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The Impact of COVID-19 on Nigeria Consumer Price Index (CPI)

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Abstract

This study models the Nigeria Consumer Price Index (CPI) and forecasts its accuracy with COVID-19 impact on the data. The CPI data is homoscedastic and having heteroscedastic in nature and as such it is modelled using models such as Autoregressive (AR) Autoregressive Conditional Heteroscedastic (ARCH), Generalized Autoregressive Conditional Heteroscedastic (GARCH), Threshold GARCH, ExponentialGARCH and Power ARCH. This study compares these models using available data for Nigeria and found the AR as the model of best fit according to the minimum information criteria. The dynamic forecast evaluation reveals that GARCH-N has the minimum forecast residuals by the Root Mean Square Error (RMSE), Mean Absolute Error (MAE) while AR has the minimum Mean Absolute Percentage Error (MAPE) among the models. On average AR has the minimum forecast residuals. Therefore, employing AR model for modelling and forecasting Nigeria CPI which results in low inflation rate when compared with the results of other models considered. This can improve the economy of the nation.

1.Introduction

CPI is considered in this study since is regarded as the chief indicators of inflationary change, and investors and others in the economies of the nation also consider the CPI to be the best gauge of inflation available. CPI is formed to show a statistical estimate of inflation. Pure inflation is when there are no changes in product but there are changes in prices [1, 2]. The all-item CPI reveals the change in consumer prices from month to month and is used to measure inflation. CPI is used to set inflation targets by governments and central banks [1,3]. Taming great inflation in 1970s has been the Central Banks instrumentation nevertheless inflation has been very unresponsive to economic slack. In the awaken of the pandemic, forces of disinflation are possible to overcome in the near term, due to additional dimensions and the constant impact of the globalisation and technology [4].

[5] discovered that there is a statistical difference in the cost-of-living index among the forty cities of Pakistan from the standard of living. [6] revealed that the level of inflation that exist in the economy of a society is the general measure of consumer price index which influence the standards

of living of the people. The elements of consumer prices index as the consumption designs are not equal, since there are changes of it from rural to urban segments of the economy and this living patterns changed with time. The major part of the index for developing economies constitute basic necessities like food and shelter, while the developed economies constitute leisure (holiday) and entertainment mainly. Therefore, most nations are country specific and the consumer price indexes may not be appropriately compared. The existence of the proportion of inflation in the economy revealed that the prices of consumables change at fluctuating rates for locally produced goods [6].

From National Bureau of Statistics [7], the measurement of the growth of Nigeria Consumer Price Index (CPI) was at 12.8 percent year on year (YoY) in Jul 2020 when compared with the previous month rate of 12.6 percent. Nigeria CPI growth data from Jan 1961 to Jul 2020 is updated monthly with an average number of 12.1 percent YoY. The data has the all-time high of 89.6 percent YoY in Jun 1995 and it is as low as -7.8 percent YoY in Oct 1967. National Bureau of Statistics of Nigeria makes available, Consumer Price Index with base November 2009=100.

In March 2020, CPI measures inflation which increased by 12.26 percent (year-on-year). There is 0.06 percent points increased of March 2020 against the February 2020 which was 12.20 percent. The lock down would not have any major impact on March 2020 inflation since the major impact started in April 2020.

CPI data is heteroscedastic in nature as revealed in most previous studies, but possibly because of COVID 19 CPI is both homoscedastic and heteroscedastic in nature and researches conducted have not revealed the impact of each models on CPI. This study reveals the impact of each model for modelling Nigeria CPI, projected the most effective estimation and forecast accuracy that will provide useful policy making for better decision.

2. Methodology

The data was from National Bureau of Statistics (NBS). The Consumer Price Index (CPI) monthly data from 1997 to 2020 is displayed in Appendix A. The six models employed in this study are presented as follows:

2.1. The Autoregressive (AR) models

Autoregressive (AR) model is when the current value of the series which can be explained as a function of p previous values, y_{t-2} ... y_{t-p}, where p controls the number of stages into the previous required forecasting the present value. An y_{t-1} autoregressive model of order p, [AR (p)] is written as;

$y_t = \delta_1 y_{t-1} + \delta_2 y_{t-2} + \cdots + \delta_p y_{t-p} + \omega_t$ (1) where,

y_t is stationary series, $\delta_1, \delta_1, \ldots, \delta_1$ are the parameters of the AR($\delta_1 \neq 0$), ω_t is a Gaussian white noise series with mean zero and variance $\sigma < \infty$, except specified otherwise. The order p of the model is the highest order.

