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THE ROLE OF HUMAN POPULATION DENSITY AND THE ELEMENTS OF WEATHER IN THE SPREAD OF COVID-19 IN NIGERIA: A NEGATIVE BINOMIAL REGRESSION MODEL APPROACH

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. Author UIN did the conceptualization, validation, investigation, writing- original draft preparation. Author CPO did the conceptualization, methodology, software, writing- original draft preparation. Author DCB did the methodology, formal analysis, writing- original draft preparation. Author HCI did the visualization, data curation, writing- review and editing. Author MJ did the validation, methodology, investigation, writing- original draft preparation. All authors read and approved the final manuscript.

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ABSTRACT

This novel study was undertaken to determine the role of human population density and the elements of weather, namely temperature, rainfall and humidity in the spread of Coronavirus 2019 in Nigeria. Secondary data from Nigerian Center for Disease and Control and Climate-data were used. The number of confirmed COVID-19 cases, which is the dependent variable is a non-negative discrete random variable. This suggested the use of the Poisson regression and the negative binomial regression to model the counts as a function of the covariates. The best distribution and regression model were chosen based on the Chi-square goodness of fit, Bayesian Information Criteria, Akaike Information Criteria, and the ability of the data to satisfy the assumptions of the models. The negative binomial regression model was identified as the best model that fits the data since the dependent variable is over dispersed and follows a negative binomial distribution. The result revealed that temperature and human population density are statistically significant at 5% level of significance in explaining the variations in the number of COVID-19 confirmed cases in Nigeria. The sign and value of the exponent of the regression parameters showed that a unit increase in temperature decreases the number of COVID-19 confirmed cases in Nigeria by 30.1% and increases it by 0.1% in a unit increase of the human population density. This implies that incidence of COVID-19 is reduced by increasing the temperature but increased, in larger gatherings. We found that the COVID-19 virus would not spread quickly in a hot environment; it prefers a cold environment to be able to infect densely populated areas.

Keywords: COVID-19; elements of weather; negative binomial regression; poisson regression; population density.

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1. INTRODUCTION

In the early 2000s, when Nigeria was dealing with the issues of high level of insurgency in various sections of the country, a heavy blow from Ebola pandemic occurred, but with the activeness of the health sector, that quickly put to stop the spread and by October of 2014, the country had been proclaimed Ebola-free [1]. While the country was searching for solutions to achieve the country's development goals in the face of persistent and widely publicized series killings, herdsmen-farmers' clashes and communal disputes; Lassa fever came up. Right now, the country is engaged in a huge battle to save lives against the mysterious coronavirus (COVID-19), which has affected the economy of most countries. Coronavirus is derived from the Latin word corona, which means crown. They are called coronavirus in biology because they have crown-like spikey projections on their surface [2]. Coronavirus belongs to the genus beta coronavirus and are responsible for pneumonia, fever, breathing difficulties, and lung infection [3,4]. COVID-19 illness is caused by SARS-COVID-19 (Severe Acute Respiratory Syndrome Coronavirus 2) virus [5].

Briefly, COVID-19 was discovered for the first time on the December 29, 2019 in Wuhan, Hubei Province, China [4,6] and was reported officially by World Health Organization on the December 31, 2019 [7] and was declared a pandemic in March 2020 [4]. The COVID-19 is thought to have spread due to a number of circumstances, including close contact with infected patients, lack of awareness, and touching the nose, eyes and mouth with hands that are infected [5]. The common symptoms of this virus appear within 14 days, but its mean incubation period is between 5-6 days. Although the pandemic started in China, the disease has spread all over the world [4].

COVID-19 did not originate from Nigeria, but due to the connections between Nigeria and Italy through business transaction it was said to have infiltrated Nigeria via an Italian citizen [8]. On March 9, 2020, the first COVID-19 illness case in Nigeria was recorded and it was an Italian man in Lagos, Nigeria. The next case was a Nigerian, and it was recorded on March 9, 2020.

