

Simultaneous equation modeling of selected econometric variables on the Nigerian economy

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Abstract. This study estimates various econometric variables to ascertain the two-way cause-and-effect relationship between Balance of Payment, Exchange Rate, and Inflation Rate in Nigeria. This aim was achieved by fitting an appropriate simultaneous equation model to Nigeria balance of payment and exchange rate. This study is limited to Nigeria Balance of Payment (BOP), exchange rate and inflation rate, which covers a period of 2001 to 2017. Based on the findings of this work, it is evident that relationships exist between exchange rate and BOP. It is clear that while exchange rate influences BOP negatively, the reverse is the case for Inflation Rate, since it influences exchange rate positively. It is therefore obvious that the outcome of this study will assist the Central Bank of Nigeria in monitoring the growth of Nigerian economy.

Keywords: balance of payment, exchange rate, inflation rate, simultaneous equation, Nigerian economy.

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1. Introduction

The balance of payment of a country is the record of all economic transactions between the residents of the country and the rest of the world in a particular period. These transactions are made by individuals, firms and government bodies. Thus the balance of payment includes all external visible and non-visible transactions of a country. It is an important issue to be studied, especially in international financial management field, for a few reasons. First, the balance of payments provides detailed information concerning the demand and supply of a country's currency. For example, if Nigeria imports more than it exports, then this means that the supply of Naira is likely to exceed the demand in the foreign exchanging market. One can thus infer that the Nigerian Naira would be under pressure to depreciate against other currencies. On the other hand, if Nigeria exports more than it imports, then the Naira would be likely to appreciate. Second, a country's balance-of-payment data may signal its potential as a business partner for the rest of the world. If a country is grappling with a major balance-of-payment difficulty, it may not be able to expand imports from the outside world. Instead, the country may be tempted to impose measures to restrict imports and discourage capital outflows in order to improve the balance-of-payment situation. On the other hand, a country experiencing a significant balance-of payment surplus would be more likely to expand imports, offering marketing opportunities for foreign enterprises, and less likely to impose foreign exchange restrictions. Third, balance-of-payments data can be used to evaluate the performance of the country in international economic competition. Suppose a country is experiencing trade deficits year after year. This trade data may then signal that the country's domestic industries lack international competitiveness. To interpret balance-of-payments data properly, it is necessary to understand how the balance of payments account is constructed (Eun and Bruce, 2007; Udude (2015) and Sloman, 2009). This can be determined by exchange rate as suggested by economic theory.

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Exchange rate is the rate at which one currency will be exchanged for another. It is also regarded as the value of one country's currency in relation to another currency (Steven, 2003) Exchange rates are determined in the foreign exchange market, which is open to a wide range of different types of buyers and sellers, and where currency trading is continuous: 24 hours a day except weekends. The spot exchange rate refers to the current exchange rate. The forward exchange rate refers to an exchange rate that is quoted and traded today but for delivery and payment on a specific future date.

The importance of Balance of Payment, Exchange rate and other macro-economic variables in determining the growth of Nigerian economy cannot be overemphasized. To this effect, several studies have been done in order to determine the relationship between balance of payment and exchange rate in addition to other macroeconomic variables. For instance, Oladipupo and Onotaniyohuwo (2011) conducted a study to determine the impact of exchange rate on Balance of Payment. Other works as reviewed in the literature have been undertaken in this regard. In all these works, the relationship between balance of payment and exchange rate were modeled using single equation models in which, either balance of payment or exchange rate was each considered as dependent variable. In other words, the cause-and-effect relationship between balance of payment and exchange rate was assumed to be one-way or unidirectional.

However, in many practical situations, such unidirectional or one-way cause-and-effect relationship is not meaningful. This is because economic theory has suggested that balance of payment could be determined by exchange rate and exchange rate is, in turn determined by balance of payment, thereby requiring the use of a simultaneous equation model. It is against this backdrop that this study was initiated so as to account for the two-way cause-and-effect relationship between balance of payment and exchange rate in Nigeria. The aim of this study is to fit an appropriate simultaneous equation model to Nigeria balance of payment and exchange rate.

