MODELLING CORONAVIRUS INFECTIONS PROGRESSION IN SOUTH AFRICA

BY

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IUSSP WEBINAR:

THE COVID-19 PANDEMIC AND
SEXUAL & REPRODUCTIVE HEALTH IN AFRICA
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BACKGROUND

- This presentation is a brief summary of the study I carried out between March and June 2020 focusing on the first 71 days of the coronavirus pandemic in South Africa.
- A full technical report of the study can be downloaded for free from www.ericudjoconsulting.co.za
- The WHO declared COVID-19 a pandemic on 11 March 2020.
- The virus has spread to 215 countries/territories as at 21 August 2020, 48 of these countries/territories are in Africa.
- According to the WHO, as at 21 August 2020, there were 22,492,312 confirmed cases of COVID-19 globally with 975,551 (4.3%) of the confirmed cases located in Africa.

BACKGROUND (CONTD).

- Furthermore, according to the WHO, there were 788,503 confirmed COVID-19 deaths globally as at 21 August 2020 with 19,557 (2.5%) of the deaths located in Africa.
- Coverage and efficiency in screening and testing for COVID-19 as well as the determination of cause of death varies from country to country.
- Therefore global figures on confirmed COVID-19 cases as well as the number of COVID-19 fatalities are likely to be under-stated at any point in time.

STATEMENT OF THE RESEARCH PROBLEM.

- Though many people infected with COVID-19 have recovered, it remains a deadly virus among all age groups because there is currently no cure and there is scepticism about the vaccine Russia has developed.
- It is unknown when COVID-19 would run its course, or an effective and massive vaccine roll out would be available.

STATEMENT OF THE RESEARCH PROBLEM (CONTD).

- The first confirmed case of COVID-19 in South Africa was on 5 March 2020.
- It is not practically possible that all the possible contacts from this first positive case could have be identified.
- It would appear therefore, that the current total national numbers of infections officially reported by the Ministry of Health probably do not reflect the actual number of infections in the country.

STATEMENT OF THE RESEARCH PROBLEM (CONTD).

- As a means of mitigating the effect of the virus, the Government of South Africa announced on 23 March 2020 a national 21-day full lock-down (later classified as level 5 lock-down) with effect from 26 March 2020 and lasting up to 15 April 2020 but was subsequently extended.
- The probable effect of the lock-down on the progression of COVID-19 in South Africa is unknown.

RESEARCH OBJECTIVES.

- Modelled the progression of the COVID-19 in South Africa:

1. Assessed the plausibility of the official numbers of COVID-19 infections in South Africa
2. Assessed the effect of the full national lock-down on progression of COVID-19 infections including prevalence rates in South Africa.
3. Computed and projected fatality from COVID-19 in South Africa.

DATA AND LIMITATIONS.

- Daily numbers of confirmed cases of COVID-19, deaths and total number of persons tested as announced by the Minister of Health in Media Release statements.
- The numbers were captured in EXCEL spreadsheet by this author and transformed in a manner amenable to analysis.

DATA AND LIMITATIONS.

- Limitations of the data include:

1. Coverage of testing of testing for COVID-19 was extremely low at the time of the study (less than 1% of the total population at the time of the study, 6% of the total population as at 20 August 2020).
2. The persons tested may not be a representative sample of South Africa's population: persons who showed symptoms or been in contact with persons who showed symptoms.

METHODS: ASSESSING THE PLAUSIBILITY OF THE OFFICIAL NUMBERS OF COVID-19 INFECTIONS

- A scatter plot was made of the official number of positive COVID-19 cases (Y-axis) for each day since the start of the pandemic in South Africa (X-axis).
- An exponential mathematical curve was then fitted to the scatter plot:

$Y = \alpha * e^{(\beta x)}$ ……………….(1)

Y is the model estimate of the number of COVID-19 infections, α and β are respectively the intercept and slope of the curve and x is the number of days since the start of the pandemic in South Africa.

- Note equation (1) implies a constant exponential rate of growth but epidemics and pandemics do not increase at a constant rate exponentially forever.
- In view of this, the best fit to the official figures in the lower part of the curve using equation (1) was examined.

METHODS: ASSESSING THE PLAUSIBILITY OF THE OFFICIAL NUMBERS OF COVID-19 INFECTIONS (CONTD).