2.2. The ARCH Model

[8] offered Autoregressive Conditionally Heteroscedastic (ARCH) model to allow the conditional variance which is the variance conditional on the previous. The conditional variance is specified as a linear function of the squared previous values of the series, allow the unconditional variance constant.

$y_t = \theta y_{t-1} + \epsilon_t$ (2) $\epsilon_t \sim N(0, h_t)$

$$h_t = \delta + \alpha_1\epsilon_{t-1}^2 + \cdots + \alpha_q\epsilon_{t-q}^2 \quad (3)$$

where,
$q > 0,\ \delta > 0$
$\alpha_i \geq 0,$ i = 1, …, q
If q = 0 then ϵ_t is white noise.
The order of the ARCH process is q and α_i is the unknown parameters.

2.3. The GARCH model

[9] presented Generalized Autoregressive Conditionally Heteroscedastic (GARCH) models to allow the conditional variance which is the variance conditional on the previous. In the conventional GARCH models, the conditional variance is expressed as a linear function of the squared previous values of the series.

$$y_t = \theta y_{t-1} + \epsilon_t \quad (4)\ \epsilon_t \sim N(0, h_t)$$

$$h_t = \delta + \alpha_1\epsilon_{t-1}^2 + \cdots + \alpha_q\epsilon_{t-q}^2 + \beta_1 h_{t-1} + \cdots + \beta_p h_{t-p} \quad (5)$$

where,
$p \geq 0, q > 0,\ \delta > 0$
$\alpha_i \geq 0,$ i = 1, …, q
$\beta_i \geq 0,$ i = 1, …, p
If p = 0 then the process is ARCH (q) process and if p = q = 0 then ϵ_t is just white noise.

2.4. The TGARCH Model

[10] offered TGARCH model which is as follows:

$$\sigma_t^2 = \alpha + \beta|y_{t-1}| + \gamma\sigma_{t-1} + \delta_T y_{t-1} \quad (6)$$

if $\alpha > 0, \beta \geq 0, \gamma \geq 0$ and $|\delta_T| < \beta|$ then the conditional standard deviation is positive.

2.5. The EGARCH Model

EGARCH model have been well-known in modelling the heteroscedastic error. It can be written as:

$$\log h_t = \alpha + \beta\,|\,z_{t-1}\,| + \delta\, z_{t-1} + \gamma \log h_{t-1}, \qquad |\,\gamma\,| < 1 \quad (7)$$

where $z_t = \epsilon_t/\sqrt{h_t}$ is the standardized shocks, $z_t \sim iid\,(0, A)$. $|\,\gamma\,| < 1$ is when there is stability. If $\delta \neq 0$ the impact is asymmetric, while there is leverage existence if $\delta < 0$ and $\beta < -\delta$ [11, 12, 13, 14].

2.6. The PARCH Model

[15] offered Power ARCH (PARCH) model which specifies σ_t as of the form:

$$\sigma_t^d = \alpha_0 + \sum_{i=1}^{p} \alpha_i\,(|\epsilon_{t-i}| + \delta_i\epsilon_{t-i})^d + \sum_{i=1}^{q} \beta_i\,\sigma_{t-i}^d \quad (8)$$

where the α_i and β_i are the parameters of standard ARCH and GARCH, the parameter of the leverage is δ_i and the power term parameter is d.

3.Results and Discussion

The time plot of the level data graph revealed non-trending behaviour as displayed in Figure 1. Unit root tests were conducted to determine whether the series was stationary or not by employing Augmented Dickey-Fuller (ADF), Phillips Perron (PP) and the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) Tests. In Table 1, ADF tests of CPI level data revealed that the exogenous regressors;

constant, and trend and constant were having no unit roots in the series (stationary) because p-values were less than significance level alpha=0.05, while the exogenous regressors; none was not stationary because p-value was greater than significance level alpha=0.05 at level data. First differentiations of CPI using ADF were stationary.

