Quarterly Journal of Econometrics Research
2022 Vol. 8, No. 1, pp. 1-10.
ISSN(e): 2411-0523
ISSN(p): 2518-2536
DOI: 10.18488/88.v8i1.2931

TREND ANALYSIS AND GARCH MODEL FOR COVID-19 NATIONAL WEEKLY CONFIRMED CASES IN NIGERIA FOR ABUJA AND LAGOS STATE

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Article History
Received: 3 January 2022
Revised: 7 February 2022
Accepted: 18 February 2022
Published: 24 February 2022

Keywords:
Weekly COVID-19 confirmed pandemic cases
Information criteria
Trend analysis models
GARCH models.

JEL Classification:
C10; C50; C51; C01.

ABSTRACT

The trend analysis and GARCH model for COVID-19 pandemic spread between FCT/Lagos and the National Weekly confirmed pandemic cases were carried out using the statistical software Minitab17 and Gretl. Four models trend behavior were considered, which are linear, quadratic, cubic and quartic trends with respect to R-square value, Adjusted R-square value, Analysis of Variance (ANOVA) p-value and the estimated coefficients p-values. In addition, GARCH(0,1),GARCH(1,0) and GARCH(1,1) models were built separately for both FCT/Lagos on the Nigeria National Weekly confirmed pandemic cases; to determine which model has best fit for predicting weekly confirmed cases of COVID-19 pandemic in those areas. The four common information criteria was used to selected the best model, which are the Akaike Information Criteria (AIC), Schwarz-Bayesian Information Criteria (BIC), Hannan-Quinn Information Criteria (HQC) and Likelihood Criteria (LKH).This study established the quadratic trend and GARCH(1,0) as the best model that describes the data sets for FCT. Hence, both models can be used to forecasts the weekly pandemic confirmed cases in these areas.

Contribution/Originality: This work is one of the few that has tried to model COVID-19 weekly confirmed cases in Nigeria. The work has been able to establish that the quadratic trend with GARCH (1,0) model was the best fit model for FCT and can be used to forecast weekly cases of COVID-19 in FCT Nigeria.

1. INTRODUCTION

The emergence of the COVID-19 disease has weakened the economy of many nations, caused confusion in communities and among the people, kept even the healthy people away from their usual or normal way of life. On the 27th day of February, 2020, Nigeria recorded its first case of covid-19 according to Nigeria Center for Diseases Control on the 25th of February. Generalized Autoregressive Conditional Heteroskedasticity (GARCH) is a statistical model used in analyzing time-series data where the variance error is believed to be serially autocorrelated. GARCH models assume that the variance of the error term follows an autoregressive moving average process.

The variance of the error term in GARCH models is assumed to vary systematically, conditional on the average size of the error terms in previous periods. In other words, it has conditional heteroskedasticity, and the reason for the heteroskedasticity is that the error term is following an autoregressive moving average pattern. This means

that it is a function of an average of its own past values, like in trend analysis. Trend analysis attempts to predict future stock price movements based on recently observed trend data.

This work tries to determine the best fit model for predicting confirmed COVID-19 cases in Abuja and Lagos based on the National Weekly Confirmed cases (NWC) using GARCH Model. Furthermore, this research work seeks to establish the trend component in both Lagos and Abuja COVID-19 confirmed cases using trend analysis method. That is to show the effect of Lagos and Abuja COVID-19 confirmed cases on National Weekly Confirmed cases. The research will determine statistically, the area that contributes more to the national weekly confirmed cases.