- To avoid generating exaggerated model numbers of COVID-19 infections in the population, it was assumed:

1. Persons tested for COVID-19 in the population is a random sample of the population. This assumption is not necessarily true.
2. The daily rates of growth in the number of positive cases since the start of the pandemic are a better reflection than a single constant exponential growth implied in equation (1).

- Based on the above revised model numbers of COVID-19 infections were estimated as:

$COVID19^{m}{}_{dn} = COVID19^{m}d_{n-1} * \ e^{rt}$ ....(2)

Where $COVID19^{m}$ is the model estimate of the number of COVID-19 infections on a specified day, *dn*, *r is* is the rate of growth in the number of observed positive cases & varies rather than a constant, $t = d_n - d_{n-1}$

METHODS: ESTIMATING PROBABLE NUMBER OF COVID-19 CASES

- On the basis of earlier assumptions, probable number of COVID-19 cases in the general population at a specified date was estimated as:

$ProbCovid\text{-}19 = Pop^t * (TPrevCOVID19^t/k)$ ……………………..(3)

ProbCovid-19 is the estimated probable number of COVID-19 cases expected in the general population at a specified date,

Pop^t is the 2020 estimated mid-year population *(see Udjo 2020)*

$TPrevCOVID19^t_c$ is the prevalence among those tested estimated as:

$PrevCOVID19^t = (COVID19^t_c/TPop^t) * k$ ……………………(4)

$PrevCOVID19^t$ is the prevalence rate at a specified point in time among those tested, $COVID19^t_c$ is the total number of COVID-19 cases (old plus new cases), $Tpop^t$ is the total number of persons tested.

METHODS: ESTIMATING PROBABLE NUMBER OF COVID-19 CASES (CONTD).

- Incidence rate (i.e. new infection rate) among persons tested was computed as:

$INCOVID19^t = (NEWCOVID19^t_c/TPop^t) * k$ ……………………(5)

Where

$INCOVID19^t$ is the incidence rate among persons tested at a specified time,

$NEWCOVID19^t_c$ is the number of new positive cases of COVID-19 at a specified time,

$TPop^t$ is the total number of persons tested at a specified time.

METHODS: COMPUTING, PROJECTING CASE FATALITY RATES AND NUMBER OF DEATHS FROM COVID-19

- Cumulated crude fatality rate was computed as:

$CCFatRateCOVID19^t = (CDeathCOVID19^t / CTCOVID19^t) * k$ ………………..(6)

Where

$CCFatRateCOVID19^t$ is the cumulative crude case fatality rate from COVID-19 at a specified time,

$CDeathCOVID19^t$ is the cumulated number of COVID-19 deaths at a specified time,

$CTCOVID19^t$ is the total number of persons tested as at the specified in time, *k* is a constant set at 1,000.

METHODS: COMPUTING, PROJECTING CASE FATALITY RATES AND NUMBER OF DEATHS FROM COVID-19 (CONTD)

- An examination of the values of $CCFatRateCOVID19^t$ showed that the rates stabilised from day 43 onwards ranging from values of about 16.7 and 19.72.
- Next the crude cumulative death rates from day 43 onwards were plotted on a graph. The intercept, a, and slope, b of these values were then estimated by fitting a straight line by least squares to the values.
- Based on earlier assumptions and the constants from the fitted line, the number of COVID-19 deaths in the general population was then estimated as

$$EDeathCOVID19^t = (PCCFatRateCOVID19^t/1000) * ProbCovid\text{-}19^t \quad \ldots\ldots\ldots \quad (7)$$