2. Literature review

Anthony (2015) examined exchange rate variations and balance of payments position in Nigeria under regulated and deregulated periods. He posits that the nation's balance of payments position has been under constant pressure since the 1980s as a result of several factors such as fluctuations in the prices of crude oil, poor performance of non-oil exports, high taste for foreign goods and services, etc. The main objective of his study was to analyze policies initiated by the Federal Government of Nigeria in attaining a realistic exchange rate and improving the balance of payments position. To achieve this objective, the econometric techniques of ordinary least squares, co-integration and error correction mechanism were used to analyze the sourced data. The results showed that exchange rate had more impact on the balance of payments position during the deregulated period than the regulated period in Nigeria. Based on the results, the study recommends that to improve the balance of payments position in the country, governments should increase their capital expenditure; exports should be stimulated and diversified in the non-oil sector such as agriculture and manufacturing sector; a contractionary monetary policy should be implemented to discourage importation of luxurious goods and the Naira should be devalued to make exports cheaper in the international market.

Ezenekwe *et al.* (2015) used aggregate data from 1970 to 2012 to investigate balance of payments adjustment and productivity growth in Nigeria by specifying a small macro-econometric model to analyze the various channels through which the economy's BOP position could be enhanced. The empirical model identifies real exchange rate, government expenditure/revenue, real trade, and foreign direct investment as the various channels that drive productivity growth of the Nigerian economy. The simultaneous equation model was analyzed using the ECM-error correction model approach rather than the conventional Ordinary Least Square (OLS) to overcome simultaneity bias while the unit roots and co-integration tests were carried out using ADF and Johansen/Juselius techniques respectively. Among the findings of the study is that there is a relationship between changes in real exchange rate misalignment and changes in actual exchange rate. This, therefore suggest that the monetary authorities can use exchange rate alignments to develop the external sector of the Nigerian economy, via the non-oil export thereby solving the BOP disequilibrium problem.

Nyong and Obafemi (1995) investigated the impact of exchange rate adjustment (devaluation)

in Nigeria's balance of payments using the instrumental variable approach. He observed that the Central Bank of Nigeria has carried out complete neutralization of the domestic money supply within the sampled period of 1960 to 1993.

Akpansung (1998) explored the applicability of the monetary approach to the balance of payments in Nigeria between the periods 1960 to 1995 using the two stage least square (2SLS) estimation technique. He observed that Nigeria's balance of payments has been dominated by monetary variables. His result confirmed the postulation that reserve accumulation is negatively related to the rate of growth of domestic output.

Furthermore, Udah (2011) investigated adjustment policies under current account behaviour in Nigeria between the periods of 1970 to 2008, employing co-integration and error correction technique. He observed that the causality between exchange rate and current account is uni-directional while the same holds true for current account and trade openness. Other researchers like Pindyck and Rubinfeld (1981), Olisadebe (2016), Pincheira and Medel (2015), Popoola, *et. al.*, (2017), Nyoni (2018), Yusifet.al. (2015), Kabukcuoglu and Martnez-Garca (2018), Mandalinci (2017). Imoisi (2012), Oladipupo and Onotaniyohuwo (2011), Aniekan (2013) and Udude (2015) have worked extensively on balance of payments, inflation rate and exchange rate but none of them have ascertain the two-way cause-and-effect relationship between Balance of Payment (BOP), Exchange Rate, and Inflation Rate in Nigeria using appropriate simultaneous equation model.