2. REVIEW OF LITERATURE

Abdulmajeed, Adeleke, and Popoola (2020) in their article titled "Online Forecasting of covid-19 cases in Nigeria using limited data", investigated the extent of the spread and effectiveness of containment strategies to stem the transmission of the disease. The combination of Autoregressive Integrated Moving Average (ARIMA) and a Hot-Winters Exponential Smoothing models combined with Generalized Autoregressive Conditional Heteroskedasticity (GARCH) was employed. They concluded that it would be difficult to model covid-19 in the real-life scenario as inherent modeling difficulties, such as the number of tests, randomness and other factors contributed to the forecast model. Onafeso et al. (2021), conducted a research on Geographical Trend Analysis of covid-19 Pandemic onset in Africa. The method of Analysis of Variance (ANOVA) was used to show that significant variations exist among African countries in the number of covid-19 confirmed cases. Awan and Aslam (2020) predicted daily covid-19 cases in European countries using Automatic Autoregressive Integrated Moving Average (ARIMA) model. Malki et al. (2021) carried out a research on ARIMA models for predicting the end of COVID-19 pandemic and the risk of second rebound. The research work was necessary so that the questions of whether or not the virus will return can be answered. In this work, a predictive model that can estimate the expected period that the virus can be stopped and the risk of the second rebound of COVID-19 pandemic. Rauf and Oladipo (2020) did a work on Forecasting the spread of COVID-19 in Nigeria using Box-Jenkins Modeling Procedure. This study focused on the analysis of the spread of Covid-19 in Nigeria, applying statistical models and available data from the NCDC. They presented an insight into the spread of Covid-19 in Nigeria in order to establish a suitable prediction model, which can be applied as a decision-supportive tool for assigning health interventions and mitigating the spread of the Covid-19 infection. Aronu, Ekwueme, Sol-Akubude, and Okafor (2021) carried out an investigation on Coronavirus (Covid-19) in Nigeria: They examined the survival rate of Covid-19 patients in Nigeria using the Autoregressive Integrated Moving Average (ARIMA) forecasting approach. Odukoya et al. (2020), conducted a research on Epidemiological Trends of Coronavirus Disease 2019 in Nigeria: From 1 to 10,000. A secondary data collected from Nigeria Centre for Disease Control (NCDC) was used and the method of line graphs was adopted to describe the data of the daily recorded cases of covid-19 in Nigeria. They discovered that the epidemic curve in Nigeria has been on an upward trajectory as the number of cases crossed the 10,000 mark.

3. METHODOLOGY

This study design is focused on Trend Analysis and GARCH Model of Covid-19 cases between the National Weekly Confirmed cases (NWC) in Lagos and Federal Capital Territory (Abuja). The data for this study is a secondary data extracted from the website of the National Centre for Disease Control (NCDC) on the daily confirmed cases of covid-19 in Nigeria. The daily and weekly reported and confirmed cases from March 16th,2020 to May 9th,2021. The Gretl statistical software and Minitab were used for the analyses.

3.1. Model Specification

GARCH (1,1) is represented as;

$$Y_t = \mu + \varepsilon_t \quad (1)$$

where $\varepsilon_t \sim (0, \sigma_t^2)$

$$\sigma_t^2 = \omega + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2 \quad (2)$$

Equation 1 represents the GARCH model and Equation 2 presents the variance of the error at time t where,

μ is the mean.

σ_t^2 is that variance of the error at time t.

ε_{i-1}^2 is the squared error at time t-1.

Under the assumption that $\alpha+\beta<1$, $\frac{\omega}{1-\alpha-\beta}$ is the unconditional variance of Y_i.

ω constant coefficient.

α_1 is the first (lag 1) ARCH Parameter.

β_1 is the (lag 1) GARCH parameter.

Estimation of GARCH model:

The popular GARCH (1,1) model is defined by Equation 1 & 2.

For σ_t^2 to be non-negative, we require all the coefficients to be non-negative.

Using the definition $\sigma_t^2 = \varepsilon_t^2 + v_t$, we have,

$\sigma_t^2 = \omega + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2$

$\varepsilon_t^2 - v_t = \omega + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 (\varepsilon_{t-1}^2 - v_{t-1})$

$\varepsilon_t^2 = \omega + (\alpha_1 + \beta_1)\varepsilon_{t-1}^2 + v_t - \beta_1 v_{t-1}$

The GARCH model is equivalent to an infinite ARCH model.

Where $\alpha_0 \geq 0$ and $\alpha_i \geq 0$, i=1,…,q, $\beta_j \geq 0$, j=1,…p. The GARCH model built in the research are GARCH models with independent variable (the state weekly confirmed cases), given as:

GARCH (1, 1) model: $$\sigma_t^2 = \omega + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2 + \lambda_1 X_i \quad (3)$$

GARCH (1, 0) model: $$\sigma_t^2 = \omega + \beta_1 \sigma_{t-1}^2 + \lambda_1 X_i \quad (4)$$

GARCH (0, 1) model: $$\sigma_t^2 = \omega + \alpha_1 \varepsilon_{t-1}^2 + \lambda_1 X_i \quad (5)$$