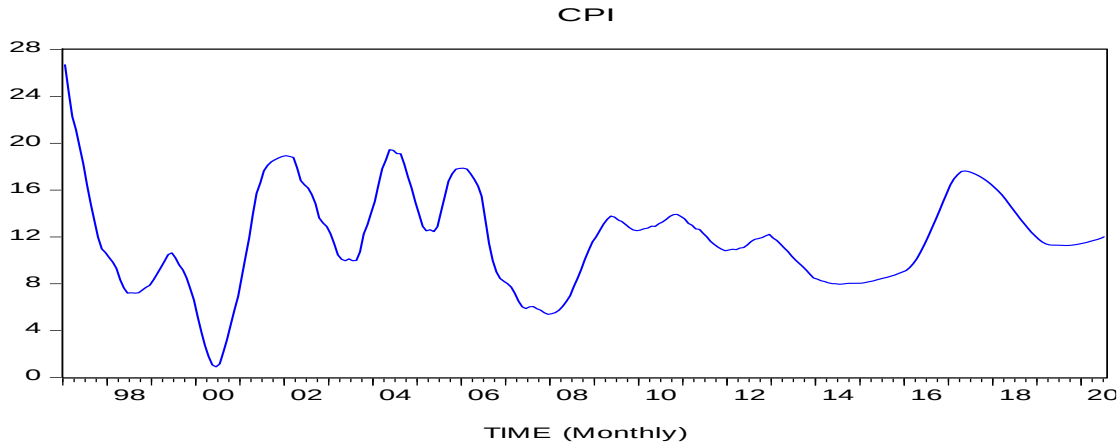

Figure 1: The time plot of Consumer Price Index (CPI) monthly level data

PP tests level and first differentiation of CPI data revealed exogenous regressors; constant, trend and constant, and none were stationary because p-values were less than significance level alpha=0.05, except the exogenous repressors; none was not stationary at level data. KPSS tests CPI level data revealed that the exogenous repressors; constant was not stationary because p-value was less than significance level alpha=0.05, while the CPI level data revealed that the exogenous repressors; trend and constant was stationary because p-value was greater than significance level alpha=0.05. KPSS tests first differentiation of CPI data revealed that the exogenous repressors; constant was not-stationary, while the first differentiation of CPI data revealed that the exogenous repressors; trend and constant was stationary. These called for additional tests to ascertain the data behaviours.

Table 1: Unit Root Tests for Nigeria Consumer Price Index Data

	Test Statistic	Constant	Tend and Constant	None
CPI	ADF	0.0011	0.0076	0.4226
Diff CPI	ADF	0.0011	0.0087	0.0000
CPI	PP	0.0005	0.0036	0.0518
Diff CPI	pp	0.0000	0.0003	0.0000
CPI	KPSS	0.0000	0.9481	-
Diff CPI	KPSS	0.1881	0.0182	-

P-values ( )

Additional tests were conducted as displayed in Table2. In **t**he level data (CPI), kurtosis and skewness were almost normal. The Jarque-Bera of residual normality tests was not significant which was an indication that the data were normally distributed, but the standard deviation was not normally distributed.

Differentiation (Diff CPI), taking logarithm (Log CPI) and differentiation of the logarithm (Dlog CPI) of CPI in Table 2 revealed that all the transformed data were non-stationary.

Table 2: Statistical Summary and Normality Tests for Nigeria Consumer Price Index Data

	Standard deviation	Skewness	Kurtosis	Jarque-Bera
CPI	4.1402	0.1865	3.3160	2.81827 (0.2444)
Diff CPI	0.6628	-0.1332	4.4292	24.8349 (0.0000)***
Log CPI	0.4492	-2.0706	10.8885	935.9886 (0.0000)***
Dlog CPI	8.9525	0.5786	18.7450	2928.611 (0.0000)***

P-values ( ) *** significant at 1%, ** significant at 5%, * significant at 10%

Since at level data; standard deviation was not stationary but kurtosis, skewness and Jarque-Bera were stationary. These called for more tests. Statistics and normality residual tests were conducted to confirm the heteroscedastic nature of the data sets as displayed in Table 3.It was observed that the data exhibited volatility clustering, skewness and kurtosis, which revealed that it was heteroscedastic in nature. ARCH LM tests were conducted to know the heteroscedasticity effect. *F*-Statistic and Obs*R-squared were significant which revealed the presence of ARCH in the data as displayed in Table 3.

Table 3: Histogram Residual Normality and ARCH Tests for Nigeria Consumer Price Index Data

	Standard deviation	Skewness	Kurtosis	Jarque-Bera	*F*-Statistic	Obs*R-squared
Nigeria CPI	0.6606	--0.1064	4.3389	21.6704 (0.0000)***	392.74 (0.0000)***	164.63 (0.0000)***

P-values ( ) *** significant at 1%, ** significant at 5%, * significant at 10%

The presence of ARCH in the data was a justification of using GARCH model as GARCH is the generalization of ARCH. It also revealed the use of other GARCH family members.

