



A comparative study between ARIMA and ARIMAX in Forecasting Gross Domestic Product (GDP) in Nigeria

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Abstract

The Gross Domestic Product (GDP) is one of the primary indicators used to measure the strength of a country's economy. The Linear class of time series models have received much attention over the years both in theory and applied research. However, the linear class of models usually do not capture vital features of most macro-economic and financial data. Since the business cycle for most economies is bound to go through either an expansion or recession, it is reasonable to assume that each kind of data set may require a different type of time series model. The data used for this work is an annual data collected for the period 1981-2020 from the Central Bank of Nigeria. The analysis was carried out with the aid of E-Views software. The Akaike Information Criterion (AIC) and Schwarz Information Criterion (SIC) serve as the accuracy criteria in evaluating the performance of the models. The Root Mean Square Error (RMSE) and Mean Square Error (MSE) serve as the error matrices in evaluating the accuracy of the out-sample forecast of the models. Based on the analysis, ARIMAX model is found to perform well with least the Akaike Information Criterion (AIC) and Schwarz Information Criterion (SIC) of 16.64667 and 16.81729 respectively as compared to the ARIMA models with Akaike Information Criterion (AIC) and Schwarz Information Criterion (SIC) of 17.72631 and 17.89869 respectively. Also the ARIMAX model have the best out-sample forecast accuracy with the least Root Mean Square Error (RMSE) and Mean Square Error (MSE) of 899.4937 and 567.9662 respectively as compared to the ARIMA models with Root Mean Square Error (RMSE) and Mean Square Error (MSE) of 1662.352 and 1160.719 respectively. The results show that ARIMAX model is absolutely suitable for forecasting the data. It is recommended that the policy makers should apply ARIMAX model in forecasting gross domestic product (GDP) in Nigeria. Government should give more attention to Agriculture, Industrial and Services sectors because of their contribution to Nigeria economy especially at this time of economic recovery.

Keywords: GDP, ARIMA, ARIMAX, Root Mean Square Error, Mean Square Error,

1. Introduction

Gross Domestic Product, GDP is the aggregate statistic of all economic activity which captures a broader coverage of the economy than other macro-economic variables. It is the market value of all final goods and services produced within the borders of a nation in a year. It is often considered the best measure of how well the economy is performing. (Stephanie & Shelly, 2007). GDP can be measured in three ways. First, the Expenditure approach, which consists of household, business

and government purchases of goods and services and net exports. Second, the Production approach: this is equal to the sum of the value added at every stage of production (the intermediate stages) by all industries within the country, plus taxes and fewer subsidies on products in the period. Third is the Income approach: this is equal to the sum of all factor income generated by production in the country (the sum of remuneration of employees, capital income, and gross operating surplus of enterprises that is, profit, taxes on production and imports less subsidies) in a period (Ard & Den 2010). Box & Jenkins (1976) proposed an entire family of models, called Autoregressive Integrated Moving Average (ARIMA) models. It seems applicable to a wide variety of situations. They also developed a practical procedure for choosing an appropriate ARIMA model out of this family of ARIMA models. However, selecting an appropriate ARIMA model may not be easy. Many literatures suggest that building a proper ARIMA model is an art that requires good judgment and a lot of experience. ARIMA models are especially suited for short term forecasting. This is because the model places more emphasis on the recent past rather than distant past. Thus, forecasting and modelling GDPs could be done using time series analysis, which is a sequence of observations on a single entity reported or measured at regular time intervals (Barro, 1990). Modelling provides not only a defined description of time series but also an important step towards predicting or controlling the series. The Box-Jenkins' Autoregressive integrated moving average (ARIMA) modelling approach enables us to identify a tentative model, estimate the parameters and perform diagnostic checking or residual analysis. This research outlines the practical steps needed in the use of autoregressive integrated moving average (ARIMA) time series models for forecasting Nigeria's GDPs. (Fischer (1993), Ghazo (2021), Abonazel & Abd-Elftah (2019), Dritsaki (2015)). The Expenditure approach of determining GDP adds up the market value of all domestic expenditures made on final goods and services in a single year, including consumption expenditures, investment expenditures, government expenditures, and net exports. Dodaro (1993). The Production approach, also called the Net Product or Value added method requires three stages of analysis. First gross value of output from all sectors is estimated. Then, intermediate consumption such as cost of materials, supplies and services used in production final output is derived. Then gross output is reduced by intermediate consumption to develop net production. The Income Approach of determining GDP requires adding up all the income earned by households and firms in the year. The total expenditures on all of the final goods and services are also income received as wages, profits, rents, and interest income (Dullah & Kasim 2010). An advantage of using the Expenditure Method is data integrity. The source data for expenditure components is considered to be more reliable than for either income or production components (Heller & Porter 1978) and Barro (1990), suggested that the level of technology is spread out from advanced nations to less developed economies, and the flow of technology will grow faster in the developing countries as diffusion closes. To them, the technology-gap and the speed of convergence depend on the rate of diffusion of technology. The neoclassical models are not commonly applied in academic circles because of the assumption of different levels of technology based on geographic regions, and they neglect the assumption of worldwide identical technology. Adenomon(2017).