Equation 3 represents GARCH (1,1) model, Equation 4 represents GARCH (1,0) model, and Equation 5 represents GARCH (0,1) model, where λ_1 is coefficient of independent variable, X_i is the independent variable and ω is the constant coefficient. Test of Heteroskedasticity and stationarity were carried out before proceeding. The approach with the Linear Model test is to use the Ordinary Least Square method to estimate the most appropriate regression equation; we run a linear regression equation to obtain the residual. The regression equation can be an autoregressive (AR) process, moving average (MA) process or a combination of AR and MA process (ARMA) depending on the adequacy of the researcher model. For example, suppose we have a return series variable y_t, we can have an AR(1) regression equation as:

$$y_t = \beta_0 + \beta_1 y_{t-1} + e_t \quad (6)$$

Equation 6 is an Autoregressive model with 1 lag.

3.1.1. Trend Analysis

Trend analysis done for the *linear trend* model:

$$Y_t = C_0 + C_1 W_t \quad (7a)$$

$$Y_t = C_0 + C_1 X_t \quad (7b)$$

Equation 7a and 7b represent the trend models for FCT and Lagos state in Nigeria, where Y is dependent variable (NNWC), W_t is independent variable for FCT Covid-19 Cases and X_t is independent variable for Lagos Covid-19 Cases.

In this model, C_i are the coefficients, representing the average change from one period to the next.

The *quadratic trend model* which can account for simple curvature in the data, is:

$$Y_t = C_0 + C_1 W_t + C_2 W_t^2 \quad (8a)$$

$$Y_t = C_0 + C_1 X_t + C_2 X_t^2 \quad (8b)$$

The *cubic trend model*

$$Y_t = C_0 + C_1 W_t + C_2 W_t^2 + C_3 W_t^3 \quad (9a)$$

$$Y_t = C_0 + C_1 X_t + C_2 X_t^2 + C_3 X_t^3 \quad (9b)$$

The *quartic trend model*

$$Y_t = C_0 + C_1 W_t + C_2 W_t^2 + C_3 W_t^3 + C_4 W_t^4 \quad (10a)$$

$$Y_t = C_0 + C_1 X_t + C_2 X_t^2 + C_3 X_t^3 + C_4 X_t^4 \quad (10b)$$

Equations 8a…10b represents the quadratic trend model, cubic trend model and quartic trend model, with C_i as the coefficients of the model, W represents FCT and X represents Lagos state.

3.1.2. Models Selection Criteria

The three selection models criteria applied were the Akaike Information Criteria (AIC), Schwarz-Bayesian Information Criteria (BIC), and Hannan-Quinn Information Criteria.

4. RESULTS

The descriptive statistics of the Covid-19 Pandemic in the Nigeria National Weekly Confirmed cases (NNWC); Lagos and Federal Capital Territory (Abuja) COVID-19 Cases in Table 1.

Table 1. Statistics of Covid-19 pandemic in the Nigeria.

Variable	Mean	SE Mean	St. Dev	Minimum	Q1	Median	Q3	Maximum	Skewness	Kurtosis
LAGOS(x)	980	142	1099	57	297	623	1281	4780	2.27	5.01
FCT (w)	335	51.4	398.5	7	71.3	148.5	449	1727	1.76	2.42
NNWC (y)	2792	353	2738	81	976	1703	3956	11179	1.55	1.89

Table 1 shows the mean of the Covid-19 Pandemic in Nigeria, where the expected value is 980 cases for Lagos area, 335 for FCT and 2792 for National Weekly Confirmed cases.

4.1. Trend Analysis

The trends of the Covid-19 Pandemic of the two densely populated areas in Nigeria against the National weekly confirmed cases were identified below in Table 2 and in the plots; Figures 1 to 8. The fitted trends are linear, quadratic, cubic and quartic (or polynomial of order four) with their R-squares.

The results in Table 2 and Figures 1-4 identified that the quadratic trend is the best trend among the trend curves to describe Covid-19 Pandemic in FCT against the National weekly confirmed cases. The R-square value indicates that the predictors explain 87.41% of the variance of the Covid-19 Pandemic. This suggests that a quadratic trend or order two polynomial is more appropriate. The quadratic trend does not appear to be overfit and has adequate predictive ability. The identified trend is:

$$Y_t = C_0 + C_1 W_t + C_2 W_t^2 = 80.25 + 11.32 W_t - (4.03 \times 10^{-3}) W_t^2$$

Table 2. Trend analysis of NNWC (y) against FCT (w).

