Change point analysis to quantify the impact of African government policy interventions to slow the spread of COVID-19. A case study of Senegal

The purpose of the Susceptible Infected Recovered (SIR) model is to describe how the corona virus spreads at a particular rate from an infected person (I) to a susceptible person (S) and how an infected person becomes a recovered person (R) at a particular rate. SIR models are used to understand how the virus expands from person to person and how each action taking by government officials influences the virus. Susceptible people are people that are not yet affected by the virus, Infected people are people infected with the virus while Recovered are people that have recovered from the virus.

The Output of a SIR model are the parameters – infection rate, recovery rate, spreading rate.

Processes that affect the generation of the COVID19 data in my country are

1. Inadequate Data report
2. Small number of test centers
3. Low test capacity
4. Negligence of people towards the virus
5. Bad Government Policies

The part of the model that handles some of these policies are the inadequate data report. The SIR model takes into cognizance the report delay which can be attributed to inadequate data report. The model is built in such a way that if the report lacks by a day or 2 days it will still be able to understand the trend of the data and how it progresses and thus will be able to make good and reliable future forecast.

The difference between the SIR and SEIR model is the known fact that Exposed people are not necessarily the infected or infectious people. This is to mean that an infected person does not guarantee to be infectious if the person self-isolate that is he/she does not meet people or does not come in contact with Susceptible people. The SEIR means Susceptible Exposed Infectious Recovered which means that before someone becomes infectious that is to transmit the virus he/she is first exposed to and becomes infected. The SEIR model gives an incubation period or stage where a person abhors the virus before transmitting it to Susceptible Exposed people.

The distinct characteristics of an exponential function is to quantify the impact of possible interventions when implemented. Interventions here means Government policies enforced. Because of the small number of infected people at the start, exponential function is needed to derive a simple expression for the spread of the virus, which in turn explains the growth rate of the virus.

The exponential growth is a specific way covid19 may increase over time. It occurs when the instantaneous rate of change of a quantity with respect to time is proportional to the quantity of the virus itself. While an exponential decay is a way a

covid19 may decrease over time. It occurs when a quantity decreases at a rate proportional to its current value. Geometric Progression also known as geometric sequence is a sequence of numbers where each term after the first one is found by multiplying the previous one by a fixed non-zero number called common ratio. Logistic growth takes place when a population's per capita growth rate decreases as population size approaches a maximum imposed by limited resources. The logistic growth and the exponential decay is similar such that both decreases as population size reach a limit while the exponential growth and geometric progression is similar because the population increases with a fixed number of non-zero value. The major difference is that exponential decay and logistic growth leads to decrease in the population while exponential growth and geometric progression tends to increase the population size.

The SIR model takes the exponential form because at the onset of the virus that is when the virus breaks out, only a small fraction of the population is infected or recovered. Thus, every person was susceptible to the virus which means anybody can be infected without knowing and then transmitting to other people and it keeps spreading like that which will make the spread increase exponentially.

The rate parameters of a SIR model are estimated using a Bayesian Inference with Markov-Chain Monte-Carlo (MCMC). Bayesian Inference interprets probability as a measure of believability or confidence that an individual may possess about the occurrence of a particular event. We may have a prior belief about an event, but our beliefs are likely to change when new evidence is brought to light. This is achieved with the use of the MCMC which helps to recursively generate new parameters to help reduce the deviation of the model with the real world data.

The Posterior Probability distribution was used to model the SIR rate parameters. The posterior distribution was used because it explains what we know about uncertain quantities in Bayesian analysis. It is a combination of the prior (what we know before) distribution and the likelihood function, which tells us what information is contained in our observed data (The new evidence).

The expected output of the modelling phase would be the rate of spread of the virus. How have the Government policies affected it? What is the rate of recovery etc. This questions would be answered at the modelling phase. The result of the model should tell us which policy to re-implement and the next cause of action would be known.

The Predictions are carried out with many assumptions in mind one of which was that the recovery rate and the spread rate do not change given that it is the start of the virus (that is COVID19 is just spreading) this may be true but it is believed to cause problems in the near future because peoples behaviors changes over time and when this happens an explicit modeling with time-dependence will be needed to make reliable predictions.

The non-pharmaceutical interventions policies can be described as the measures put in place by government in other to reduce the rate of spread of the virus. This can be

called the governmental interventions like closing of schools, banning large gatherings etc.

The effectiveness of the non- pharmaceutical intervention policies is evaluated based on the change points. A decrease in spread rate means the policy is effective while vice versa.