The first instance of COVID-19 in Nigeria was also the first in Sub-Saharan Africa [9]. The numbers of those infected by the virus grew rapidly with advancing time. Due to the massive increase in the number of confirmed cases, there was a lockdown in Nigeria, to restrict the spread of the virus. From March 25, 2020, the government implemented total or partial lockdowns on human activities. Over the first three months, the nature and intensity of these lockdowns imposition varied in the different States in Nigeria. Lockdowns were in place in many States for three to four days a week. The pathological impact of the virus and the lockdown affected the economy severely [10]. There was a hike in the prices of goods and part of the price increase in regional marketplaces was due to delay in delivery. In fact, goods were not arriving as planned.

The world has been adversely affected by COVID-19 since its emergence. Economically and socially, no country was spared. Given the virus's unavoidable propagation, researchers have been working to identify the elements that prevent it from spreading with the intention of making useful recommendations. Many original studies on COVID-19 have investigated clinical and public health factors that affect rate of COVID-19 infection and morbidity. Many epidemic and mathematical modeling approaches have been used in further studies of COVID-19 disease. Proper evaluation of existing studies has necessitated the incorporation of human population density and weather parameters in epidemic modeling of COVID-19 transmission. This aspect of COVID-19 investigations is necessary because the role of human population density and weather parameters have largely been untested in a practical manner.

In the present study, we considered factors of global importance, namely human population density, temperature, rainfall and humidity and their effects on the spread of COVID- 19 in the different States in Nigeria. Population density is the number of people living in an area per square kilometer. Temperature is the amount of heat and cold within an area. Rainfall is the result of atmospheric water vapor condensing and falling due to the gravitational pull of clouds whereas humidity is the presence of water vapor in the atmosphere. Notably, different Governmental and non-governmental organizations and citizens in different parts of the world have presented controversial opinions on the influence of environmental factors on the spread of COVID-19 infection [4]. Information on a disease pandemic as serious as COVID-19 should not be hinged on assumptions. This provided part of the rationale to undertake the present study with hope of practical outcomes.

The outcomes are expected to provide clues on where efforts should focus in combating the virus. The findings of the current study will be particularly useful to the Nigerian COVID-19 Presidential Task Force (PTF) in advising the presidency on the virus's next course of action. More importantly, the current study's findings would provide accurate advice on the risks involved with visiting any State in Nigeria. Findings will also provide comprehensive and enhanced knowledge of the COVID-19 in Nigeria and other countries of the world.

Shima et al. [11] studied the relationship between connectivity and density to the spread of COVID-19 pandemic. According to them, density causes residents to be closer and interact more, making them a potential hotspot for the rapid spread of new illness. Dense areas, on the other hand, are more likely to adhere to measures put in place, such as social distance, lowering the likelihood of infection. The most significant predictors of infection rates were found to be metropolitan population, with larger areas seeing greater infection rates. After controlling the metropolitan population, researchers discovered that there was no link between density and infection rates, probably due to adherence to social distance in dense areas as well as improved health care. These findings suggested that in the transmission of the COVID-19 pandemic, connection is more important than density. This agrees with the findings of Carol [12] that the risk of disease transmission is higher for those who live in close quarters.

Several researches have probed the relationship between the density of territory and the current epidemic, with the majority of them concluding that the relationship is positive [13]. Some studies assume that population density is unimportant and that it cannot be a decisive factor in the spread of COVID-19. Cities such as Seoul, Singapore, New York, and Shanghai were cited as counter examples because of their high population densities and the number of COVID-19 infections they produce is comparable to that of low-density cities. Furthermore, the findings of an empirical investigation conducted in China do not support the opinion that density is a primary driver of the probability of COVID-19 transmission. It was also said that cities with a population density of between 5000 and 10,000 people per square kilometer are the most affected [14]. Similarly, a research of the United States of America (USA) and European countries discovered that population density had a tiny but significant effect on the rate of COVID-19 spread [15]. According to data from Japan, population density was more important than any weather component [16].