2. Materials and Method

2.1 Autoregressive integrated moving average process ARIMA (p,d,q)

To create an ARIMA model, we begin with an econometric equation with no independent variables ($Y_t = \beta_0 + \varepsilon_t$) and add to it both the autoregressive (AR) process and the moving-average (MA) process.

$$\Delta^d Y_t = \beta_0 + \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \dots + \phi_p Y_{t-p} + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \dots + \theta_q \varepsilon_{t-q} \dots \quad (1)$$

where

ϕ_p and θ_q are the coefficients of the autoregressive and moving-average processes respectively.

ARIMA model takes historical data and decomposes the data into an autoregressive (AR) process which maintains memory of past events, an Integrated (I) process which makes data stationary for easy forecast and a Moving Average (MA) process of forecast errors. It does not suffer from existence of serial correlation between the error residuals and their own lagged values. An ARIMA (p, d, q) model can be checked if it is of a good statistical fit for data or not, using Akaike Information Criterion (AIC) and Schwarz Criterion (SC) method. Autocorrelation (AC) and partial autocorrelation (PAC) statistics help to determine the right parameters for ARIMA model (Gujarati, 2004). Box-Jenkins has specified four stages for ARIMA model selection (Borensztein, Gregorio & Lee, 1998). These include: Determining values of p, d, q ; Estimating the parameters of the model; Checking whether considered model fits data properly or not, if not consider another model; and Estimation using the best selected model. Stationarity and invertibility is assumed in the ARIMA model. Garnitz & Wohlrabe (2019)

2.2 ARIMA (p, d, q) with exogenous variable

An ARIMAX model simply adds in the covariate on the right hand side:

$$\Delta^d Y_t = \beta X_t + \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \dots + \phi_p Y_{t-p} + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \dots + \theta_q \varepsilon_{t-q} \dots \quad (2)$$

Where X_t is a covariate at time t and β is its coefficient. While this looks straight-forward, one disadvantage is that the covariate coefficient is hard to interpret. The value of β is *not* the effect on Y_t when the X_t is increased by one (as it is in regression). The presence of lagged values of the response variable on the right hand side of the equation mean, that β can only be interpreted conditional on the value of previous values of the response variable, which is hardly intuitive. (Garnitz & Wohlrabe 2019). If we write the model in (3) using backshift operators, the ARIMAX model is given by

$$\phi(\beta)Y_t = \beta X_t + \phi(\beta)\varepsilon_t \quad \text{and} \quad Y_t = \frac{\beta}{\phi(\beta)} X_t + \frac{\theta}{\phi(\beta)} \varepsilon_t \quad (3)$$

Where

$$\phi(\beta) = 1 - \phi_1\beta - \dots - \phi_p\beta^p \quad \text{and} \quad \phi(\beta) = 1 - \phi_1\beta - \dots - \phi_q\beta^q$$

2.3 Identification of an appropriate model for forecasting GDP in Nigeria

The first step in modelling a series is to check the structure of the data in order to obtain some preliminary knowledge about the stationarity of the series (existence of a trend or a seasonal pattern). Before performing formal tests, the graph of the time series under study is plotted. Such plots give initial clue about the likely nature of the time series. The figures below show the line graph of the historical performance of the GDP used in this study.

