

Analysing Secondary infections of Coronavirus Disease 2019 Across the Geopolitical Zones of Nigeria Using Estimated Rt

Bibi Umar Muhammed^{*1}, Saad Aliyu Ahmed^{2,3}, Idris M. Jega⁴

¹ Department of Geography, Federal University of Kashere, PMB 0182 Gombe, Nigeria

² Department of Pathology, Ahmadu Bello University Zaria, 810001 Nigeria

³ Federal Medical Centre, Abuja – Nigeria.

⁴ Department of Strategic Space Applications, National Space Research Development Agency (NASRDA) Airport Road Abuja, Nigeria

*Corresponding author email: bibi.muhammed@gmail.com

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Abstract: Time dependent reproduction number (represented as TD – R_0) is a measure of secondary infections or transmissibility of a disease useful in monitoring changes in the rate of infection and assessing policies put in place to control the spread of a disease. In this study, we used daily infections situation report of COVID – 19 were published by the Nigeria Centre for Disease Control (NCDC) to estimate Nigeria's TD – R_0 then repeated the same method for the six geo – political zones in the country. Estimates of TD – R_0 values for the country from the 23rd of March – 27th of May 2020 fluctuated with a maximum of 2.3 (95% CrI) on the 19th of April and a minimum of 0.83 (95% CrI) on the 16th May 2020. Despite the decline in TD – R_0 since the early stages of the outbreak of COVID – 19 in Nigeria, suggesting a fall in the expected rate of secondary infection, apart from the northwest and the northeast geo – political zones values remain above 1.0 for other zones and the country, generally. The Kolmogorov – Smirnov (KS) test was used to test the null hypothesis stating that the means of TD – R_0 across the geo-political zones does not follow the same distribution pattern. After making adjustments for Type 1 – error, we accepted the null hypothesis ($p < 0.05$) for six pairs of geo-political zones. We conclude that our findings are significant in studying the COVID – 19 epidemic in Nigeria and important in evaluating the strategies deployed by governments at the national and regional levels, thus, the same method can be replicated across Africa.

Keywords: COVID – 19, pandemic, time dependent reproduction number, Nigeria, Geo-political zones

1. Introduction

The novel Coronavirus Disease 2019 is a strain of influenza related to the severe acute respiratory syndrome (SARS) officially named by the World Health Organisation (WHO) as COVID – 19 [1]. An outbreak of the disease was first reported in the city of Wuhan, China on the 29th of December 2019 [1] and by the 11th of March 2020 it was declared a pandemic by WHO [2]. Many countries in the world were unprepared for a pandemic of such magnitude coupled with little knowledge about the disease. Therefore, the only early intervention strategies that governments can adopt to mitigate the spread of the disease is to delay the peak of the infection (popularly referred as “flattening the curve”) in order to prevent the health system from being overwhelmed and have time for the development of an anti – virus treatment and a vaccine [3].

In Nigeria Covid – 19 infections were first brought into the country by returning citizens and foreign nationals coming from countries where the number of infections had already reached levels of epidemics. The country reported its first index case of COVID – 19 on the 27th of February, 2020 [4]. A number of preventive and mitigation strategies were

adopted before and after the first index case coordinated by the Nigeria Centre for Disease Control – NCDC [5] in conjunction with the Presidential Task Force (PTA) on COVID – 19. These include mass sensitization programs on COVID – 19, the deployment of thermal scanning devices at the major ports of entry into the country and two weeks self isolation for people arriving into the country as preventive measures, then followed by closure of the country's national and interstate borders, stay at home advisory, closing of public facilities and total lockdown of areas with high infections as mitigation measures.

Considering the impact of the mitigation measures are adopted in the country on the control of the spread of COVID – 19 and the livelihoods of the general population it is necessary to monitor and evaluate the progress made in the implementation of such strategies both at national and regional levels. Among several proxies are used in monitoring the progress of a disease during outbreaks is the time – dependent reproduction number TD – R_0 [6]. The basic reproduction number R_0 is the average number of secondary infections resulting from a single primary infection (Cori et al., 2013) over the course

of an outbreak. However, $TD - R_0$ is time bound and a measure of the expected number of secondary infections from a primary infection at time t [7]. It is a measure of the transmissibility of a disease. In the course of an outbreak the values of $TD - R_0$ changes varying with the reported cases of infection. A $TD - R_0$ value of 2.0 suggest that two secondary cases of infection are expected from a single primary case. When the value of $TD - R_0$ falls to below 1.0, it is expected that the number of secondary cases of infection will gradually disappear.