3. Materials and methods

3.1 Simultaneous equation model

Simultaneous Equation Model (SEM) is a system of equations representing a set of relationship among variables. By this definition, determines the values of one set of variables in terms of another set of variables. Thus, the model consists of a series of equations with each equation serving to explain one variable whose values are determined within the model on the basis of the variables whose values are determined outside the model. The general M linear simultaneous equation model in M endogenous variables is given in (Gujarati and Porter, 2009) as

$$\begin{aligned}
 Y_{1t} &= \beta_{12}Y_{2t} + \beta_{13}Y_{3t} + \dots + \beta_{1M}Y_{Mt} + \gamma_{11}X_{1t} + \gamma_{12}X_{2t} + \dots + \gamma_{1K}X_{Kt} + \mu_{1t} \\
 Y_{2t} &= \beta_{21}Y_{1t} + \beta_{23}Y_{3t} + \dots + \beta_{2M}Y_{Mt} + \gamma_{21}X_{1t} + \gamma_{22}X_{2t} + \dots + \gamma_{2K}X_{Kt} + \mu_{2t} \\
 Y_{3t} &= \beta_{31}Y_{1t} + \beta_{32}Y_{2t} + \dots + \beta_{3M}Y_{Mt} + \gamma_{31}X_{1t} + \gamma_{32}X_{2t} + \dots + \gamma_{3K}X_{Kt} + \mu_{3t} \\
 &\vdots \\
 Y_{Mt} &= \beta_{M1}Y_{1t} + \beta_{M2}Y_{2t} + \dots + \beta_{M,M-1}Y_{M-1,t} + \gamma_{M1}X_{1t} + \gamma_{M2}X_{2t} + \dots + \gamma_{MK}X_{Kt} + \mu_{Mt}
 \end{aligned} \tag{3.1}$$

Alternatively, equation (3.1) can be written as

$$\begin{aligned}
 \beta_{11}Y_{1t} + \beta_{12}Y_{2t} + \dots + \beta_{1M}Y_{Mt} + \gamma_{11}X_{1t} + \gamma_{12}X_{2t} + \dots + \gamma_{1K}X_{Kt} &= \mu_{1t} \\
 \beta_{21}Y_{1t} + \beta_{22}Y_{2t} + \dots + \beta_{2M}Y_{Mt} + \gamma_{21}X_{1t} + \gamma_{22}X_{2t} + \dots + \gamma_{2K}X_{Kt} &= \mu_{2t} \\
 \beta_{31}Y_{1t} + \beta_{32}Y_{2t} + \dots + \beta_{3M}Y_{Mt} + \gamma_{31}X_{1t} + \gamma_{32}X_{2t} + \dots + \gamma_{3K}X_{Kt} &= \mu_{3t} \\
 &\vdots \\
 \beta_{M1}Y_{1t} + \beta_{M2}Y_{2t} + \dots + \beta_{MM}Y_{Mt} + \gamma_{M1}X_{1t} + \gamma_{M2}X_{2t} + \dots + \gamma_{MK}X_{Kt} &= \mu_{Mt}
 \end{aligned} \tag{3.2}$$

The model as specified in (3.2) can be regarded as the theory explaining the determination of the endogenous variables in terms of the predetermined variables and disturbance terms. The theory will in general state that some of the β and γ coefficients are zero, otherwise the M equations will not be distinguishable from one another. Also, a constant term may be included in each equation by setting one of the X -variables equal to unity. The β and γ coefficients are known as the structural parameters. To achieve the set objective, the following tests were carried out;

- i. Assumptions of the simultaneous equation model
- ii. Estimation of parameters simultaneous equation model
- iii. Test of simultaneity
- iv. Test for exogeneity
- v. Assess the identifiability of the simultaneous equations
- vi. Rank and order conditions for identification

3.2 The simultaneous equation model for balance of payments and exchange rate

Given the functional form given in equation (3.1), we obtain the following model:

$$Y_t = \beta_{10} + \beta_{11}X_t + \beta_{12}Z_t + U_{1t} \quad (3.3)$$

$$X_t = \gamma_{10} + \gamma_{11}Y_t + \gamma_{12}I_t + U_{2t} \quad (3.4)$$

where Y_t is the value of BOP at time, t ; X_t is the value of Exchange rate at time, t ; Z_t is the inflation rate at time, t ; U_{1t} is the disturbance term corresponding to Y_t ; U_{2t} is the disturbance term corresponding to X_t ; β_{10} is the average value of Y_t when X_t and Z_t are zero; β_{11} is the rate of change in Y_t as a result of a unit change in X_t when Z_t is held constant; β_{12} is the rate of change in Y_t as a result of a unit change in Z_t when X_t is held constant; and γ_{10} is the average value of X_t when Y_t is zero.