Scenario: **Public interest in corruption**

Population: Twitter users in Nigeria
Susceptible: Number of handles that tweeted on Corruption
Infected: number victims (whistle blowers or people that reported incidents)
Recovered: Solved and Acquitted cases

The right model to explain this scenario would be a SIRS meaning Susceptible Infectious Recovered Susceptible, where recovery does not confer lifelong immunity and individuals may become susceptible again. The infectious rate controls the rate of spread which represents the probability of transmitting corruption between susceptible and an infectious individual. Recovery rate is determined by the average duration of infection. This is how long an infectious person spends or stays with another infectious person in terms of social interactions. The susceptible would be people who viewed the tweets, has viewed the tweet and interact with the tweets with a like, comment or retweet and people who ignored the tweet. The output of this model would be rate of increase/decrease in corruption cases and rate of spread of corruption.

Change points introduced by the Government of Senegal with dates

1. Banning Major Gatherings — 10th March, 2020
2. School Closures — 15th March, 2020
3. Required Social Distancing — 31st March, 2020
4. Mask Wearing Mandatory — 3rd April, 2020
5. Relaxing Rules — 12th May, 2020

Interpretation of Model Result

The case of Coronavirus outbreak in Senegal was not so much different from other African Countries as the first case was observed from a returnee On 2 March 2020, a 54-year-old man from France was the first confirmed case of COVID-19 in Senegal, living in the Almadies Arrondissement of Dakar, having been tested positive at the Pasteur Institute in Dakar. He had travelled on Air Senegal on 29 February 2020. Senegal became the second Sub-Saharan country to report confirmed cases after Nigeria. The second confirmed case of COVID-19 was a French expat who came to Dakar from France. The Government of Senegal began to enforce some rules including the closing

large gatherings like worship centers on 15th March 2020. The wide spread of rumors by some clerics that individuals were immune to the virus also did not help the situation. On March 23rd, Senegal declared a state of emergency and by the end of the month, there had been 175 confirmed cases, 40 of whom recovered
while 135 remained active cases at the end of the month.

When faced with the outbreak of a novel epidemic such as coronavirus disease 2019 (COVID-19), rapid response measures are required by individuals, as well as by society as a whole, to stop the spread of the virus. During this initial and time-critical period, neither the central epidemiological parameters nor the effectiveness of interventions such as cancellation of public events, school closure, or social distancing is known.

For the purpose of Understanding the effect of these interventions, data about daily confirmed cases of COVID-19 is needed. Based on the data, the norm was that every day, recorded cases are always high, but what we cannot ascertain is by
how much and which intervention leads to the increase or decrease of the spread of the virus. To answer these questions, data about daily confirmed cases were studied and lead us to recondition our initial belief of the spread of the virus. A framework was developed using the confirmed number of cases in Senegal. The framework is designed to infer the effectiveness of past measures and to explore potential future scenarios, along with propagating the respective uncertainties. In the following, I explained the potential impact of time and report our inference about the three past governmental interventions (Ban of Large Gatherings, School Closure and Strong Social Distancing) in Senegal. The framework is built on an established class of models for epidemic outbreaks: The susceptible-infected-recovered (SIR) model which specifies population compartments and the rates at which they change (susceptible people becoming infectious and
infectious people recovering). The model was selected because of its effectiveness in dealing with epidemic spread. The model was built on the epidemic data and enhanced by the time-dependent spreading rate. The time dependence was implemented as potential change points in the spreading rate, which we assume to be driven by governmental interventions and the associated change of individual behavior (non-pharmaceutical interventions).

Governmental Interventions and their Respective Change Points

1. **Restrictions on gatherings**: - a change was observed in the spread rate of the virus from an initial value of 0.64 to 0.34 spread rate. The date at which the change point was observed 16th of March Confidence Interval [10, 21] correlates with the date on which the Governmental intervention of restriction on large gatherings was enforced 15th of March.

2. **Restrictions on internal movement (Curfew)**: - another change was observed in the spread rate of the virus from an initial value of 0.34 to 0.05 spread rate. The date on which the change point was inferred 24th of March Confidence

Interval [20, 27] correlates with the date on which the Governmental intervention on restrictions of internal movement was imposed 23rd of March.

3. **<u>Strong Social Distancing</u>:** - a change was observed in the spread rate of the virus from an initial value of 0.05 to 0.18 spread rate. The date at which the change point was inferred 31st of March Confidence Interval [28, 33] correlates with the date on which the Governmental intervention of relaxation of curfew along with the enforcement of strong social distancing 31st of March. It should however be noted that unlike the first two change points, the change here is incremental as the spread rate increases.

The number of change points required in the model to best fit the data is 2 which includes restrictions of large gatherings and restrictions on internal movement (curfew).

Limitations

1. The behavior and responses of the citizens of Senegal to the Governmental Interventions could not be measured with respect to how it affects the spread of the virus.

Lessons (Recommendations) Countries could adopt for future Pandemic

1. Quick and necessary precautions should be taken whenever news about the outbreak of a contagious disease in a country is received.

2. Sensitizations and Awareness Campaign should be regularly observed