It is useful for assessing the success of intervention measures put in place during an outbreak of a disease. Apart from that $TD - R_0$ is also useful for monitoring trends during an epidemic, the identification of “super spreader events” and a parameter for epidemic/ disease outbreak are related mathematical models [6]. Musa et al. [8] estimated the basic and exponential reproduction number of COVID - 19 for the African continent. Apart from the work of Adegboye et al. [9] and Adekunle et al. [10] that attempted to estimate $TD - R_0$ for the country during the early stages of the pandemic to the best of our knowledge, there is no effort has been made to further estimate $TD - R_0$ as the epidemic progressed. In this study, we intended to further this method by estimating $TD - R_0$ over a longer period when the outbreak is well established in the country,

reduce the error margins in the estimate and also estimate $TD - R_0$ across the six geo-political in the country. We attempted to test a null hypothesis stating “that the estimated $TD - R_0$ between geo - political zones do not follow the same pattern”, and if it is true will suggest heterogeneity among the zones and a more specific intervention approach which is required for each zone to control COVID - 19.

The following section describe the geographical characteristics of the study area, the data and analysis method used (materials and method section). We present our findings in the result section. This is followed by the discussions and conclusion, that made based on the findings presented in the discussion and conclusion sections.

2. Materials and Methods

The study developed a research design (see Figure 1) that is aimed at achieving the set objectives which is to estimate TD_R_0 for Nigeria and the six geopolitical zones in the country and also determine the difference/similarities in the pattern of secondary infections across the geo - political zones in the country. Sources of the daily Covid - 19 infection report used in estimating TD_R_0 , analysis methods and a brief description of the study area are further explained in this section.

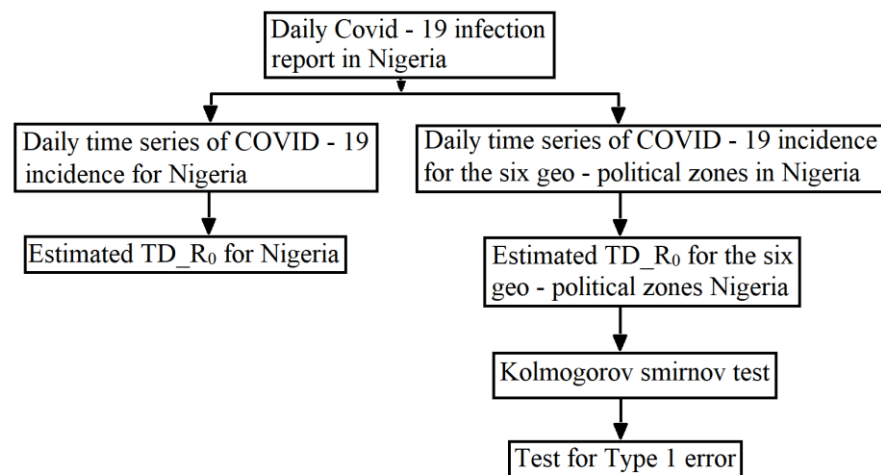


Figure 1: Research flow chart

2.1 The Study Area

Nigeria with an estimated population of 206 million [11] is the most populous country in Africa. It is located in West Africa and lies between latitude $4^{\circ} - 14^{\circ}$ north of the Equator and longitude $3^{\circ} - 15^{\circ}$ east of the Greenwich meridian line. The country comprises of 36 states and the Federal Capital Territory (FCT) Abuja are often grouped into six geo - political zones (see Figure 2 and Table 1).