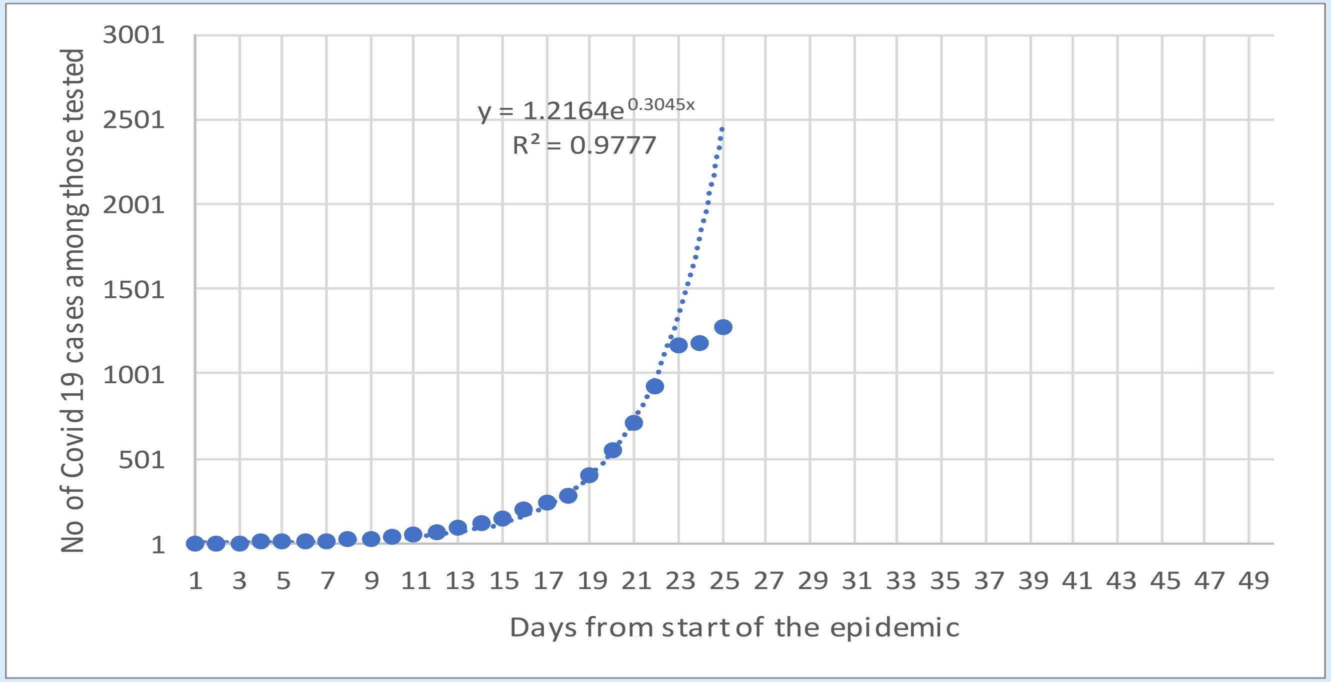
Where

Where $EDeathCOVID19^t$ is the estimated number of COVID-19 deaths in the general population at a specified time,

$PCCTFatRateCOVID19^t$ is the projected cumulative crude fatality rate due to COVID-19 at mid-year, $ProbCovid\text{-}19^t$ is as earlier defined.

RESULTS: PLAUSIBILITY OF THE OFFICIAL NUMBERS OF COVID-19 INFECTIONS IN SOUTH AFRICA

Figure 1: Number of COVID-19 Infections Among Those Tested in South Africa



Source: Author’s graph from official numbers

RESULTS: PLAUSIBILITY OF THE OFFICIAL NUMBERS OF COVID-19 INFECTIONS IN SOUTH AFRICA

- Figure 1 is a graphical illustration of the official numbers of COVID-19 infections by days since the start of the pandemic in South Africa up to day 25.
- The blue dots are the official numbers reported while the broken line is an exponential curve fitted to the official numbers.
- The graph shows that at the initial stage, COVID-19 is time dependent exponential progression confirms that COVID-19 behaved like any other historical epidemic at the initial stage.
- Figure 1 was deliberately truncated at day 25 of the epidemic because of a puzzling pattern. Note that an epidemic curve should be like a stretched S.
- There is a sudden drop in the gradient of the curve starting from day 24 (28 March 2020) from the start of the pandemic in South Africa i.e. two days after full national lock-down commenced.