Coefficients	Linear	Quadratic	Cubic	Quartic
β_0	818.24 (0.001**)	80.25 (0.771)	453.79 (0.171)	146.93 (0.724)
β_1	5.89 (0.000**)	11.32 (0.000)**	7.03 (0.007)**	12.49 (0.020)**
β_2		-4.03×10^{-3}(0.000)**	3.70×10^{-3}(0.361)	-1.48×10^{-2}(0.356)
β_3			-3.37×10^{-6}(0.053)	1.56×10^{-5} (0.331)
β_4				-5.82×10^{-09} (0.235)
R^2	73.4%	87.41%	81.1%	81.6%
$\overline{R}^2$	72.9%	85.90%	80.1%	80.3%
Analysis of Variance	Source P-Value Regression 0.000** FCT (w) 0.000**	Source P-Value Regression 0.000** FCT (w) 0.000** w^2 0.000**	Source P-Value Regression 0.000** FCT (w) 0.007** w^2 0.361 w^3 0.053	Source P-Value Regression 0.000** FCT (w) 0.020** w^2 0.356 w^3 0.331 w^4 0.235

Note: ** significant at 5% level of significance.

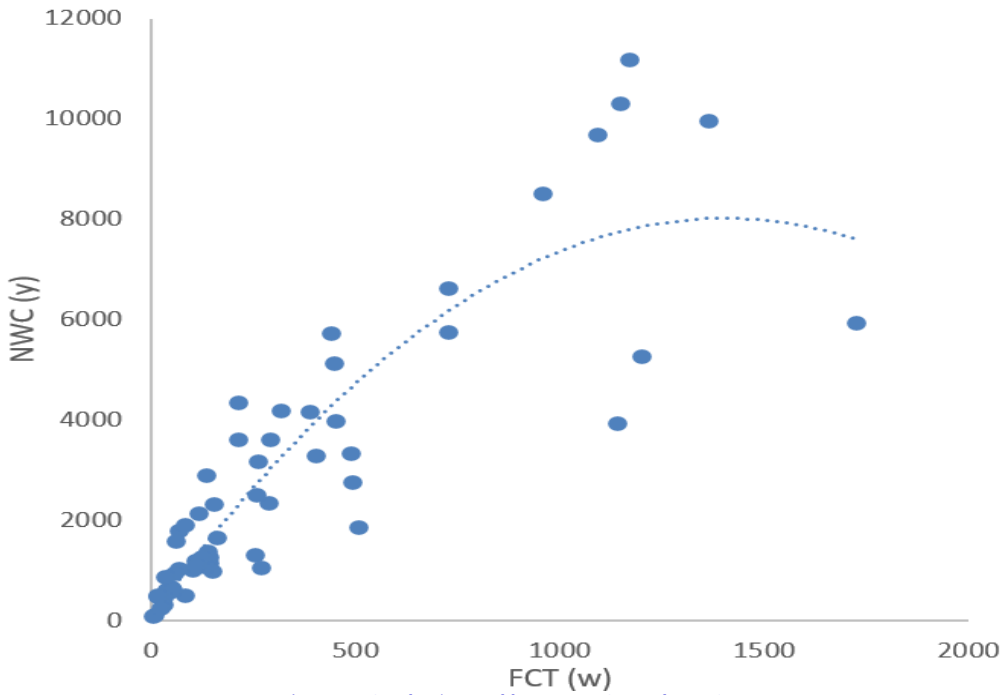

Figure 1. Quadratic trend between FCT and NWC.