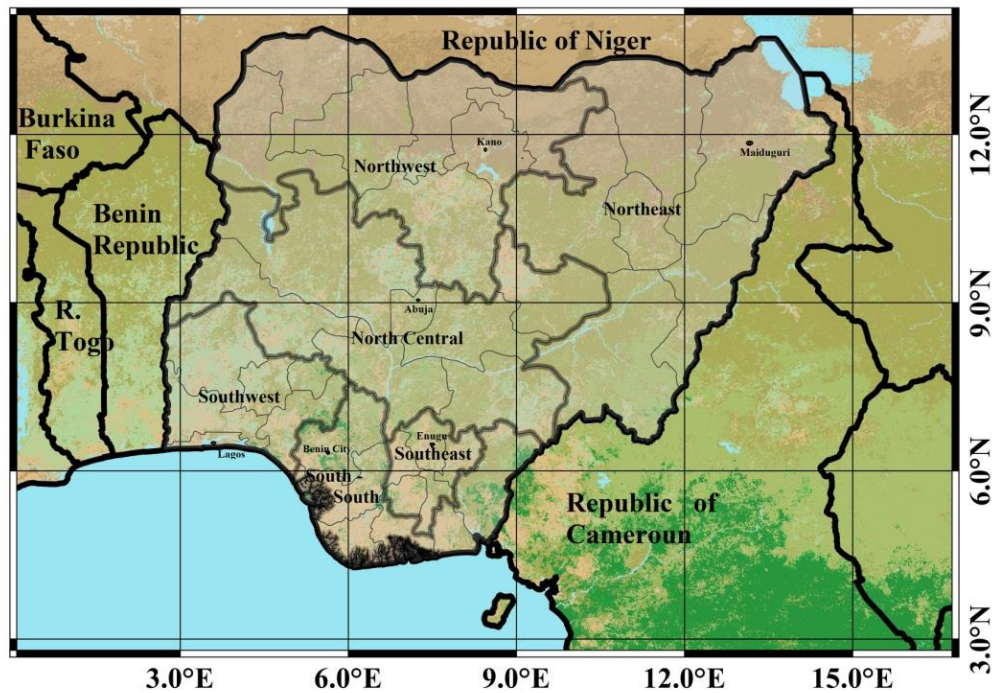


Figure 2: Map of Nigeria showing the six geo – political zones

Table 1. The Six geo – political zones in Nigeria comprising of 36 states and the Federal Capital Territory (FCT) Abuja

S/No.	Geo – political zones	States
1	North Central	Benue, Kogi, Kwara, Nasarawa, Niger, Plateau, FCT
2	Northeast	Adamawa, Bauchi, Borno, Gombe, Taraba, Yobe
3	Northwest	Jigawa, Kaduna, Kano, Katsina, Kebbi, Sokoto, Zamfara
4	South West	Ekiti, Lagos, Ogun, Ondo, Osun, Oyo
5	Southeast	Abia, Anambra, Ebonyi, Enugu, Imo
6	South – South	Akwa Ibom, Bayelsa, Cross River, Delta, Edo, Rivers

2.2 Sources of data

In estimating $TD - R_0$, we used the daily COVID – 19 infections situation report in Nigeria numbers 01 – 89 from the 28th of February to 27th of May 2020 downloaded from the country's Nigeria Centre for Disease Control (NCDC) website (<https://ncdc.gov.ng/diseases/sitreps/?cat=14&name=An%20update%20of%20COVID-19%20outbreak%20in%20Nigeria>). The NCDC daily COVID – 19 infection data for the whole country comprises of daily infection data for each of the 36 states in the country and the Federal Capital Territory (FCT) Abuja. In some reports are also contained the daily data on the number of people screened for the virus, those discharged from COVID – 19 care centers across the country and the deceased.

2.3 Data Analysis Techniques

We used EpiEstim package installed on R version 3.6.1 to estimate $TD - R_0$. EpiEstim uses

time series data of infections to create a distribution of the serial interval - SI (time between the manifestation of symptoms from a primary case and that of a secondary case) and estimate $TD - R_0$. The method was first developed by Cori et al. (2013) and further modified by Thompson et al. (2019) to include imported and local incidence of a disease. The method assumes that the first incidence of a disease is imported and can incorporate several of such cases in the time series. The method was chosen for this study because of its simplicity of use and the ability to incorporate a single data set (time series of infections) in making estimates of $TD - R_0$. Several studies [7,9,10,12–14] have also applied this method in estimating $TD - R_0$, studying the spread of a disease and evaluation of intervention strategies. In order to minimize errors, in initial estimates of $TD - R_0$, we skipped the first few reported incidences characterized by gaps in the data and wide time intervals between reported cases which is naturally

the period between the first reported case and a full outbreak of the disease. A conservative mean SI of 4.8 days and standard deviation of 2.3 days were adopted from Nishiura et al. [15] in making the TD – R₀ estimates.