3. Results and Findings

Autoregressive integrated moving average ARIMA (p,d,q)

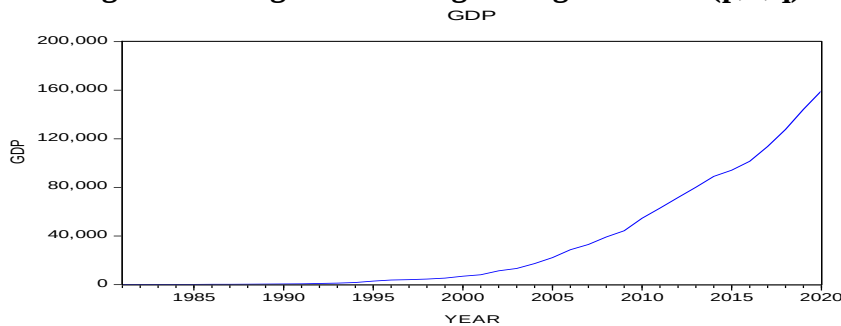


Figure 1: Time Series plot of GDP in Nigeria (1981–2020)

A stationary series must be obtained before it can be used to specify and estimate a model. The data is found non-stationary after applying the Augmented Dickey-Fuller (ADF) unit root test until after the second differencing as shown below.

Table 1. Augmented Dickey-Fuller test

Null Hypothesis: D(GDP,2) has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=16)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-7.465811	0.0000
Test critical values: 1% level	-3.621023	
5% level	-2.943427	
10% level	-2.610263	

*MacKinnon (1996) one-sided p-values.

From the result of the ADF test shown in table 1 above, since the p-value = 0.000 < α -value = 0.05 the null hypothesis is rejected, indicating that the D(GDP, 2) is stationary at 5% level of significant.

Date: 07/11/21 Time: 14:27
Sample: 1981 2020
Included observations: 38

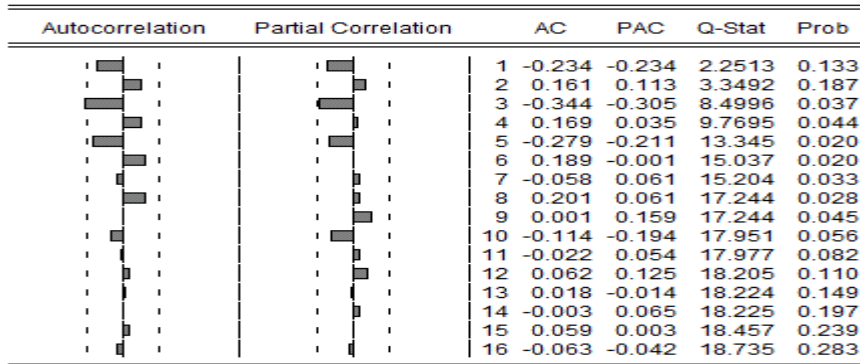


Figure 2: ACF and PACF of the series

From our results of ACF and PACF above we note that there is stationary in the data of series at the second differencing and most of the values are within the confidence interval.

3.1 Model identification

Firstly, from the table we have computed the series correlogram which consists of ACF and PACF values. We also calculated the Ljung-Box Q-statistics. The correlogram for ACF and PACF of the series is plotted in Figure 2. Also, 16 lags of autocorrelation and partial autocorrelation were generated. The autocorrelation function ACF died out after lag 1 (MA) and partial autocorrelation function PACF died out slowly after lag 1 (AR). Thus, the p and q values for the ARMA model are set at 1 and 1 respectively. So, we temporarily set our ARIMA model to be ARIMA (1, 2, 1). From the correlogram of the series, it seems an AR (1) and MA (1) was only adequate. This therefore suggests the possibility of the following combinations of ARIMA: ARIMA (1, 2, 1). From these possible ARIMA combinations, the AIC and SIC criteria will be used to select the most desirable ARIMA model. The results of all the ARIMA combinations are presented in Table 2.

Table 2. The Statistical Indicators for the Models

Z	RMSE	AIC	SIC	R ²
ARIMA (1, 2, 2)	1684.859	17.79750	17.96988	0.158321
ARIMA (2, 2, 1)	1684.203	17.79675	17.96913	0.159054
ARIMA (1, 2, 1)	1622.487	17.72631	17.89869	0.626751
ARIMA (2, 2, 2)	1682.341	17.79737	17.96974	0.161133

Considering the tentative models (as shown in table 2) the best model is ARIMA (1,2,1) since it has the smallest root mean square error (RMSE) of 1622.487, least Akaike Information Criteria (AIC) of 17.72631, least Schwarz Information Criteria (SIC) of 17.89869 and the highest coefficient of determination of 0.626751 which implies that about 62.68% of the variation in gross

domestic product in Nigeria is explained by past values of gross domestic product and the past errors. Garnitz & Wohlrabe (2019)

3.2 Testing the validity of the ARIMA model (1,2,1)

To test for the significance of the model coefficients, we proceed to analyze and the the following results were obtained as shown in table 3.