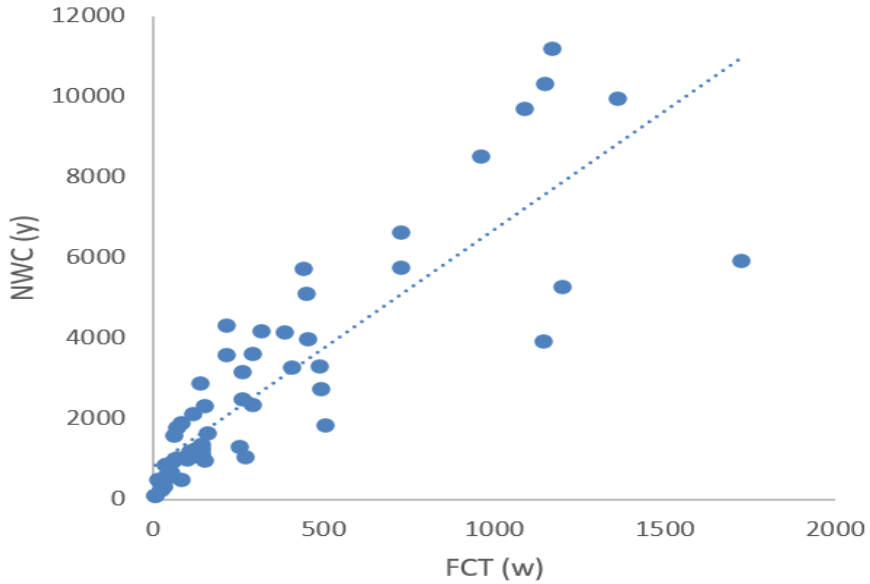

Figure 2. Linear trend between FCT and NWC.

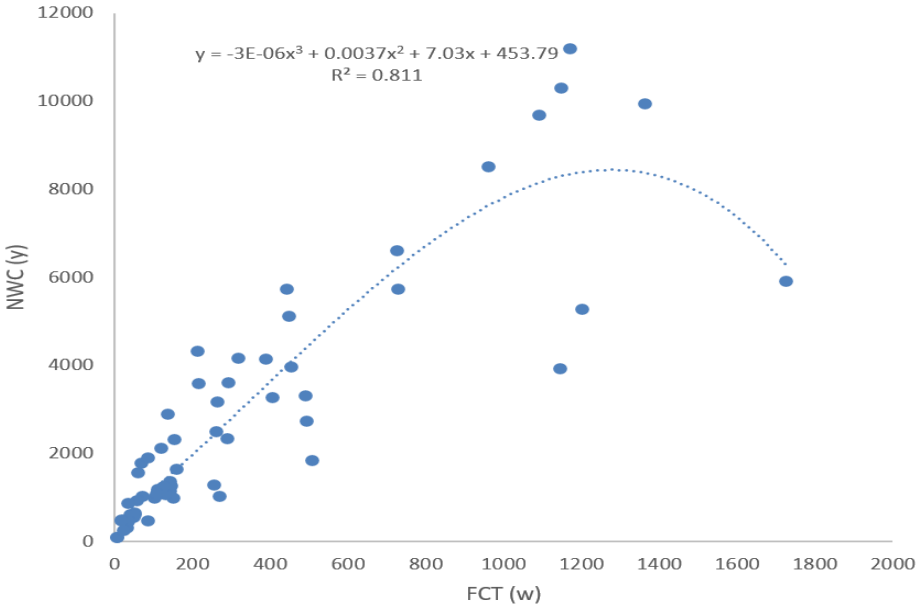

Figure 3. Cubic trend between FCT and NWC.

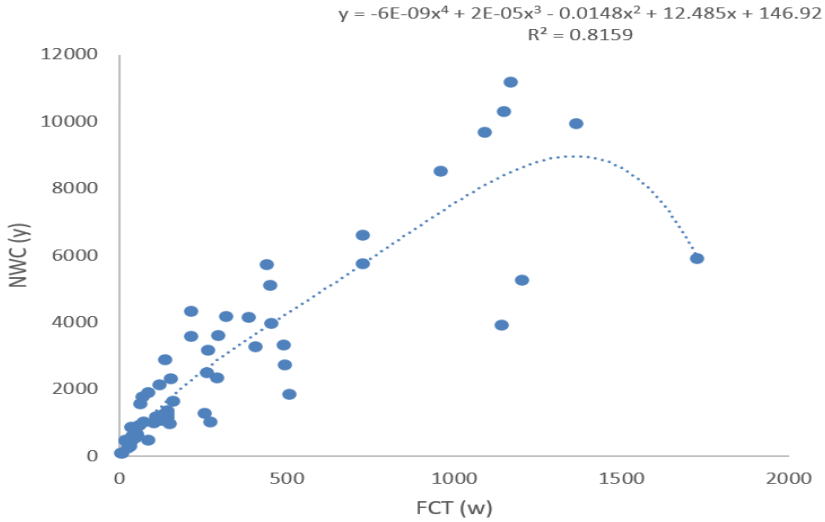

Figure 4. Quartic trend between FCT and NWC.

Table 3. Trend analysis of NNWC (y) against LAGOS (w).