In the R software platform the Kolomogorov Smirnov (KS) test was used to test for regional differences pair wise in order to test for the null

hypothesis “that the estimated TD – R₀ between geopolitical zones do not follow the same distribution pattern”. P – values of the KS test were adjusted for Type 1 error using the Bonferroni, Holm [16], Hochberg [17], Hommel [18], Benjamini and Hochberg [19] and Benjamini and Yekutieli [20] tests.

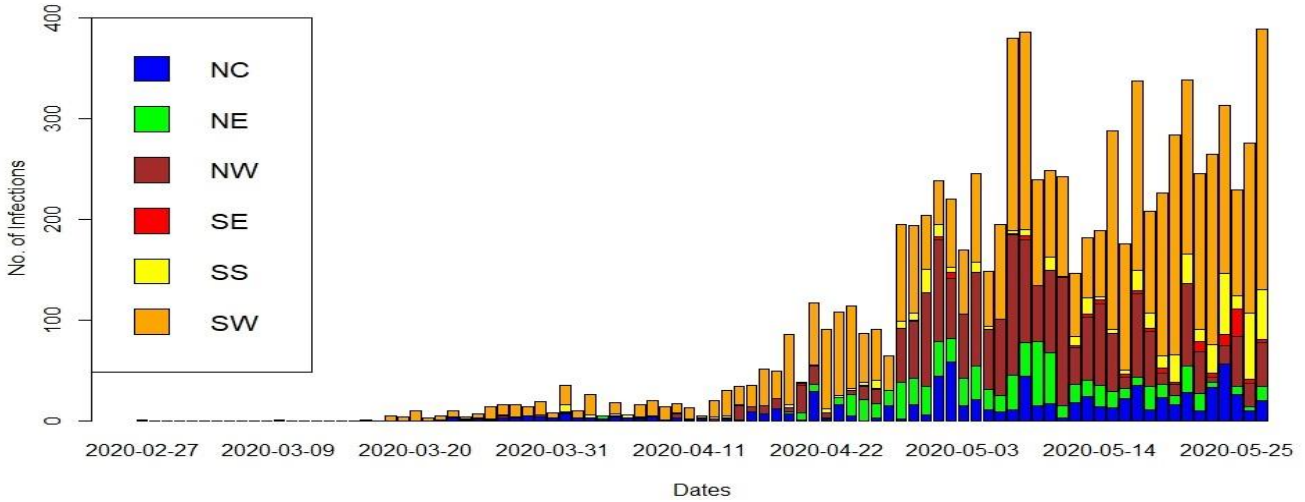


Figure 3. Daily infection of COVID – 19 in Nigeria and the six geo – political zones from 27th of February 2020 – 27th May 2020

*Note: NC – North central, NE – Northeast, NW – Northwest, SE – Southeast, SS – South south and SW – Southwest

3. Results

Like other studies such as Hu [13] and Adekunle et al. [10], we assume that all cases of COVID – 19 infections in the country are reported for our results to qualify as a true reflection of trends in the country. The total number of COVID – 19 infections in Nigeria from the 27th of February 2020 to the 27th of May 2020 was collated from the NCDC infections situation report for the period and is

presented in Figure 3 showing the contribution of each geo – political zone. The total number of COVID – 19 infections in the country stands at 8,735 with the southwest geo – political zone having the highest number of infections (52.7%) followed by the northwest (22.6%) and the north central (9.2%), respectively. COVID – 19 infections from the other 3 geo – political zones (northeast, southeast and south – south) form only 15.5% of recorded cases during the period under study.

Table 2: Summary table of important dates used in estimating TD – R₀

Place	Date of 1st reported case	Estimate duration		
		start date	end date	Number of days
National	27 th of February, 2020	16 th of March 2020	27 th of May, 2020	73
North central	22 nd of March 2020	22 nd of March 2020		67
Northeast	19 th of May 2020	19 th of May 2020		39
Northwest	28 th of March 2020	10 th of April 2020		48
Southeast	27 th of March 2020	25 th of April 2020		33
South – south	23 rd of March 2020	5 th of May 2020		53
Southwest	27 th of February 2020	16 th of March 2020		73