Table 3. Testing the Model Coefficients

Dependent Variable: D(GDP,2)

Method: ARMA Maximum Likelihood (BFGS)

Date: 07/11/21 Time: 14:36

Sample: 1983 2020

Included observations: 38

Convergence achieved after 16 iterations

Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	409.1010	304.2413	1.344660	0.1876
AR(1)	-0.868217	0.159355	-5.448318	0.0000
MA(1)	0.692084	0.285090	2.427598	0.0206
SIGMASQ	2355361.	413256.3	5.699517	0.0000
R-squared	0.626751	Mean dependent var	402.7221	
Adjusted R-squared	0.549700	S.D. dependent var	1664.373	
S.E. of regression	1622.487	Akaike info criterion	17.72631	
Sum squared resid	89503732	Schwarz criterion	17.89869	
Log likelihood	-332.7999	Hannan-Quinn criter.	17.78764	
F-statistic	1.645023	Durbin-Watson stat	1.900703	
For Prob(F-statistic)	0.197254			

the model coefficients are statistically significant. Thus the model equation is;

$$GDP_t = 409.1010 - 0.8682GDP_{t-1} + 0.6921\varepsilon_{t-1}$$

3.3 ARIMA (1, 2, 1) Diagnostic Tests

After estimating the parameters for ARIMA (1, 2, 1) model, it was also necessary to examine the statistical properties of the estimated ARIMA model in checking the model adequacy. The estimated model is tested for normality of residuals and autocorrelation of errors.

Testing the hypothesis of residuals normality

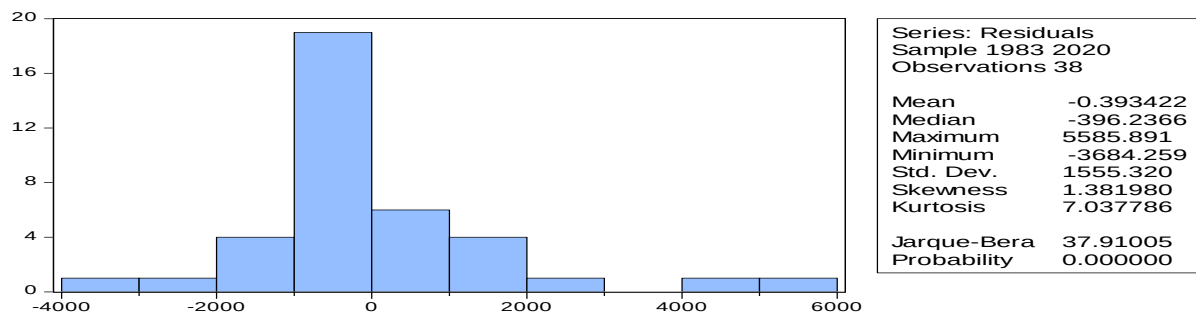


Figure 3: Histogram of Residuals

From figure 3 above, the Jarque-Bera test indicates that the residual from ARIMA (1, 2, 1) model is normally distributed.

Testing the autocorrelation errors

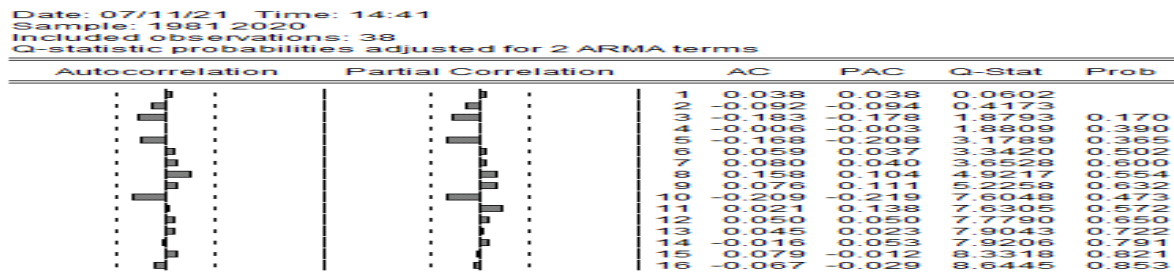


Figure 4: Correlogram of Errors

Q-statistic and its associated probability represent a statistical test which has as null hypothesis that there is no autocorrelation up to lag k. According to the errors correlogram above, there are no serial autocorrelation of the errors. Garnitz & Wohlrabe (2019)