Coefficients	Linear	Quadratic	Cubic	Quartic
β_0	482.51(0.003)**	-181.48(0.352)	-63.19(0.810)	-86.91(0.80)
β_1	2.356(0.000)**	3.713(0.000)**	3.263(0.000)**	3.38(0.011)**
β_2		-3.10×10^{-4}(0.000)**	1.41×10^{-5}(0.977)	-1.3×10^{-4}(0.925)
β_3			-5.123×10^{-8}(0.503)	2.49×10^{-8}(0.996)
β_4				-6.248×10^{-12}(0.911)
R^2	89.5%	92.5%	92.5%	92.5%
$\overline{R}^2$	89.4%	92.2%	92.1%	92.0%
Analysis of Variance	Source P-Value Regression 0.000** LAGOS x 0.000**	Source P-Value Regression 0.000** LAGOS x 0.000** x^2 0.000**	Source P-Value Regression 0.000** LAGOS x 0.000** x^2 0.977 x^3 0.503	Source P-Value Regression 0.000** LAGOS x 0.011** x^2 0.925 x^3 0.996 x^4 0.911

Note: ** significant at 5% level of significance.

The results in Table 3 and Figures 5 – 8 identified that the quadratic trend is the best trend among the trend curves to describe Covid-19 Pandemic in LAGOS against the National weekly confirmed cases. The R-square value indicates that the predictors explain 92.5% of the variance of the Covid-19 Pandemic. This suggests that a quadratic trend is more appropriate. The quadratic trend does not appear to be over fit and has adequate predictive ability.

The identified trend is: $Y_t = C_0 + C_1 X_t + C_2 X_t^2 = -181. + 3.713 X_t - (3.10\times10^{-4}) X_t^2$

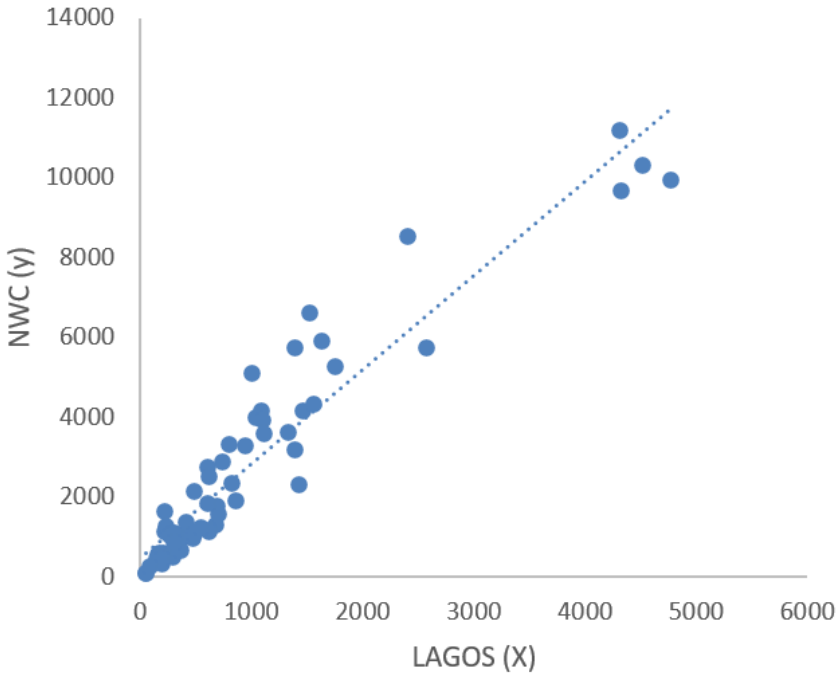

Figure 5. Linear trend between Lagos and NWC.

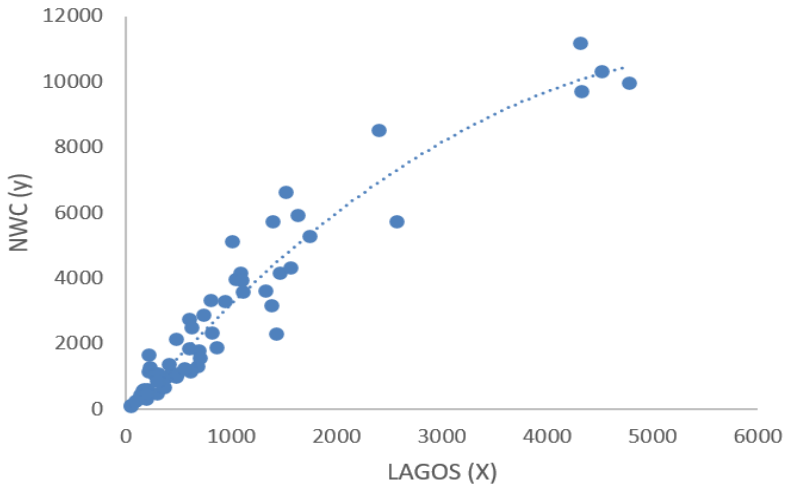

Figure 6. Quadratic trend between Lagos and NWC.