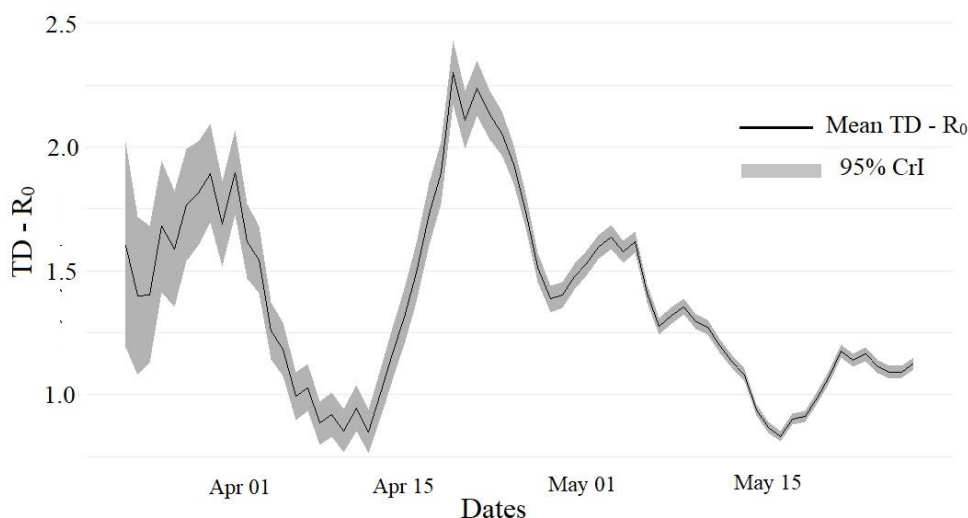


Figure 4. Estimated TD – R_0 for Nigeria from 23rd March 2020 – 17th May 2020

The time series data of COVID – 19 infections in the country were used in estimating TD – R_0 for the country, then repeated for each of the six geo – political zones. The start date and time length of each estimate are presented in Table 2. The start date for the estimates in each area was chosen based on the consistency of reported daily cases to minimize error. The mean TD – R_0 for the country and the geopolitical zones were plotted against a credible interval (CrI) of 95% (see Figures 4 and 5). There was a time interval of one week between the start date of estimate and the resulting TD – R_0 based on the output configuration further explained by Thompson et al. [7]. The estimated mean TD – R_0 for the country from the 23rd of March to the 27th of April 2020 fluctuated with a maximum of 2.30 (95% CrI) recorded on the 19th of April and a minimum of 0.83 (95% CrI) recorded on the 16th of May 2020 with an overall median of 1.34 (95% CrI). Our estimates of TD – R_0 for Nigeria are lower than those obtained by

Adegboye et al [9] during the early transmission stage of COVID 19 in the country and also for the month of April. For instance, our estimated TD – R_0 for the 11th of April is 0.95 (95% CrI) compared to their estimate of 2.71 (95% CrI).

There are variations in the estimated TD – R_0 across the geo – political zones (Figure 5). The southwest has a maximum TD – R_0 of 2.30 (95% CrI) that recorded on the 19th of April and a minimum of 0.87 (95% CrI) on the 10th of April 2020 and a median of 1.31. Other geo – political zones have recorded much higher maximum and lower minimum TD – R_0 than the southwest. For instance, the northwest recorded a maximum TD – R_0 of 3.97 (95% CrI) on the 1st of May and a minimum of 0.62 (95% CrI) on the 24th of May 2020. Apart from the northeast and the northwest geo – political zones TD – R_0 is still above 1.0 for the country and the other four zones (95% CrI) as of the 27th of May 2020.