ARIMA (p, d, q) with exogenous variable

Table 4. Testing the Model Coefficients

Dependent Variable: D(GDP)

Method: Least Squares

Date: 07/11/21 Time: 15:32

Sample (adjusted): 1982 2020

Included observations: 39 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	139.8685	214.5263	0.651988	0.5187
AGRICULTURE	0.930015	0.168450	5.521025	0.0000
INDUSTRY	0.186205	0.087721	2.122700	0.0409
SERVICES	-0.267082	0.048043	-5.559222	0.0000
R-squared	0.863731	Mean dependent var		4086.647
Adjusted R-squared	0.860623	S.D. dependent var		4784.906
S.E. of regression	949.5032	Akaike info criterion		16.64667
Sum squared resid	31554469	Schwarz criterion		16.81729
Log likelihood	-320.6101	Hannan-Quinn criter.		16.70789
F-statistic	310.0076	Durbin-Watson stat		2.186882
Prob(F-statistic)	0.000000			

From the table above, since all the p-values are less than 0.05 the null hypothesis is rejected, hence the model coefficients are statistically significant. Thus the model equation is;

$$GDP_t = 139.8685 + 0.9300AGRIC + 0.1862IND - 0.2671SER$$

The ARIMAX equation above can be used to estimate or predict the GDP_t based on known income on Agriculture sector, Construction sector and Services sector values.

3.4 Examination of the performance of both models using AIC and SIC

Based on the experiments results can be analyzed which best method between ARIMA and ARIMAX that can be used to forecast the gross domestic product in Nigeria. The selection of the best method can be done with some comparisons, such as:

3.5 Level of Accuracy.

The GDP and exogenous variable result from ARIMAX method have better accuracy level than ARIMA method. Comparison of forecasting accuracy both of methods are shown in Table 5. This accuracy is viewed by Akaike Information Criterion (AIC) and Schwarz Information Criterion (SIC). Gujarati & Porter (2009)

Table 5. Comparison of ARIMA and ARIMAX accuracy

METHOD	DEGREE OF OPTIMUM			AIC	SIC
	P	D	Q		
ARIMA	1	2	1	17.72631	17.89869
ARIMAX	1	1	1	16.64667	16.81729

It can be seen that the accuracy of some value criteria such as AIC and SIC are produced by ARIMAX has smaller value than ARIMA method. These smaller values indicate that ARIMAX model have better performance than ARIMA model.

3.6 Examination of the out-sample forecast performance of both models.

Based on the experiments results can be analyzed which best method between ARIMA and ARIMAX perform best in out-sample forecast on the gross domestic product in Nigeria. The selection of the best out-samples forecast performance can be done with some comparisons as follows:

3.7 Forecast of gross domestic product by ARIMA (1, 2, 1) model.

The forecast of Nigerian gross domestic product series using ARIMA (1, 2, 1) model was conducted. EViews software provides the one-step ahead static forecasts which are more accurate than the dynamic forecasts.