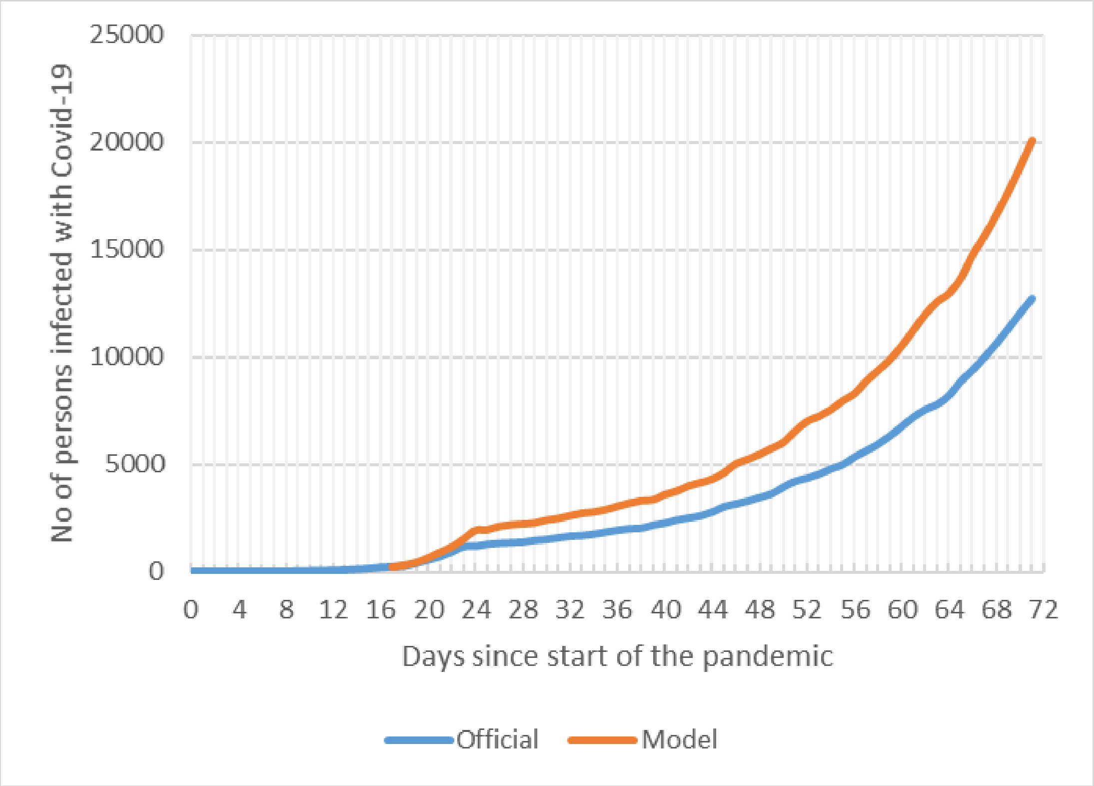
RESULTS: PLAUSIBILITY OF THE OFFICIAL NUMBERS OF COVID-19 INFECTIONS IN SOUTH AFRICA (CONTD)

- The sudden drop in the gradient of the curve starting on day 24 cannot possibly be the sudden effect of lock-down.
- If full lock-down had any effect, one would only expect to see a decline in the gradient in the number of infections from day 35 of the pandemic irrespective of the number of persons tested during the lock-down period.
- What was responsible for the sudden change in the gradient?

1. Has it got to do with differences in the characteristics of persons who tested from March 14, 2020 onwards compared with persons who tested prior to March 14 2020?
2. Is the sudden drop in the gradient an artefact of the data?
3. Some scientists claimed on national Television at the time that the curve of COVID-19 in South Africa is different from the experience of other countries. Aside a flawed logic, we now know that is not true.

RESULTS: PLAUSIBILITY OF THE OFFICIAL NUMBERS OF COVID-19 INFECTIONS IN SOUTH AFRICA (CONTD).

Figure 2: Model Estimates of COVID-19 Infections Compared with Official Figures in South Africa



Source: Author's model from official numbers

RESULTS: PLAUSIBILITY OF THE OFFICIAL NUMBERS OF COVID-19 INFECTIONS IN SOUTH AFRICA (CONTD)