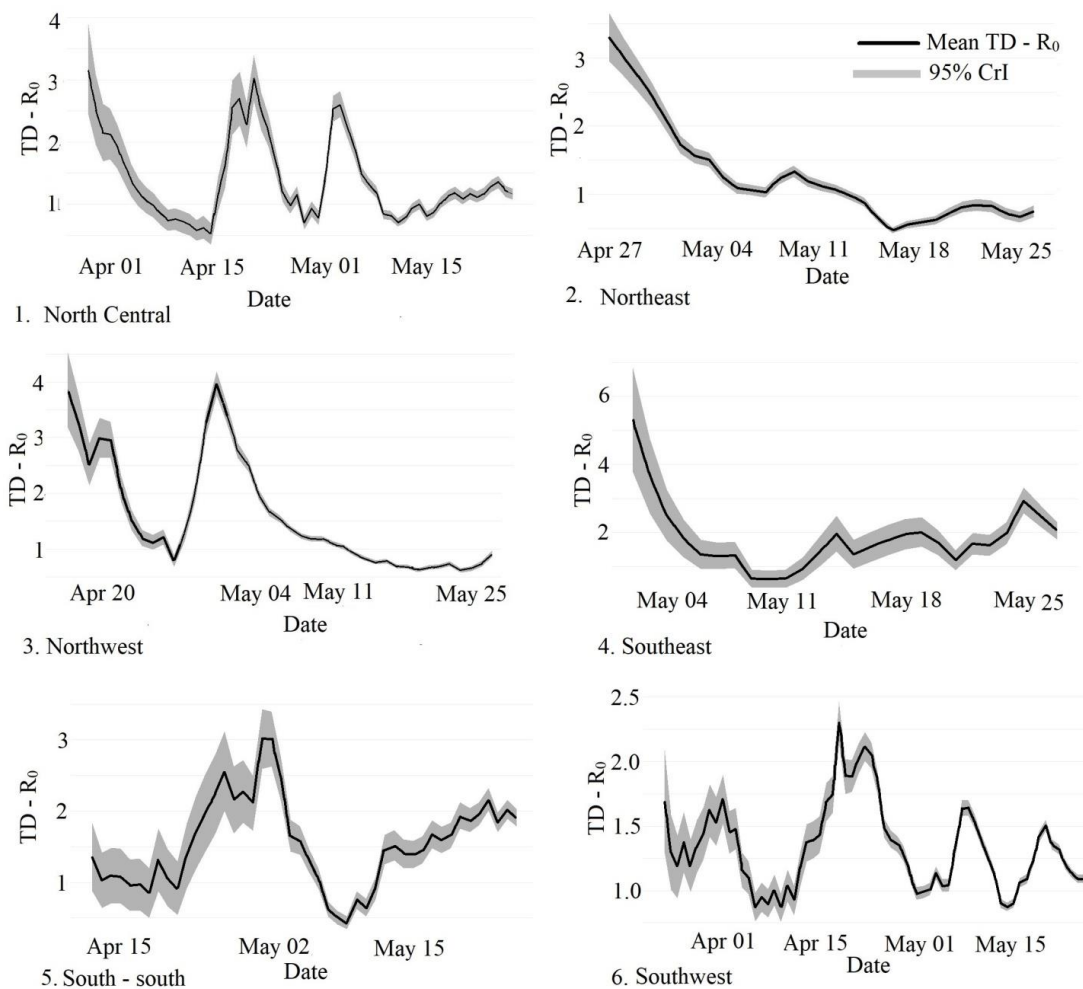


Figure 5. $TD - R_0$ across the six geo – political zones in Nigeria

We intended to test the statistical significance of the differences in the estimated $TD - R_0$ among the geo – political zones and also verify our null hypothesis by carrying out a pair wise KS test. The results of the KS test were adjusted for Type 1 error based on six methods and are presented in Figure 6. The null hypothesis is to be accepted if $p < 0.05$. Adjusted values $p < 0.05$ were obtained between pair wise comparison of southeast and four other geo – political zones (north central, northeast, northwest and southwest) based on all the six methods used in the Type 1 error adjustment. Our results are similar to the findings of Arruda et al. [6] on regional differences in the transmissibility of influenza in a breed of domestic animals in the United States of America. Also, adjusted value of $p < 0.05$ was obtained between the northeast and south – south geopolitical zones.

4. Discussion

Comparisons of the $TD - R_0$ curves in Figures 4 - 5 for the country and the six geo – political zones suggest a certain consistency with $TD - R_0$

fluctuating before finally decreasing apart from the south – south. Such fluctuations correspond to the implementation of certain policies by the national and the regional governments to control the spread of COVID – 19. The first response by the authorities when the number of reported cases started to increase was to restrict movement of people and encourage social distancing. This was implemented by closure of public facilities and imposing lockdowns within and outside individual states. As indicated by the curves this led to the initial drop in $TD - R_0$. In the second week of April, an effort was made to increase the number of screenings for COVID -19 across the country, and subsequently, the number of reported cases also increased. This process was slightly delayed in Kano which is the epicenter of the disease in the northwest and reflected in the $TD - R_0$ curve for the northwest. $TD - R_0$ is a measure of the transmissibility of a disease. Despite the decrease in transmissibility of COVID – 19 in Nigeria, there are some parts of the country like the southeast and the southwest where the level of transmissibility of the disease is high even though the number of reported