These were the evidences that CPI function as homoscedastic and heteroscedastic data; this could be as a result of COVID-19 and the suitable model will be revealed in the analysis. Therefore, AR, ARCH, GARCH, TGARCH, EGARCH and PARCH were models considered to know the effect of each model in modelling Nigeria CPI data. Each model is with distribution description that reveals model suitability as displayed in Tables 4.

Table 4 showed that AR contributed 97.4% of R^2 goodness fit which was very good fit. While the rest models contributed a little above 70% which were good fits. minimum Standard Error (STDE)was revealed in AR. The results revealed that AR has the smallest Sum of Squared Error (SSR). The minimum information criteria (AIC, BIC, HQ) were in AR which revealed the best model fit. The highest value of Log-likelihood (LL) was in AR which indicated good distribution fit.

Table 4: Nigeria CPI Models Output

	AIC	BIC	HQ	LL	R^2	STDE	SSR
AR	2.0540	2.0929	2.0695	-287.64	0.9743	0.0054	14.428
ARCH	4.2664	4.3181	4.2871	-597.56	0.7296	0.0122	6089.4
GARCH-N	4.0028	4.0674	4.0287	-5593.9	0.7289	0.0230	6105.7
GARCH-ST	3.8251	3.9026	3.8562	-533.35	0.7197	0.0481	6311.9
GARCH-GED	3.8490	3.9264	3.8801	-536.71	0.7123	0.0395	6479.9
TGARCH-ST	3.8205	3.9109	3.8568	-531.70	0.7209	0.0481	6284.6
TGARCH-GED	3.8422	3.9326	3.8784	-534.75	0.7124	0.0442	6477.1
EGARCH-ST	3.8417	3.9192	3.8728	-535.68	0.7114	0.0171	6500.0
EGARCH-GED	4.2378	4.3281	4.2740	-590.52	0.7114	0.1841	6500.0

PARCH-ST	3.8275	3.9179	3.8637	-532.68	0.7204	0.5290	6297.3
PARCH-GED	3.8464	3.9497	3.8878	-534.34	0.7135	0.6981	6452.2

Table 5 showed that GARCH-N has minimum Root Mean Squared Error (RMSE) value, minimum Mean Absolute Error (MAE) value, while AR has the minimum Mean Absolute Percentage Error (MAPE) value which revealed the forecast accuracy among the models employed. On average AR has the forecast accuracy in Table 5.

Table 5: Nigeria CPI Forecast

	RMSE	**MAE**	**MAPE**
AR	11.4251	10.4589	141.0242
ARCH	8.9427	4.9080	305.6041
GARCH-N	8.8035	4.7418	154.8627
GARCH-ST	8.9747	5.3073	423.2097
GARCH-GED	9.6470	5.4183	306.6571
TGARCH-ST	8.9532	5.2136	388.8172
TGARCH-GED	9.6142	5.3771	296.9617
EGARCH-ST	19.2495	18.7077	220.2341
EGARCH-GED	12.5758	10.0978	1594.761
PARCH-ST	8.9662	5.2976	419.2026
PARCH-GED	9.2983	5.1441	319.0194

4.Conclusion

The data distributions from different tests revealed that some were normal including the Jarque-Bera tests while some were not normal for confirmation of the suitability of the models. The good distribution fit was revealed in AR which has the highest log-likelihood value. The best model fit was revealed in AR which has minimum information criteria among the models. AR has the minimum standard error, minimum information criteria values and highest value of log-likelihood [16]. The dynamic forecast evaluation indicated that GARCH-N has the minimum forecast residuals values of RMSE and MAE, while AR revealed the minimum MAPE among the models. On average AR has the forecast accuracy. The best forecast accuracy was from the model that has the minimum forecast residuals values [17] which were displayed in Table 5. The outperformance of AR model yielded low inflation rate when compared with the other models results. AR is employed for effective estimation and GARCH-N with AR for forecast accuracy that will provide useful policy making for better decision to boost the economy of the nation; this could be as a result of COVID 19. The future work is to improve on Root Mean Squared Error (RMSE), Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE) for more accurate forecasting.