Since the exchange rate variable, X enters into the balance of payment equation in (3.3) and the balance of payment variable, Y enters the exchange rate equation in (3.4), the two variables are jointly dependent. For this reason, we refer to equations (3.3) and (3.4) as a simultaneous equation model. It is important to state that the model is mathematically complete in the sense that it contains two endogenous variables X and Y . The remaining variable Z is exogenous.

4. Results and discussion

4.1 Estimation of reduced-form coefficients using ordinary least squares

Table 4.1: Average official balance of payments, exchange rate, inflation rate in Nigeria

Year	Balance of Payments (N' Billion)	Exchange Rate of the Naira (N/US\$1.00)	Inflation Rate of the Naira (N/US\$1.00))
2001	314.1	102.1052	5.8
2002	24.7	111.9433	18.7
2003	563.5	120.9702	13.2
2004	162.3	129.3565	13.0
2005	1,124.2	133.5004	16.1
2006	2,394.9	132.1470	17.8
2007	2,206.5	128.6516	8.5
2008	1,811.8	125.8331	5.5
2009	2,463.4	118.5669	10.9
2010	3,927.5	148.8802	12.6
2011	2,276.2	150.2980	13.9
2012	810.1	153.8616	11.0
2013	787.3	157.4994	12.1
2014	4,205.7	157.3112	8.8
2015	2,074.8	158.5526	8.1
2016	12942	193.2792	8.9
2017	4420	253.4923	15.0

Source: Central Bank of Nigeria website: www.cenbank.org (2001- 2017) data sets

Using the data shown in Table 4.1, we obtain the OLS estimated reduced-form models as:

$$\hat{Y}_t = -825560 + 50312Z_t + 72003I_t \quad (4.1)$$

$$\hat{X}_t = 120 + 7.25Z_t - 0.68I_t \quad (4.2)$$

4.2 Testing for simultaneity of balance of payment and exchange rate model

Our interest is to determine whether or not the endogenous explanatory variables are correlated with the disturbance terms. If they are, then the simultaneity problem exists. In Section the Hausman-Specification Error Test can be used to test for simultaneity.

To conduct the test, let us suppose that the estimated reduced form equation for balance of payments is

$$\hat{Y}_t = \hat{\Pi}_0 + \hat{\Pi}_1 Z_t + \hat{\Pi}_2 I_t \quad (4.3)$$

$$\Rightarrow Y_t = \hat{Y}_t + \hat{V}_{1t} \quad (4.4)$$

where $\hat{Y}_t$ are estimated values of Y_{1t} and $\hat{V}_{1t}$, the estimated values of V_{1t} . Substituting (4.4) into (3.4), we obtain

$$X_t = \gamma_{10} + \gamma_{11} (\hat{Y}_t + \hat{V}_{1t}) + \gamma_{12} I_t + U_{2t}$$

$$\Rightarrow X_t = \gamma_{10} + \gamma_{11} \hat{Y}_t + \gamma_{12} I_t + \gamma_{11} \hat{V}_{1t} + U_{2t} \quad (4.5)$$

Applying OLS to equation (4.5) using data of Table 4.1, we obtain

$$X_t = 242 + 0.00164\hat{Y}_t - 13.2I_t + 8.60\hat{V}_{1t} \quad (4.6)$$

The hypotheses being tested are stated as follows:

$$\begin{aligned} H_0 : & \text{There is no simultaneity (i.e. } Y_t \text{ is not an endogenous variable) versus} \\ H_1 : & \text{There is simultaneity (i.e. } Y_t \text{ is an endogenous variable)} \end{aligned} \quad (4.7)$$

The test statistic is given as

$$t = \frac{\hat{\beta}}{se(\hat{\beta})} = \frac{0.00016389}{0.00006657} = 2.46 \quad (4.8)$$