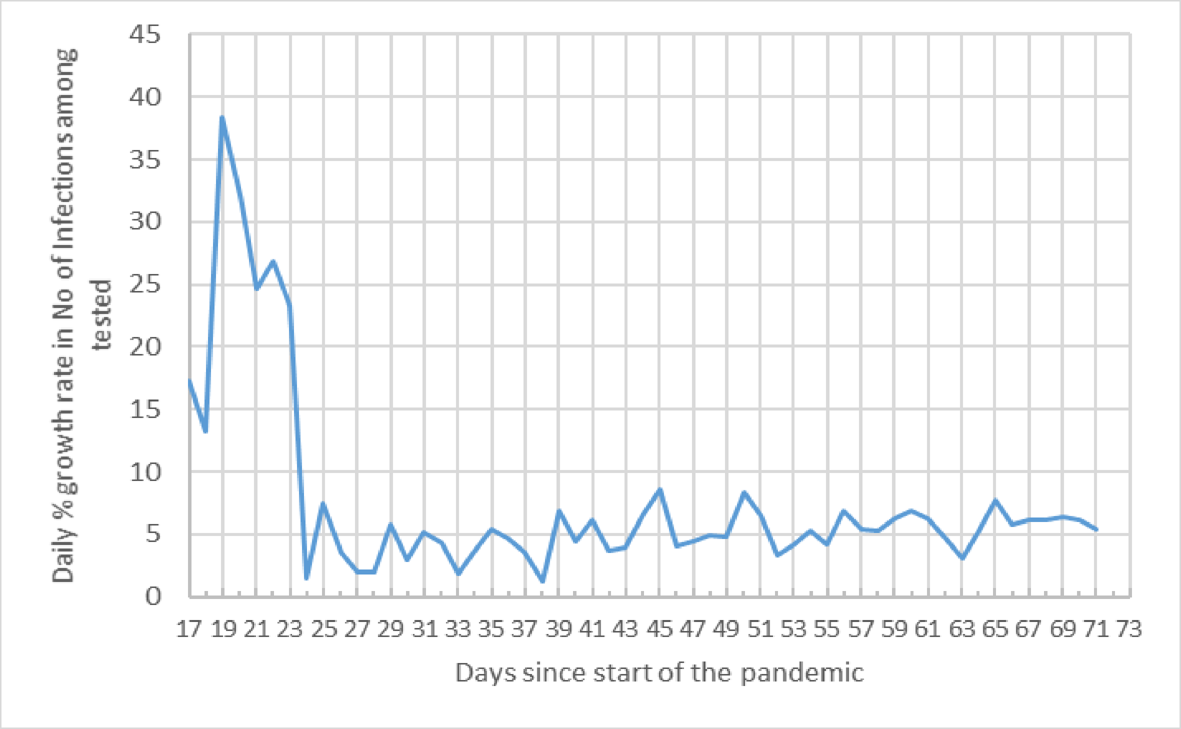
- Figure 2 suggests the official figures probably underrepresent the number of COVID-19 infections in South Africa. This is understandable because:
- Coverage of testing was exceptionally low at the beginning and even at present compared to the size of the population. Some people who are infected may be in the asymptomatic and therefore not captured by the Government's efforts.
- Whereas on day 65 of the pandemic i.e. 8 May 2020, the official number of COVID-19 positive cases reported in the media release was 8,895 but the model suggests there were probably about 13,700 COVID-19 cases in the country as a difference of 4,805 between the official and model figures as of that date.

RESULTS: EFFECT OF LOCK-DOWN ON PROGRESSION OF COVID-19 IN SOUTH AFRICA

- One way of looking at the effect of the full lockdown is to examine the gradient in the official numbers for days 35 -71 in Figure 2.
- There was no decline in the gradient in the official number of infections during that period.
- Another way of looking at the effect of the full lock-down is to examine the percent daily growth rates in the number of infections among those tested. This is illustrated in Figure 3.

RESULTS: EFFECT OF LOCK-DOWN ON PROGRESSION OF COVID-19 IN SOUTH AFRICA (CONTD).

Figure 3: Percent Daily Growth Rates in the Number of COVID-19 before and During full National Lock-down in South Africa.