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Appendix A
Nigeria Consumer Price Index (CPI) Data (monthly on average percent)

Year	All Items	Year	All items	Year	All items	Year	All items	Year	All items	Year	All items
1997	*26.7*	2001	*8.6*	2005	*14.0*	2009	*12.0*	2013	*11.9*	2017	*16.4*
	24.4		*10.3*		*12.9*		*12.6*		*11.7*		*17.0*
	22.3		*11.9*		*12.5*		*13.1*		*11.4*		*17.3*
	21.2		*13.9*		*12.6*		*13.5*		*11.1*		*17.6*
	19.7		*15.7*		*12.5*		*13.8*		*10.8*		*17.63*
	18.2		*16.6*		*12.9*		*13.7*		*10.4*		*17.58*
	16.4		*17.7*		*14.2*		*13.4*		*10.0*		*17.47*
	14.8		*18.1*		*15.5*		*13.3*		*9.8*		*17.33*
	13.4		*18.4*		*16.8*		*13.1*		*9.5*		*17.17*
	12.0		*18.6*		*17.4*		*12.8*		*9.2*		*16.97*
	11.0		*18.7*		*17.8*		*12.6*		*8.8*		*16.76*
	10.7		*18.9*		*17.9*		*12.5*		*8.5*		*16.50*
1998	*10.2*	2002	*18.9*	2006	*17.9*	2010	*12.6*	2014	*8.4*	2018	16.22
	9.8		*18.9*		*17.8*		*12.7*		*8.3*		15.93
	9.3		*18.8*		*17.4*		*12.8*		*8.2*		15.60
	8.3		*17.9*		*16.9*		*12.9*		*8.1*		15.20
	7.6		*16.8*		*16.4*		*12.9*		*8.0*		14.79
	7.2		*16.4*		*15.5*		*13.1*		*8.0*		14.37
	7.2		*16.2*		*13.5*		*13.3*		*8.0*		13.95
	7.2		*15.6*		*11.4*		*13.5*		*8.0*		13.55
	7.2		*14.8*		*10.0*		*13.8*		*8.0*		13.16
	7.5		*13.6*		*9.0*		*13.9*		*8.0*		12.78
	7.7		*13.2*		*8.5*		*13.9*		*8.0*		12.41
	7.9		*12.9*		*8.2*		*13.7*		*8.0*		12.10
1999	*8.3*	2003	*12.3*	2007	*8.0*	2011	*13.5*	2015	*8.1*	2019	11.80
	8.8		*11.4*		*7.7*		*13.2*		*8.1*		11.56
	9.4		*10.5*		*7.2*		*13.0*		*8.2*		11.40
	9.9		*10.1*		*6.5*		*12.7*		*8.2*		11.31
	10.5		*10.0*		*6.0*		*12.6*		*8.3*		11.299
	10.6		*10.1*		*5.9*		*12.3*		*8.4*		11.297
	10.2		*10.0*		*6.0*		*12.0*		*8.5*		11.291
	9.6		*10.0*		*6.1*		*11.6*		*8.6*		11.271
	9.2		*10.7*		*5.9*		*11.4*		*8.7*		11.27
	8.5		*12.3*		*5.7*		*11.1*		*8.8*		11.30
	7.6		*13.0*		*5.5*		*11.0*		*8.9*		11.35
	6.6		*14.0*		*5.4*		*10.8*		*9.0*		*11.40*
2000	*5.2*	2004	*15.0*	2008	*5.5*	2012	*10.9*	2016	*9.1*	2020	*11.46*
	3.9		*16.5*		*5.5*		*11.0*		*9.4*		*11.54*

2.7	*17.8*	*5.8*	*10.9*	*9.8*	*11.62*
1.8	*18.5*	*6.1*	*11.1*	*10.2*	*11.71*
1.1	*19.4*	*6.5*	*11.1*	*10.7*	*11.79*
0.9	*19.4*	*7.0*	*11.3*	*11.4*	*11.90*
1.2	*19.1*	*7.8*	*11.6*	*12.0*	*12.05*
2.2	*19.1*	*8.5*	*11.8*	*12.7*	
3.3	*18.2*	*9.2*	*11.9*	*13.5*	
4.5	*17.1*	*10.1*	*11.9*	*14.2*	
5.8	*16.1*	*10.9*	*12.1*	*15.0*	
6.9	*15.0*	*11.6*	*12.2*	*15.7*	