Similarly, we can determine whether or not exchange rate is actually endogenous variable, by noting that the estimated reduced-form equation for exchange rate is

$$\hat{X}_t = \hat{\Pi}_3 + \hat{\Pi}_4 Z_t + \hat{\Pi}_5 I_t \quad (4.9)$$

$$\Rightarrow X_t = \hat{X}_t + \hat{V}_{2t} \quad (4.10)$$

where $\hat{X}_t$ are estimated values of X_{1t} and $\hat{V}_{2t}$, the estimated values of V_{2t} . Substituting (4.10) into (3.3), we obtain

$$Y_t = \beta_{10} + \beta_{11} (\hat{X}_t + \hat{V}_{2t}) + \beta_{12} Z_t + U_{1t}$$

$$\Rightarrow Y_t = \beta_{10} + \beta_{11} \hat{X}_t + \beta_{12} Z_t + \beta_{11} \hat{V}_{2t} + U_{1t} \quad (4.11)$$

Applying OLS to equation (4.11) using data of Table 4.1, we obtain

$$Y_t = 9979699 - 105483\hat{X}_t + 815497Z_t + 873\hat{V}_{2t} \quad (4.12)$$

The hypotheses being tested are stated as follows:

$$H_0 : \text{There is no simultaneity (i.e. } X_t \text{ is not an endogenous variable) versus}$$

$$H_1 : \text{There is simultaneity (i.e. } X_t \text{ is an endogenous variable)} \quad (4.13)$$

The test statistic is given as

$$t = \frac{\hat{\gamma}}{se(\hat{\gamma})} = -9.60 \quad (4.14)$$

Since, it has been established that balance of payment and exchange rate are truly endogenous, the next task is to incorporate their estimates in the original model as explanatory variables and conduct a test of significance on them. Thus, equation (3.3) can be re-defined as:

$$Y_t = \beta_{10} + \beta_{11} X_t + \beta_{12} Z_t + \lambda_1 \hat{X}_t + U_{1t} \quad (4.15)$$

where $\hat{X}_t = \hat{\Pi}_3 + \hat{\Pi}_4 Z_t + \hat{\Pi}_5 I_t$. Applying OLS to equation (4.15) using data of Table 4.1, we obtain

$$Y_t = 9979699 + 873X_t + 815497Z_t - 1063561\hat{X}_t \quad (4.16)$$

$$H_0 : \lambda_1 = 0 \text{ (There is no exogeneity ; i.e. } Z_t \text{ is not an endogenous variable) versus}$$

$$H_1 : \lambda_1 \neq 0 \text{ (There is exogeneity i.e. } Z_t \text{ is an endogenous variable)} \quad (4.17)$$

The test statistic is given as

$$t = \frac{\hat{\lambda}_1}{se(\hat{\lambda}_1)} = -10.61 \quad (4.18)$$

Similarly, the equation for exchange rate can be re-defined as:

$$X_t = \gamma_{10} + \gamma_{11} X_t + \gamma_{12} I_t + \lambda_2 \hat{Y}_t + U_{2t} \quad (4.19)$$

where $\hat{Y}_t = \hat{\Pi}_0 + \hat{\Pi}_1 Z_t + \hat{\Pi}_2 I_t$. Applying OLS to equation (4.30) using data of Table 4.1, we obtain

$$X_t = 221 + 0.000003Y_t - 11.1 I_t + 0.000141\hat{Y}_t \quad (4.20)$$

$$H_0 : \lambda_2 = 0 \text{ (There is no exogeneity ; i.e. } I_t \text{ is not an endogenous variable) versus}$$

$$H_1 : \lambda_2 \neq 0 \text{ (There is exogeneity i.e. } I_t \text{ is an endogenous variable)} \quad (4.21)$$

The test statistic is given as

$$t = \frac{\hat{\lambda}_2}{se(\hat{\lambda}_2)} = \frac{0.000141076}{0.0006634} = 2.12 \quad (4.22)$$