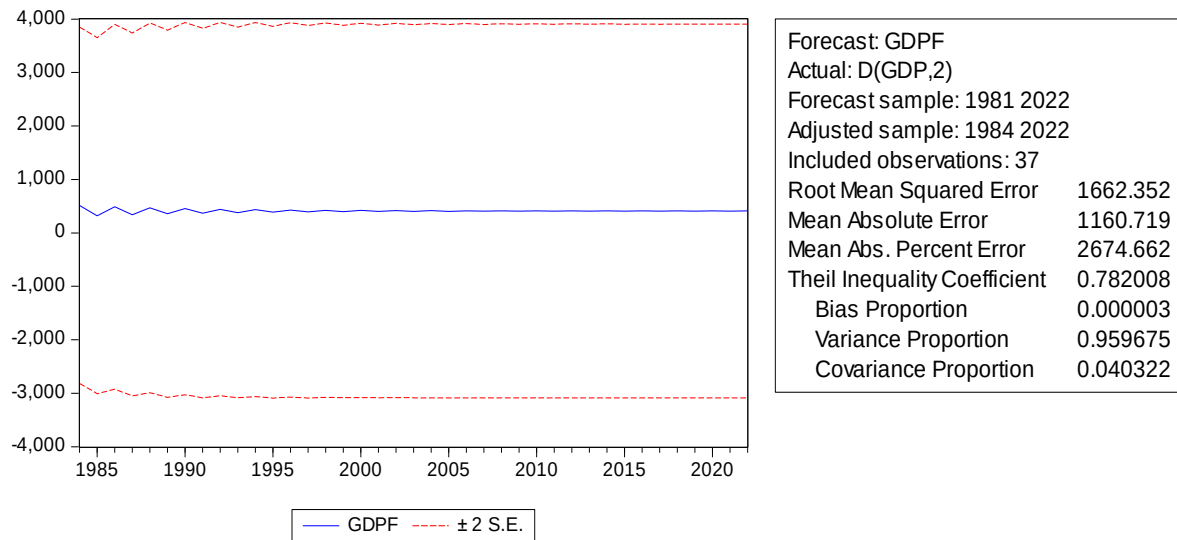
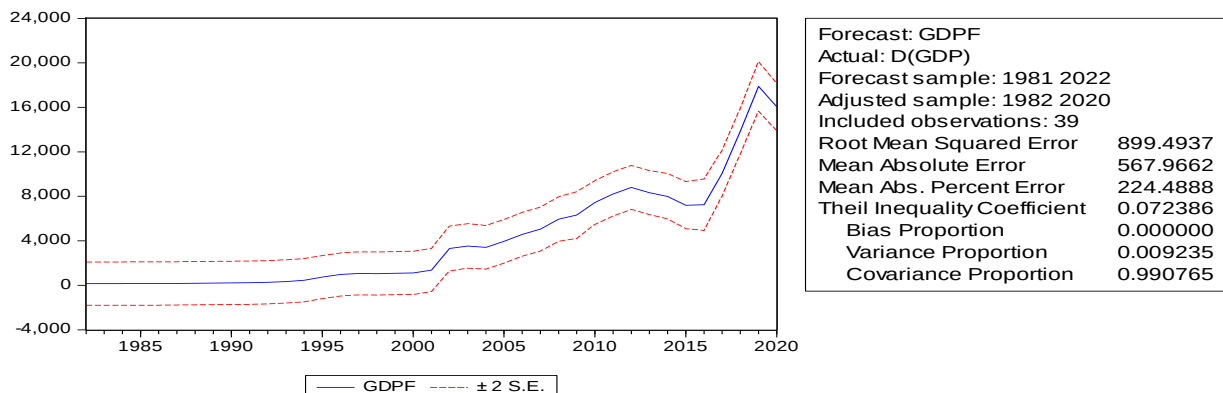


Figure 5: Forecast of gross domestic product by ARIMA (1, 2, 1) model.

In Figure 5, the middle line represents the forecast value of gross domestic product. Meanwhile, the lines which are above or below the forecasted yearly gross domestic product series show the forecast with ± 2 of standard errors. The root mean square error (RMSE) which determine the efficiency of the model was estimated at 1662.35, this indicate that the model built is efficient. Using an ARIMA (1, 2, 1) model the annual value series of gross domestic product for 2021 and 2022 are estimated to be ₦408.54 billion and ₦409.59 billion.

3.8 Forecast of gross domestic product by ARIMAX model.

The forecast of Nigerian gross domestic product series using ARIMAX model was conducted. EViews software provides the one-step ahead static forecasts which are more accurate than the dynamic forecasts.



In Figure 6, the middle line represents the forecast value of gross domestic product. Meanwhile, the lines which are above or below the forecasted yearly gross domestic product series show the forecast with ± 2 of standard errors. The root mean square error (RMSE) which determine the efficiency of the model was estimated at 899.4937, this indicate that the model built is efficient.

Table 6. Comparison of ARIMA and ARIMAX accuracy of the out-sample forecast

METHOD	DEGREE OF OPTIMUM			RMSE	MSE
	P	D	Q		
ARIMA	1	2	1	1662.352	1160.719
ARIMAX	1	1	1	899.4937	567.9662

It can be seen that the accuracy of some value criteria such as RMSE and MSE produced by ARIMAX has smaller value than ARIMA method. These smaller values indicate that ARIMAX model have better performance than ARIMA model.