infections are low compared to other geo-political zones. Coupled with the fluctuations in TD – R_0 many zones of the geo-political zones of the country there is need to review and strengthen its mitigation strategies for controlling COVID - 19. The review of

strategies is especially necessary for some geo – political zones like the southeast where the pattern of transmissibility of the disease is quite different from the rest of the country.

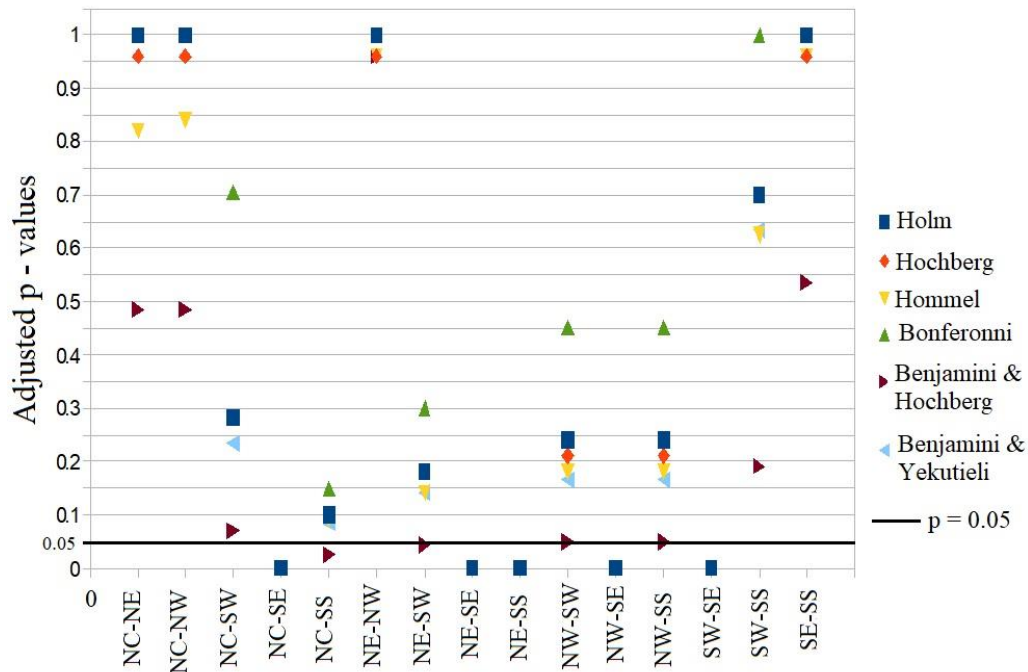


Figure 6. Results of Type 1 error adjustments of p – values obtained from the pair wise KS test of estimated TD – R_0 among geo – political zones. Type 1 error test was carried out using 6 different methods. Adjusted p = 0.05 marked by the black line is the upper boundary limit for accepting the null hypothesis.

Note: null hypothesis is accepted for adjusted p < 0.05 based on all the six adjustment methods for Type 1 error test. This is true for at least 5 pair wise comparisons. The following abbreviations represents: NC – North central, NE – Northeast, NW – Northwest, SE – Southeast, SS – South – south and SW – Southwest

5. Conclusion

Our findings indicate a decline in the rate of secondary infections of COVID – 19 in Nigeria as presented in the TD – R_0 curves. It has also been established that such potentials for secondary infections are sensitive to control measures aimed at mitigation. Notable, of such government efforts, is the screening of more people for COVID – 19 as the credibility of this method and similar others depend on the proportion of infection incidences recorded. Nevertheless, we are able to show that a simple technique like the one that we used can be effective in studying trends in an epidemic and evaluate strategies adopted to mitigate the spread of a disease. The study was able to establish that apart from the

southeast the transmissibility pattern across the geo – political zones is homogeneous. Therefore, we propose the use of similar methods as the one in this paper across Africa for the study of the COVID – 19 pandemic.

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