A seasonal cyclic repeat has been detected in viral respiratory infections, according to research. During the winter and colder seasons, viral respiratory infections are more common. In temperate locations, for example, influenza outbreaks occur every winter [17]. In addition, a research in China based on SARS outbreaks in Hong Kong, Guangzhou, Beijing, and Taiyuan found that the outbreaks were linked to temperature differences. Temperature and humidity were found to be positively related to the rate of viral transmission. Variations in temperature were also discovered to have an indisputable effect on the virus's mortality rates [18]. Given the lack of a link between COVID-19 distribution and atmospheric temperatures ranging from 26.00 1.66°C to 33.38 1.43°C, Wang et al. [19] concluded that greater temperatures (and may be, high humidity) may have a more significant negative influence on disease transmission., despite being distressing or uncomfortable. Another study found that in China, there is a negative relationship between temperature and COVID-19 transmission, but no link between humidity and the disease [20]. In addition, a study in Jakarta, Indonesia, found a link between COVID-19 transmission and temperature, but no link between humidity and the disease [21]. A large-scale study that looked at data from 21 nations, including France, Germany, Italy, Spain, Iran, Malaysia, the United Kingdom, Australia, and the USA, discovered that raising the temperature reduced the disease's early spread [22]. Research on COVID-19 in 224 Chinese cities discovered no link between disease incidence and humidity or temperature, although mortality had a link between COVID-19 humidity and temperature in Wuhan [23].

2. METHODS

The data used for the study are secondary data and were retrieved from sources indicated as follow: The total number of confirmed COVID-19 cases for each State in Nigeria including the FCT (Federal Capital Territory) were retrieved from a situation report published by NCDC (The Nigeria Centre for Disease Control) on the 23rd of April 2021. The data on the humidity, rainfall, and temperature were retrieved from en.climate-data.org. R statistical programming language was employed in data analysis.

In 2006, the National Population Commission conducted the country's last population census. Researchers and other government organizations have depended on Nigeria's projected population since then, employing various models to calculate the predicted population for each year. In this study, the National Bureau of Statistics' exponential model (equation 1) was used.

$$\text{Predicted population} = ae^{rt} \quad (1)$$

where,

a is the population of each State in 2006, including the FCT, according to the 2006 census
r is an annual population growth rate that is fixed
t is the number of years from 2006
e is the exponential constant.

The population density was obtained using the projected population and land mass area of each States including FCT as shown in equation (2).

$$\text{Population density} = \frac{\text{Projected Population}}{\text{Land Mass Area}} \quad (2)$$

Counts are non-negative integers. They represent the number of occurrence of an event within a fixed period. The number of confirmed COVID-19 cases, which is our dependent variable is a non-negative discrete random variable (not taking decimal) making it a count data. For this type of data, the PR (Poisson Regression) and NBR (Negative Binomial Regression) is often used to model the counts as a function of covariates.

2.1 The PR Model

The PR model is a generalized linear model that is used to model the relationship between a count data response variable and a set of explanatory variables. The mean of the response variable is the same as the variance. A random variable of the number of times an event occurs within a specified time period follows a Poisson distribution. The random variable is non negative and the sum of the probabilities of the values of the random variable is unity. Supposed Z is the random variable of the number of COVID-19 confirmed cases with a known mean α, where $\alpha > 0$; the probability mass function of the random variable Z is given by:

$$p(z;\alpha) = \begin{cases} \frac{e^{-\alpha}\alpha^{z}}{z!} \; ; & z = 0,1,...; \; \alpha > 0 \\ 0 & otherwise \end{cases} \quad (3)$$

The mean and variance of the distribution is α

There is over dispersion in the Poisson regression model if the variance is higher than the mean. The Poisson regression model assumes that the logarithm of the expectation of an observation of a response variable that follows a Poisson distribution can be modeled by a linear combination of the explanatory variables. The Poisson regression for an observation i is given as:

$$\log(\alpha_i) = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + ... + \beta_n x_{in} \quad (4)$$