4.3 Estimation of structural parameters of the balance of payment and exchange rate equations

Having established that the structural equations for both balance of payments and exchange rates are exactly identified, the next task is to employ the indirect least squares;

$$\hat{\beta}_{10} = \hat{\Pi}_3 \left(\frac{\hat{\Pi}_0}{\hat{\Pi}_3} - \frac{\hat{\Pi}_2}{\hat{\Pi}_5} \right) = 102 \left(\frac{-825560}{102} - \frac{72003}{-0.68} \right) = 9974890 \quad (4.23)$$

$$\hat{\beta}_{11} = \frac{\hat{\Pi}_2}{\hat{\Pi}_5} = \frac{72003}{-0.68} = -105886.7647 \quad (4.24)$$

$$\hat{\beta}_{12} = \left(\hat{\Pi}_1 - \frac{\hat{\Pi}_2 \hat{\Pi}_4}{\hat{\Pi}_5} \right) = \left(50312 - \frac{72003 \times 7.25}{-0.68} \right) = 817991.0441 \quad (4.25)$$

$$\hat{\gamma}_{10} = \hat{\Pi}_0 \left(\frac{\hat{\Pi}_3}{\hat{\Pi}_0} - \frac{\hat{\Pi}_4}{\hat{\Pi}_1} \right) = -825560 \left(\frac{102}{-825560} - \frac{7.25}{50312} \right) = 220.9639 \quad (4.26)$$

$$\hat{\gamma}_{11} = \frac{\hat{\Pi}_4}{\hat{\Pi}_1} = \frac{7.25}{50312} = 0.000144 \quad (4.27)$$

$$\hat{\gamma}_{12} = \left(\hat{\Pi}_5 - \frac{\hat{\Pi}_2 \hat{\Pi}_4}{\hat{\Pi}_1} \right) = \left(-0.68 - \frac{72003 \times 7.25}{50312} \right) = -11.0557 \quad (4.28)$$

Using the results of equations (4.23) through (4.28), we define the estimated structural equations for balance of payments and exchange rates respectively as:

$$Y_t = 9974890 - 105886.7647X_t + 817991.0441Z_t \quad (4.29)$$

$$X_t = 220.9639 + 0.0001Y_t - 11.0557I_t \quad (4.30)$$

4.4 Discussion of results

This result $\hat{\beta}_{10} = 9974890$ shows that if there is no exchange rate and inflation rate, then BOP would on the average stand at N9, 974,890.00 per US dollar. However, in practice, this result is difficult to realize because rarely can exchange rate and inflation be zero. The result $\hat{\beta}_{11} = -105886.76$ shows that if the exchange rate increases by one unit, then BOP will decrease by N 105886.76. This implies that a reduction in exchange rate encourages the BOP. This result agrees with that work done by Oladipopo (2015). The statistic $\hat{\beta}_{12} = 9974890$ shows if the inflation rate increases by 1 percent, then BOP increases by N 817991.04 per US dollar. This means that the higher the rate of inflation,

the higher the BOP. This result does not agree with the work of Anthony (2015). The obtained value $\hat{\gamma}_{10} = 220.9639$ implies that, when BOP drops to zero, exchange rate would stand at N 220.96 per US dollar. The result $\hat{\gamma}_{11} = 0.000144$ indicates an increase of one unit of BOP leads to an increase of N 0.0001 million in exchange rate. Thus, BOP positively affects exchange rate. Furthermore, the statistic $\hat{\gamma}_{12} = -11.06$ shows that exchange rate decreases by N 11.06 per US dollar.

5. Conclusion

This work discusses fitting of simultaneous equation model to Nigeria balance of payment and exchange rate for the period January 2001 to December 2017 obtained from the CBN Statistical Bulletin. The ultimate objective is to construct a statistical model which may be used to obtain future values of Nigeria balance of payment and exchange rate necessary for policy formulation, implementation and monitoring. The result of data evaluation for the assumptions of simultaneous equation model shows that the data satisfied the simultaneity and exogeneity assumptions. The result of the rank and order condition of identifiability shows that the two equations: BOP and Exchange rate are exactly identified. In view of this, the appropriate model for the estimation of parameters of BOP and Exchange rate model is the Indirect Least Squares estimation procedure. This model has therefore been recommended for use in the study of Nigeria external reserve until further studies prove otherwise.

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