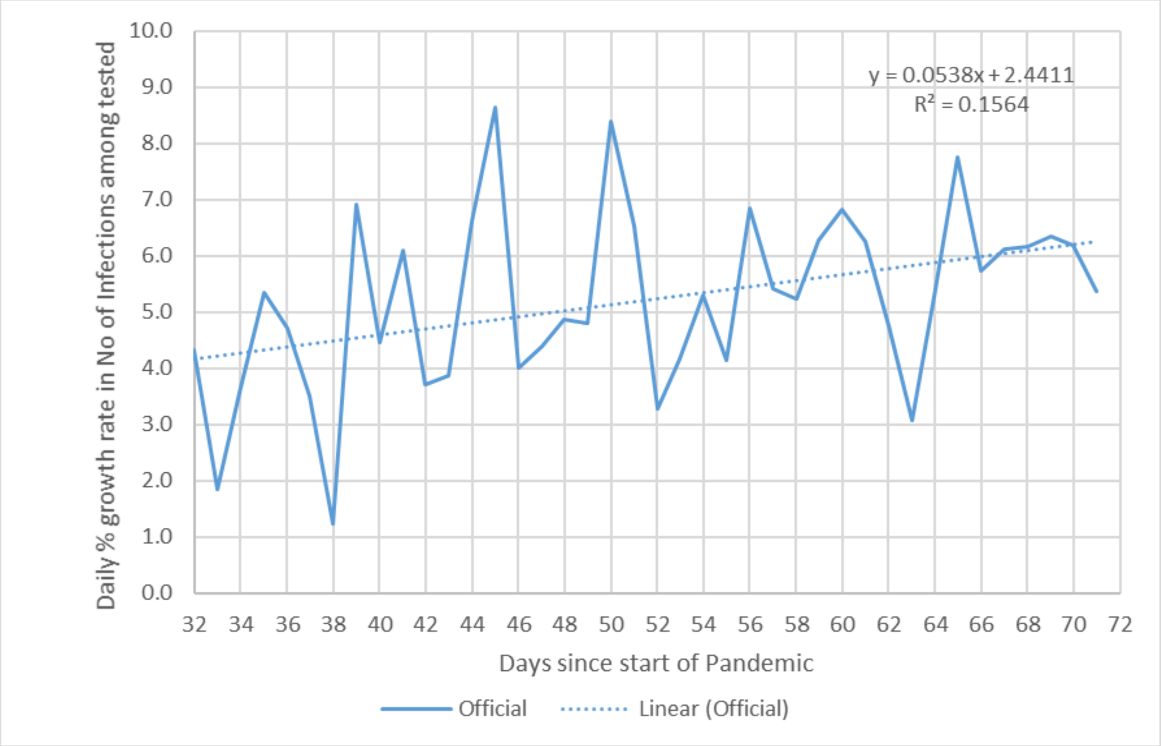
Source: Author's model from official numbers

RESULTS: EFFECT OF LOCK-DOWN ON PROGRESSION OF COVID-19 IN SOUTH AFRICA (CONTD).

- As seen in the Figure 3, the daily growth rate of COVID-19 infections apparently dropped sharply from about 25% on day 22 to less than 5% on day 24.
- This is related to the odd sudden change in the gradient of the progression of the virus noted earlier.
- Focusing on the entire period 35-71, the daily growth rates are erratic probably partly due to time lag in confirmation of some of the positive cases.
- For example, the daily growth rates declined marginally between days 35 and 38 then increased marginally between days 38 and 39.

RESULTS: EFFECT OF LOCK-DOWN ON PROGRESSION OF COVID-19 IN SOUTH AFRICA (CONTD).

Figure 4: Percent Daily Growth Rates in the Number of COVID-19 Infections that Occurred during Lock-down among those Tested in South Africa



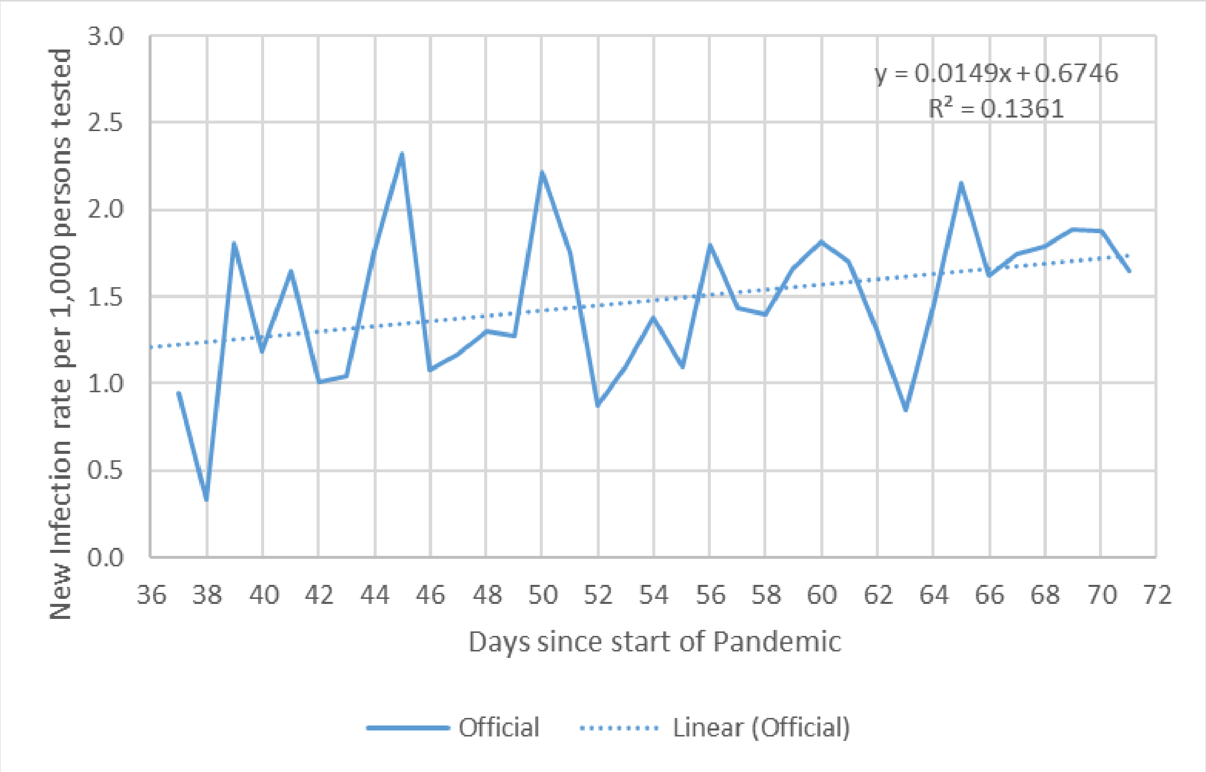
Source: Author's model from official numbers