$i = 1, 2, ..., v \quad ; \quad v$ *is the number of observations in the data*

$Y \sim$ *Poisson with parameter* α

where

α_i is the expectation and variance of Y_i

β_j are the regression coefficients

x_{ij} are the explanatory variables

$j = 1, 2, ..., n$

Taking the exponent of equation (4), we have:

$$\alpha_i = \exp(\beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + ... + \beta_n x_{in}) \quad (5)$$

The exponent of the regression coefficient $\exp(\beta_j)$ gives us the multiplicative effect of the jth explanatory variable on the mean. A one-unit increase in x_j multiplies the mean by a factor $\exp(\beta_j)$. The coefficients of the Poisson regression model are estimated using the maximum likelihood estimation technique.

2.2 The PR Model Assumptions

The PR model depends on some assumptions for it to yield efficient estimate of the regression coefficients. The assumptions are given below:

1. The dependent variable must be a count data
2. There must be equal dispersion, this implies that the mean must be equal to the variance.
3. The response or dependent variable must follow a Poisson distribution.
4. The observations should be independent of each other. This means that an observation cannot tell you anything about another one in the dataset.

2.3 The NBR Model

The NBR is also a generalized linear model that is used to model the relationship between a count data response variable and a set of explanatory variables. The NBR model gives allowance for over dispersion. It does not have the assumption of equality of the mean and variance like the PR model and is usually used when there is over dispersion in the count response variable. There is over dispersion when the variance is more than the mean of the count response variable while there is under dispersion when the variance is less than the mean of the count response variable. Most real life count data are over dispersed.

The probability mass function of the negative binomial distribution is given as:

$$P(z) = \begin{cases} \binom{z+d-1}{d-1}(1-\theta)^z \theta^d & z = 0,1,\ldots;\ 0 \le \theta \le 1;\ d \le z \\ 0 & otherwise \end{cases} \tag{6}$$

The NBR model assumes that the logarithm of the expectation of an observation of a response variable that follows a negative binomial distribution can be modeled by a linear combination of the explanatory variables. The NBR for an observation i is given as:

$$\log(Y_i) = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_n x_{in}$$

Where Y_i, is the number of confirmed COVID 19 cases (7)

$$E(Y_i) = \mu_i = \frac{d_i\theta}{1-d_i} \quad \Rightarrow \quad d_i = \frac{\mu_i}{\mu_i + \theta} \tag{8}$$

where

μ_i is the expectation of Y_i

Y_i ~ Negative binomial distribution with parameters d and θ

β_j are the regression coefficients

x_{ij} are the explanatory variables

Taking the exponent of equation (7), we have:

$$Y_i = \exp\left(\beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_n x_{in}\right) \tag{9}$$

The exponent of the regression coefficient $\exp(\beta_j)$ gives us the multiplicative effect of the $j-th$ explanatory variable on the mean. A one-unit increase in x_j multiplies the mean by a factor $\exp(\beta_j)$.

The coefficients of the NBR model are estimated using the maximum likelihood estimation technique.

2.4 The NBR Model Assumptions

The NBR model depends on some assumptions just like the Poisson regression model for it to yield efficient estimate of the regression coefficients. The assumptions are given below:

1. The dependent variable must be a count data
2. The negative binomial regression allows the variance to be greater than the mean.
3. There is independence of observation; i.e. one observation cannot provide any information on another observation.
4. The response or dependent variable must follow a negative binomial distribution.

2.5 Model Selection Criteria

The Chi-square goodness of fit test was used to test the hypothesis that the count data follow a Poisson and a negative binomial distribution. A significant Chi-square test at 0.01 level of significance means that the data do not follow the distribution that was tested. Furthermore, the AIC (Akaike Information Criteria) and BIC (Bayesian Information Criteria) were used to know the best distribution between the Poisson and the negative binomial distribution. The model with the least AIC and BIC is chosen as the best fit for the count response variable.