4. Conclusion

In forecasting accuracy of GDP using the ARIMA models with/without an exogenous variable, it is empirically evident that ARIMA model with an exogenous variable (ARIMAX) performed creditably well in all cases and scenarios. ARIMAX model have better performance than ARIMA method. It is seen from the comparison of AIC and SIC from ARIMAX smaller than ARIMA. Ability ARIMAX method to include the variation of year effect in the form of exogenous variables, make ARIMAX method can generate the forecasting result with more accuracy level than ARIMA method. There are independent variables that can be used to generate forecasting with greater accuracy, namely agriculture sector, industry sector and services sector.

5. Recommendations

In this research work, the model uncertainty was accounted for in the two models namely the Box-Jenkins Method with/without an exogenous variable in all time regimes. The results show that ARIMAX model is absolutely suitable for forecasting. It is thus recommended that:

- I. The policy makers should apply ARIMAX model in forecasting gross domestic product (GDP) in Nigeria and It is also recommend that the government should give more attention to Agriculture, Industry and Services sectors because of their contribution to Nigeria economy especially at this time of economic recovery.
- II. Measures should be put in place to increase the service sectors contributing to the GDP since all the other sectors of the economy benefited from it.
- III. Other sectors of the economy such as manufacturing, real estate should be given more attention. This will be a turn of diversification of the economy of the country.
- IV. Economic policy should be designed in such a manner that government intervene in the market with agriculture and service because of their contribution in Nigeria economy to enhance growth of the domestic economy. For further study more research should be done

by an interested researcher especially in the area of service and industry to improve more production of goods and services improve the research work.

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APPENDIX I

Nigeria Gross Domestic Product (GDP) from 1981-2020

YEAR	GDP	INDUSTRY	SERVICES	AGRIC
1981	144.83116	54.13	73.65	17.05
1982	154.97839	51.38	83.47	20.13
1983	162.99981	52.45	86.76	23.80
1984	170.37778	48.59	91.42	30.37
1985	192.27327	60.90	97.14	34.24
1986	202.43623	62.63	104.11	35.70
1987	249.43908	78.35	120.80	50.29
1988	320.32854	100.83	145.74	73.76
1989	419.19639	144.69	186.24	88.26
1990	499.67685	172.72	220.33	106.63
1991	596.04469	215.11	257.70	123.24
1992	909.80331	336.94	388.75	184.12
1993	1259.0705	409.59	554.16	295.32
1994	1762.8128	541.45	776.09	445.27
1995	2895.2014	931.10	1,173.96	790.14
1996	3779.1331	1,232.15	1,476.47	1,070.51
1997	4111.6406	1,261.36	1,638.82	1,211.46
1998	4588.9898	1,168.07	2,079.88	1,341.04
1999	5307.3615	1,440.31	2,440.07	1,426.97
2000	6897.4825	2,239.63	3,149.45	1,508.41
2001	8134.1418	2,182.62	3,936.10	2,015.42
2002	11332.253	2,432.60	4,648.13	4,251.52
2003	13301.559	3,211.19	5,504.45	4,585.93
2004	17321.295	4,391.70	7,994.33	4,935.26
2005	22269.978	5,591.36	10,646.29	6,032.33
2006	28662.469	6,843.07	14,306.10	7,513.30
2007	32995.384	7,679.74	16,763.67	8,551.98
2008	39157.884	9,216.17	19,841.39	10,100.33
2009	44285.561	9,008.26	23,651.86	11,625.44
2010	54612.264	13,826.43	27,736.94	13,048.89
2011	62980.397	17,853.11	31,089.46	14,037.83
2012	71713.935	19,587.72	36,310.22	15,816.00
2013	80092.563	20,853.85	42,422.17	16,816.55
2014	89043.615	22,213.01	48,812.00	18,018.61
2015	94144.96	19,188.58	55,319.41	19,636.97
2016	101489.49	18,641.17	61,324.81	21,523.51
2017	113711.63	25,639.90	64,119.18	23,952.55
2018	127736.83	33,218.33	67,147.20	27,371.30
2019	144210.49	39,879.69	72,426.66	31,904.14
2020	159524.08	40,479.99	85,494.56	33,549.53

Source: Central Bank of Nigeria Bulletin, 2020