RESULTS: EFFECT OF LOCK-DOWN ON PROGRESSION OF COVID-19 IN SOUTH AFRICA (CONTD).

- Figure 4 amplifies the daily growth rates by focusing on the period that infections occurred during the lock-down period assuming a 14-day incubation period in COVID-19.
- Fitting a straight line to the trend by least squares suggests a slightly upward trend in the daily growth rates in the number of infections that occurred during the lock-down period.
- However, the correlation coefficient r, is 0.40 implying weak effect of lock-down period on the daily growth rates of infections among those tested.
- The effect of the full lock-down on the progression of COVID-19 was also examined by looking at the trend in the incidence rates. This is illustrated in Figure 5.

RESULTS: EFFECT OF LOCK-DOWN ON PROGRESSION OF COVID-19 IN SOUTH AFRICA (CONTD).

Figure 5: Trend in Incidence Rates in COVID19 During Full Lock-down



Source: Author’s model from official numbers

RESULTS: EFFECT OF LOCK-DOWN ON PROGRESSION OF COVID-19 IN SOUTH AFRICA (CONTD).

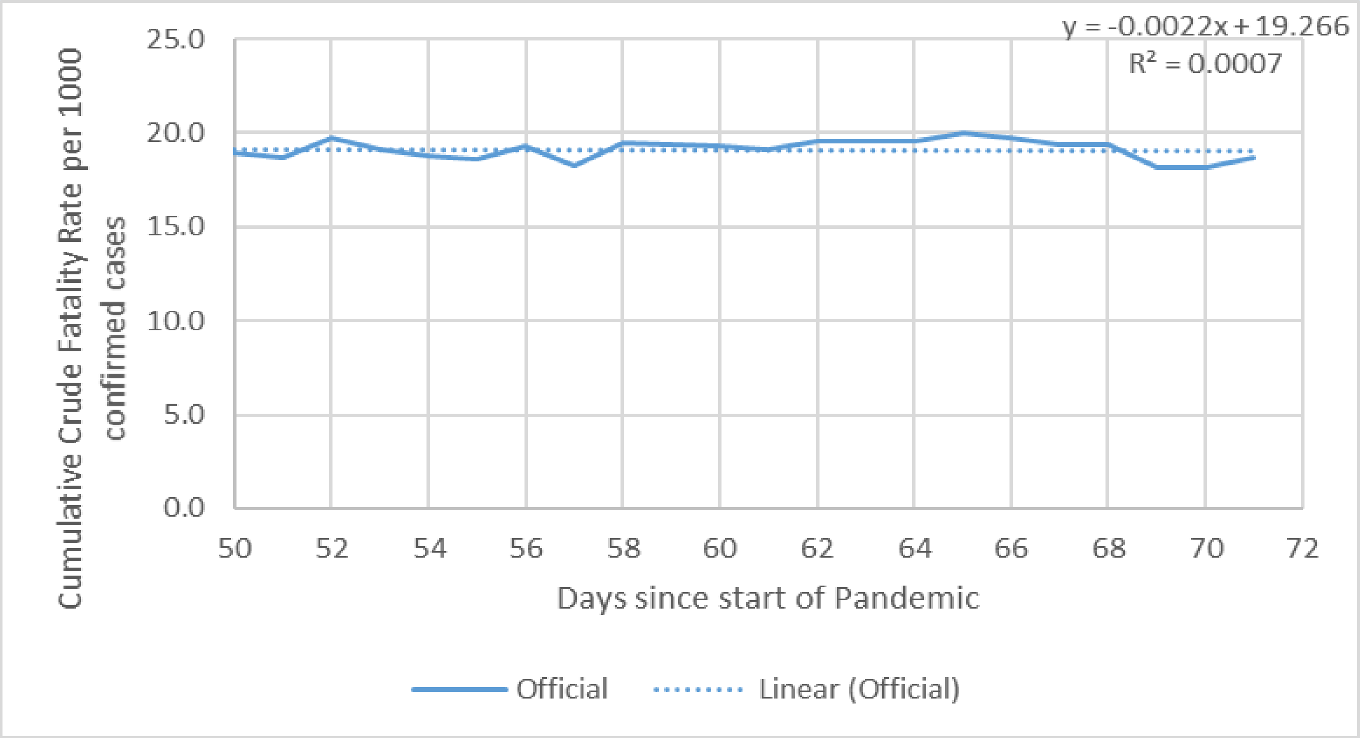
- Figure 5 indicates there were two pronounced peaks in new infection rates on days 45 and 50.
- The erratic pattern could partly be due to time lag in confirmation of test results of new cases.
- Fitting a straight line to the trend by least squares suggests a slightly upward trend.
- We see from these analyses that there is no evidence from the data that the full national (level 5) lock-down reduced the daily growth or the incidence rates in COVID-19 infections in South Africa.

RESULTS: PROJECTIONS OF CASE FATALITY IN COVID-19 IN SOUTH AFRICA

- Figure 6 shows the cumulative crude case fatality rates computed from the official numbers of COVID-19 deaths from day 50 to day 71 onwards as well as a linear fit (the dotted line) to the official numbers.
- The starting point of day 50 was the point at which the cumulative rates had begun to stabilise ranging between 17.97 and 20.1 per 1,000 confirmed cases.
- The linear projection suggests that fatalities due to COVID-19 could reach about 32,400 (95% confidence interval: 32,355 – 33,666) deaths in South Africa by the end of 2020 if the t trends observed during the period 50-71 days of the pandemic continued.