The AIC's goal is to find the model with the least negative likelihood, as measured by the number of parameters. The AIC is expressed as:

$$AIC = 2k - 2\ln L \tag{10}$$

where L is the likelihood function under the fitted model and k is the number of model parameters.

The BIC is used to obtain the most probable model given the data. The BIC is expressed as:

$$BIC = k\ln(n) - 2\ln L \tag{11}$$

where n is the sample size.

The Pearson Chi-square was also used to test for the goodness of fit of the models. The Pearson Chi-square value is divided by the degree of freedom to give us a constant p that will be used to know if there is equal dispersion, over dispersion or under dispersion.

$$p = \frac{Pearson\ Chi-square}{df} \tag{12}$$

If $p = 1$; there is equal dispersion
$p > 1$; there is over dispersion
$p < 1$; there is under dispersion.

2.6 Significance of the Model

The likelihood ratio Chi-square test is used to test for the significance of the regression model. The likelihood ratio test compares the fitted model with the independent variables and the model with only the intercept and test if they are the same or not. A significant test means that the addition of the explanatory variables collectively improved the model and is suitable to model the dependent variable.

2.7 Significance of Each of the Explanatory Variables

The Wald Chi-square test is used to test for the significance of each of the explanatory variables used in this study. A significant test for any of the explanatory variables means that the explanatory variable is significant in predicting the dependent variable.

3. RESULTS

The projected population and population density were obtained using equations (1) and (2), respectively. The choice of the model for this research work was determined using the dependent variable which are count data and are nonnegative. Two generalized linear models that can be fitted on count data are the PR model and the NBR model. The link function for both models is the Log link function. The assumptions of the PR model are tested to know if the data are suitable for the model or not, and if not, the NBR model will be used and also compared to the PR model.

The variance of the dependent variable (9789.97^2) in Table 1 is greater than the mean (4445.62). This failed to satisfy the assumption of equality of variance and mean in the Poisson model. The data are over dispersed. The expected frequency used to calculate the Chi-square test statistic for all the groups in Table 2 are all less than 5 except group "2576 – 4647" and they cannot be combined to get a number greater than 5. This is also a problem in the data being Poisson distributed as the reported P-value of 0.00 may be incorrect. The Chi-square value (3387.311) in Table 3 also confirmed that the Poisson regression model did not fit the data. The data are over dispersed since the Chi-square value is greater than 1.

The PR model cannot be used to model the data as the data failed to satisfy the assumptions of the model.

The NBR model will be used since it does not assume that the variance must be equal to the mean of the dependent variable and it has an extra parameter (dispersion parameter) that makes it possible to model over dispersed data. Two of the expected frequencies in Table 4 for the test of the dependent variable being Negative binomial distributed are greater than 5, and the remaining four groups can be merged into two groups to get numbers for the two groups greater than 5. The P-value of the Chi-square statistic (0.04) in Table 5 is greater than 0.01, which means that the null hypothesis (which states that the dependent variable follows a Negative binomial distribution) will not be rejected at 0.01 level of significance. The AIC and BIC of the Negative binomial distribution were less than and better than the Poisson distribution, this proves that the dependent variable follows a Negative binomial distribution instead of the Poisson distribution. The Chi-square value (1.041) in Table 6 also confirmed that the NBR model fit the data.

Table 1. Descriptive statistics

		N	Minimum	Maximum	Mean	Std. Deviation
Dependent Variable	COVID-19	37	5.00	58209.00	4445.62	9789.97
Covariate	Humidity (%)	37	.36	.86	.63	.18
	Pop	37	63.22	4264.40	475.68	705.67
	Rainfall (mm)	37	33.17	257.67	116.02	67.39
	Temp (^{o}C)	37	21.91	29.35	26.50	1.36

Table 2. The observed and expected frequency for the PR model

COVID-19 confirmed cases	Observation frequency	Poisson expected frequency
<=450	5	0.00
451 – 910	5	0.00
911 – 1547	5	0.00
1548 – 2030	5	0.00
2031 – 2575	5	0.00
2576 – 4647	5	36.95
> 4647	7	0.05