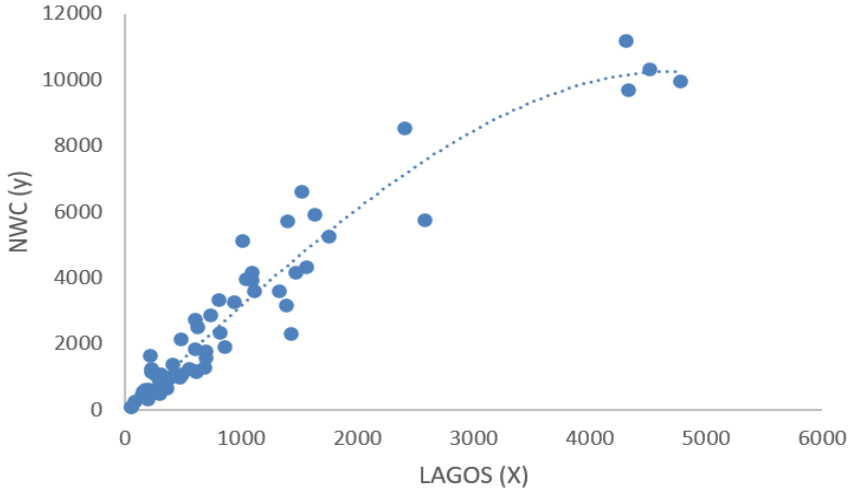

Figure 7. Cubic trend between Lagos and NWC.

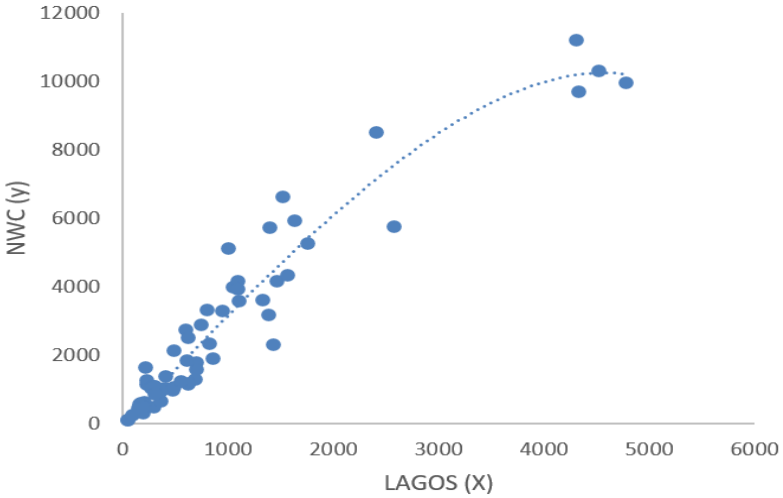

Figure 8. Quartic trend between Lagos and NWC.

4.2. GARCH Model

Three GARCH models were built to the COVID 19 pandemic FCT and Lagos against the Nigeria National weekly confirmed case, which are ARCH(1) or GARCH(0,1); GARCH(1,0) and GARCH(1,1). The summarized result is in Table 4.

Table 4. GARCH (p,q) models parameter estimate and selection criteria values for FCT against the national weekly confirmed case.

Variable	Model	Parameter Estimate (p-values)	Selection Criteria	Remark Suitable Model
FCT (∇w_t)	GARCH (1,1) With constant	$\hat{\mu}$=347.413(0.00251**) α_0=123014(0.06893*) α_1=0.758674(0.00453**) β_2=0.241326(0.11860)	AIC=999.2664 HQC=1004.182 LKH=493.6532 SCW=1011.832	Not suitable
FCT (∇w_t)	GARCH (0,1) With constant	$\hat{\mu}$=312.973(0.00868**) α_0 =300765(0.00840**) α_1=1(0.00430**)	AIC=999.7568 HQC=1003.853 LKH=-494.8784 SCW=1010.229	GARCH (0,1) is Most suitable
FCT (∇w_t)	GARCH (1,0) With constant	$\hat{\mu}$=347.413(0.00251**) α_0= 123014(0.06893**) α_1= 0.758674(0.00453**) β_2=0.241326(0.11860)	AIC=999.2664 HQC=1004.182 LKH=-493.6332 SCW=1011.832	Not suitable

Note: **-Sig. at 5%; *-Sig. at 10%.

