td>0.00</td>
</tr>
<tr>
<td>Normality</td>
<td>JB</td>
<td>13.0</td>
<td>0.001</td>
</tr>
</tbody>
</table>

The null hypothesis of independence of the residuals of the state space model is tested using the Ljung-Box (1979) Q-statistics which can be tested given a selected combined lags of autocorrelation in the correlogram. This test follows a chi-square distribution based on the level of significance and the selected lag. Table 2 shows that the Q-statistic value of 7.8 is insignificant. More so, p-value of 0.66 indicate that the Q-statistic is statistically insignificant. Therefore, the null hypothesis of independence of the residuals of the state space model is not rejected and we conclude that there is no serial correlation in the residual. The homoscedastic (H) test is further deployed to test for presence of heteroscedasticity of the residuals of the state space model. Using White test of heteroscedasticity against the null hypothesis of residual heteroscedasticity which follows the F-distribution, the value of 73.9 and p-value of 0.00 indicate that the test is statistically significant. Therefore, the null hypothesis of residual heteroscedasticity is rejected which implies that the residual from the state space model is homoscedastic and constant. Finally, the Jarque-Bera statistics (JB) which follows a chi-square distribution with two degrees of freedom was used to test whether the residual of the state space model is normally distributed. The JB statistic value of 13.0 was quite high and may indicate non-normality of the residual. The p-value of 0.001 indicate statistical significance of the JB test and therefore the null hypothesis of normality in the residual is rejected. This was expected from the level shift observed from the Logoilpf around 1986 in Figure 6.

From the result analysis, we can conclude that oil price is a latent variable in the evolution of consumer price index in Nigeria. It is obvious that there is an inherent relationship between the two variables in this study. Therefore, it is expected that policies that are targeted towards inflation control should incorporate oil price changes. Consequently, a forward-looking inflation forecast should be conducted within allowable confidence interval that will accommodate the likelihood of oil price changes. In this way, the effect of oil price shocks to domestic prices will be ameliorated.

5. CONCLUSION AND RECOMMENDATION
The study focused on analyzing the latent relationship that exists between the Nigerian consumer price index and international oil price by fitting a bivariate state space model on monthly data of the two selected variables. The results show that the state space model traced the evolution of the two variables very closely. The dynamics of the evolution of the variables were captured by the estimated model while the diagnostic tests conducted shows that the model was suitable for this study. This suggest that domestic prices are indirectly dictated by movements in the international price of crude oil. Therefore, we recommend that oil price movements should be incorporated in the process of fiscal and monetary policy-making in Nigeria beyond just national budgets. Inflation control policies should incorporate oil price changes. Furthermore, we recommend that forward-looking inflation forecast should be conducted within allowable confidence interval to accommodate the likelihood of oil price changes. This will further serve as a buffer on the economy during periods of oil price shocks.

REFERENCES