RESULTS: PROJECTIONS OF CASE FATALITY IN COVID-19 IN SOUTH AFRICA

Figure 6: Cumulative Crude Case Fatality Rates from COVID-19 in South Africa



Source: Author's model from official numbers

DISCUSSION AND CONCLUSION

- Fitting mathematical/demographic models to the official COVID-19 progression figures, this study assessed the plausibility of the official numbers, the effect of the full lock-down and projected case fatality rates from COVID-19 in South Africa.
- The results suggest that the official figures under-state the number of COVID-19 infections in the general population.
- Flattening the curve have become buzz words in the era of COVID-19.

DISCUSSION AND CONCLUSION (CONTD)

- Any epidemic will eventually run its course (with or without intervention) hence the first half of an epidemic curve resembles a sigmoid or logistic curve. When the epidemic reaches maturity, the curve becomes flat from the apex until the epidemic starts waning.
- There is no evidence from this study that the national full lock-down flattened the curve of COVID-19 progression in South Africa.

DISCUSSION AND CONCLUSION (CONTD)

- In the course of this study, two questions kept cropping up in my mind: (1) the focus of this study was the first 71 days of the pandemic in South Africa:

1. What is going to happen to the progression of COVID-19 in South Africa as the country moves from one lock-down level to the other?
2. From a demographic perspective, what will be the long-term demographic effects of COVID-19 globally and in individual countries especially regarding population age structures, growth rates and net reproduction rates, and impact on the natural environment?

- Further research is required to address these and other questions.

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- The views expressed in this paper however, are those of the author and not necessarily the views of UNFPA or the University of South Africa (UNISA), or the College of Economics and Management Sciences, UNISA or the Department of Economics, UNISA.