From the Table 4, the identified GARCH model is GARCH (0,1), since all its parameters are significant at 5% and 10% also two of its model selection criteria are smaller than the other two GARCH models.

Table 5. GARCH (p,q) Models parameter estimate and selection criteria values for LAGOS against the national weekly confirmed case.

Variable	Model	Parameter Estimate (p-values)	Selection Criteria	Remark Suitable Model
Lagos (∇w_t)	GARCH (1,1) With constant	$\hat{\mu}$=58.0152(0.45922) α_0= 77236.5(0.18789) α_1= 0.783045(0.03635**) β_1=0.216955(0.14515)	AIC=971.7802 HAQ=976.6955 LKH=-479.8901 SCW=984.3463	Not Suitable
Lagos (∇w_t)	GARCH (0,1)	–	–	Not Suitable
Lagos (∇w_t)	GARCH (1,0) Without constant	$\hat{\mu}$=NILL α_0= 65622.2(0.00001**) α_1= 0.77876(0.01017**) β_1 =0.22124(0.09431*)	AIC=970.7934 HAQ=974.8894 LKH=-480.3967 SCW=981.2651	GARCH (1,0) Without constant is most suitable

Note: **-Sig. at 5%; *-Sig. at 10%;

From the Table 5, the identified GARCH model is GARCH (1,0), since all its parameters are significant at 5% and 10% and all its model selection criteria are smaller better than the other GARCH model.

4.2.1. Comparison of the Identified GARCH Model of the Two AREA

We compare the two identified GARCH model in the two areas to determine the model that has more effect on National weekly confirmed cases in Table 6.

Table 6. GARCH (p,q) models parameter estimate and selection criteria values between FCT/LAGOS against the national weekly confirmed cases.

Variable	Model	Parameter Estimate (p-values)	Selection Criteria	Remark
FCT(∇w_t)	GARCH(0,1) with constant	$\hat{\mu}$=312.973(0.00868**) α_0 =300765(0.00840**) α_1=1(0.00430**)	AIC=999.7568 HQC=1003.853 LKH=-494.8784 SCW=1010.229	Not suitable
LAGOS(∇x_t)	GARCH(1,0) without constant	$\hat{\mu}$=NILL α_0= 65622.2(0.00001**) α_1= 0.77876(0.01017**) β_1 =0.22124(0.09431*)	AIC=970.7934 HQC=974.8894 LKH=-480.3967 SCW=981.2651	GARCH(1,0) Is more suitable

Note: **-Sig. at 5%; *-Sig. at 10%.

Table 6 show that GARCH model with the highest effect on Nigeria National weekly confirmed cases is GARCH (1,0) for LAGOS, since all its parameters are significant at 5% and 10% and all its model selection criteria are smaller better than of FCT GARCH model (GARCH (0,1).

5. SUMMARY AND CONCLUSION

The trend analysis and GARCH model on covid-19 pandemic spread between FCT/Lagos and the National Weekly confirmed pandemic cases were carried out using the Minitab17 software and Gretl. The Figures 1 to 8 show the linear, quadratic, cubic and quartic trends for both FCT and Lagos, Tables 2 to 4 show the analysis of the GARCH models. However, this study has established the quadratic trend and the Lagos GARCH (1,0) as the best model that describes the data. GARCH (0,1), GARCH (1,0) and GARCH (1,1) were built separately for both FCT and Lagos to determine which one was best for the weekly reported cases of covid-19 pandemic in those areas. GARCH (0,1) was identified as the best of the three (3) models built for FCT weekly confirmed cases. While GARCH (1,0) was identified for Lagos weekly pandemic confirmed cases. Comparing the two models; GARCH(0,1) of FCT and GARCH(1,0) of Lagos, considering the model selection criteria (AIB,BIC,HQC and LKH)and parameter estimates (p-values), GARCH (1,0) was found to be better. This implies that the effects of the number of pandemic cases confirmed will be more on Lagos.

Funding: This study received no specific financial support.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study.

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