Table 3. Goodness of fit for the PR model

	Value	Df	Value/df
Deviance	81672.102	32	2552.253
Pearson Chi-square	108393.950	32	3387.311

Table 4. The observed and expected frequency for the NBR model

COVID-19 confirmed cases	Observed frequency	Negative binomial expected frequency
<=450	5	6.84
451 – 910	5	3.69
911 – 1547	5	3.82
1548 – 2030	5	2.33
2031 – 2575	5	2.23
2576 – 4647	5	6.06
> 4647	7	12.04

Table 5. Comparison of the Negative binomial and the Poisson distribution for the dependent variable

	Negative binomial	Poisson
Chi-square statistic	10.14	
Chi-square P-value	0.04	0.00
AIC	694.2	322554.3
BIC	697.4	322555.9

Table 6. Goodness of fit for the NBR model

	Value	df	Value/df
Deviance	33.254	32	1.039
Pearson Chi-square	33.296	32	1.041
Log Likelihood	-329.728		
AIC	669.457		
BIC	677.512		

The likelihood ratio Chi-square test in Table 7 that compares if the fitted model with the independent variables is the same as the model with only the intercept was significant (P-value (0.00) < 0.01). The addition of the explanatory variables collectively improved the model and is suitable to model the number of COVID-19 confirmed cases in each State of the country.

Table 7. Likelihood ratio test

Likelihood Ratio Chi-square	Df	Sig.
36.127	4	.000

The test for the significance of the independent variables is given in Table 8. Only the population density and temperature variables have a significant effect in modeling the COVID-19 confirmed cases in each State. The amount of rainfall and humidity have no significant effect in determining the number of COVID-19 confirmed cases in each State in Nigeria.

Table 8. Test of the significance of the independent variables

Source	Type III		
	Wald Chi-square	Df	Sig.
(Intercept)	17.742	1	.000
Humidity	.390	1	.532
Population	9.066	1	.003
Rainfall	.287	1	.592
Temperature	6.667	1	.010

The analysis was repeated and the non-significant variables – rainfall and humidity – removed. The Chi-square value (1.041) in Table 9 confirmed that the new Negative binomial regression model with only two independent variables also fit the data. The model with only two independent variables have a lesser AIC (665.859) and BIC (670.692) than the model with all the independent variables (AIC = 669.457 and BIC = 677.512 from Table 6).

Table 9. Goodness of fit for the NBR model

	Value	df	Value/df
Deviance	33.656	34	.990
Pearson Chi-square	31.494	34	.926
Log Likelihood	-329.929		
AIC	665.859		
BIC	670.692		

The likelihood ratio Chi-square test in Table 10 that compares if the fitted model with the independent variables is the same as the model with only the intercept was significant (P-value (0.00) < 0.01). The addition of only two of the significant explanatory variables collectively improved the model and is suitable to model the number of COVID-19 confirmed cases in each State.

Table 10. Likelihood ratio test

Likelihood Ratio Chi-square	df	Sig.
35.725	2	.000

The test for the significance of the independent variables is given in Table 11. The population density and temperature variables have a significant effect in modeling the COVID-19 confirmed cases in each State. The estimate of the regression coefficients (β) and the exponent of the regression coefficients (e^{β}) are given in Table 12.

Table 11. Test of the significance of the independent variables

Source	Type III		
	Wald Chi-square	Df	Sig.
(Intercept)	24.469	1	.000
Population	11.456	1	.001
Temperature	7.755	1	.005

Table 12. The estimate of the coefficients of the NBR model

Parameter	B	Std. Error	Exp(B)
(Intercept)	17.102	3.4574	26758322.131
Population	.001	.0002	1.001
Temperature	-.362	.1299	.697
(Scale)	1		
(Negative binomial)	1		

There is 0.1% increase in the incident rate of COVID-19 confirmed cases for every unit increase in the human population density. Also, there is a 30.3% $[(1-0.697)\times 100]$ decrease in the incident rate of COVID-19 confirmed cases for every unit increase in temperature. The Nigerian States with higher temperature will have a lesser reported COVID-19 confirmed cases while the States with higher population density will have a higher reported COVID-19 confirmed cases. The COVID-19 virus would not spread quickly in a hot environment; it prefers a cold environment to be able to infect more people.

4. DISCUSSION

A novel finding of this study is that rainfall and humidity have no relationship with the COVID-19 confirmed cases. Population density was found to have a positive effect but temperature was found to have a negative effect on the number of COVID-19 confirmed cases. The finding on population density is in agreement with Shima et al. [11], Carol [12], Fang and Wahba [14] and Babbit et al. [15] but disagrees with the findings of Diao et al. [16] and Ma et al. [23] on temperature since according to the findings of this research, temperature constituted 30.1% which is higher than 0.1% by population density. The findings of this work on temperature are in agreement with the findings of Tosepu et al. [21] and Demongeot et al. [22] since there is an established link between temperature and number of COVID-19 confirmed cases. Therefore, it is not surprising to emphasize that there are debatable reports in literature on the environmental conditions that affect the spread of COVID-19. However, the methods applied, and findings of the present study are supported by literature [24,25,26] and [27].

5. CONCLUSION

The secondary data used for the purpose of this study have the dependent variable as the number of COVID-19 confirmed cases and the independent variables as population density, humidity, temperature and rainfall. The idea was to build a model that can predict the dependent variable as a linear combination of some values of the independent variables. However, since for some fixed values of the independent variables; the dependent variable was not normally distributed and is a count data, then linear regression was inappropriate. Therefore, the two most suitable regression models for count data – PR and NBR models – were fitted on the data. The Negative binomial distribution best modeled the number of COVID-19 confirmed cases following the Chi-square goodness of fit and it showed least BIC and AIC values when compared to Poisson distribution. Again, the dependent variable had an over dispersion and the PR model assumes equal dispersion while the NBR overlooks this assumption. So, the NBR was used to model the number of COVID-19 confirmed cases using the independent variables.

The NBR model showed that only two of the independent variables are statistically significant at 5% level of significance in explaining the variations in the number of COVID-19 confirmed cases in each Nigerian States. The independent variables are temperature and population density. The likelihood ratio test revealed that modeling the number of COVID-19 confirmed cases with temperature and population density as independent variable is better than with the intercept only model (p-value = 0.000 is less than alpha = 0.05). The signs and the exponent of the regression parameter values indicate that there is 0.1% increase in the incident rate of COVID-19 confirmed cases for every unit increase in the human population density with 30.3% $[(1-0.697)\times 100]$ decrease in the incident rate of COVID-19 confirmed cases for every unit increase in temperature. Based on these, we conclude that the Nigerian States with higher temperature will have a lesser reported COVID-19 confirmed cases while the States with higher population density will have a higher reported COVID-19 confirmed cases. The COVID-19 virus would not spread quickly in a hot environment; it prefers a cold environment to be able to infect densely populated areas.

6. RECOMMENDATION

Based on the findings from this study, the following recommendations apply: Nigerian Government through the PTF on COVID-19 and NCDC should pay more attention to social activities such as weddings, funeral and parties which encourage the gathering of more than 50 persons and ensure that social distancing is strictly adhered to with the use of nose mask strictly in check. Furthermore, individuals should be educated on how to keep their environment warm always by avoiding cold temperatures (food, drinks and places), should take more of warm water especially during the cold season. Again, the number of COVID-19 confirmed cases can also be modeled with more independent variables to include: genotype, blood group, family wealth index, residence etc. in order to identify more statistically significant variables that influence the incidence of COVID-19 confirmed cases in Nigeria.

AVAILABILITY OF DATA AND MATERIAL

(Figshare)
https://figshare.com/articles/dataset/The_Role_of_Population_Density_and_the_Elements_of_Weather_in_the_Spread_of_COVID-19_in_Nigeria_A_Negative_Binomial_Regression_Model_Approach/14906778

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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