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Regression Model of Covid-19

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Abstract
The COVID-19 pandemic is not the first, and certainly not the last to fiercely hit the world. History is replete with such events. The last two decades of this millennium have already made us confront severe acute respiratory syndrome coronavirus (SARS-CoV), Middle East respiratory syndrome coronavirus (MERS-CoV), avian flu, HINI flu pandemic and SARS-CoV-2 - all of which saw these causative viruses spread quickly and causing widespread havoc.
The 2019 novel coronavirus disease (COVID-19; previously known as 2019-nCoV) outbreak that originated from Wuhan, Hubei province, China, at the end of 2019 was declared a public health emergency of international concern on Jan 30, 2020, by WHO.As a newly appearing infectious disease, COVID-19 garnered great research interest. 210 Countries and Territories around the world have reported a total of more than 31,00,000 confirmed cases and a death toll of more than 2,25,000 deaths.
Lot of research had been done on previous pandemics and even on the current COVID-19 pandemic.Some of the researchershave compared the incidence of COVID-19 cases in countries where the BCG vaccine is used with countries where it is not used and observed that countries that routinely used the vaccine in neonates had less reported cases of deaths due COVID-19 to date. In this paper we are trying to put forward our findings that there is no major impact of BCG vaccination program on number of deaths due to COVID – 19 disease. And also, that development status of the countries has impact on number of deaths due to COVID – 19. We have also modelled number of deaths due to COVID – 19 using regression analysis.
Key-words:*COVID – 19, box-plot, Wilcoxon test, Regression*

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I. Objectives

In this paper we are trying to study the impact of BCG vaccination and development status of the country on number of deaths due to COVID – 19 disease. We have also attempted to model number of deaths due to COVID – 19. For this we took data of all (210) countries affected by COVID – 19. Out that, we removed countries where there were no deaths due to COVID – 19 and also countries for which BCG vaccination data was not available.Data of 157 countries regarding population, number of positive cases, number of deaths and then we also collected the data of whether the country had BCG vaccination program and also whether the country is developed or developing country as per International Monetary Fund (IMF). Purpose of considering whether the country is developed or developing so that the factor of level of medical infrastructure can be considered.

II. Data

Data regarding population, number of positive cases and number of deaths(as on 2nd May 2020)of countries is taken from https://www.worldometers.info/.And the data regarding BCG vaccination program is taken fromhttp://www.bcgatlas.org/and classifying the countries as developed or developingas per IMF data is presented in Table 1.

Table 1. Data of first 20 countries (alphabetically) out of our total data of 157 countries.

Sr. No.	Country	dev.status	BCG.status	Population	positive.cases	no.of.deaths
1	Afghanistan	Developing	Yes	38928346	2335	68
2	Albania	Developing	Yes	2877797	782	31
3	Algeria	Developing	Yes	43851044	4154	453
4	Andorra	Developed	No	77265	745	43
5	Angola	Developing	Yes	32866272	30	2
6	Antigua and Barbuda	Developing	No	97929	25	3
7	Argentina	Developing	Yes	45195774	4532	225

8	Armenia	Developing	Yes	2963243	2148	33
9	Aruba	Developing	No	106766	100	2
10	Australia	Developed	No	25499884	6767	93
11	Austria	Developed	No	9006398	15531	589
12	Azerbaijan	Developing	Yes	10139177	1854	25
13	Bahamas	Developing	No	393244	81	11
14	Bahrain	Developing	No	1701575	3170	8
15	Bangladesh	Developing	Yes	164689383	8238	170
16	Barbados	Developing	Yes	287375	81	7
17	Belarus	Developing	Yes	9449323	14917	93
18	Belgium	Developed	No	11589623	49032	7703
19	Belize	Developing	Yes	397628	18	2
20	Benin	Developing	Yes	12123200	90	2
…						
…						
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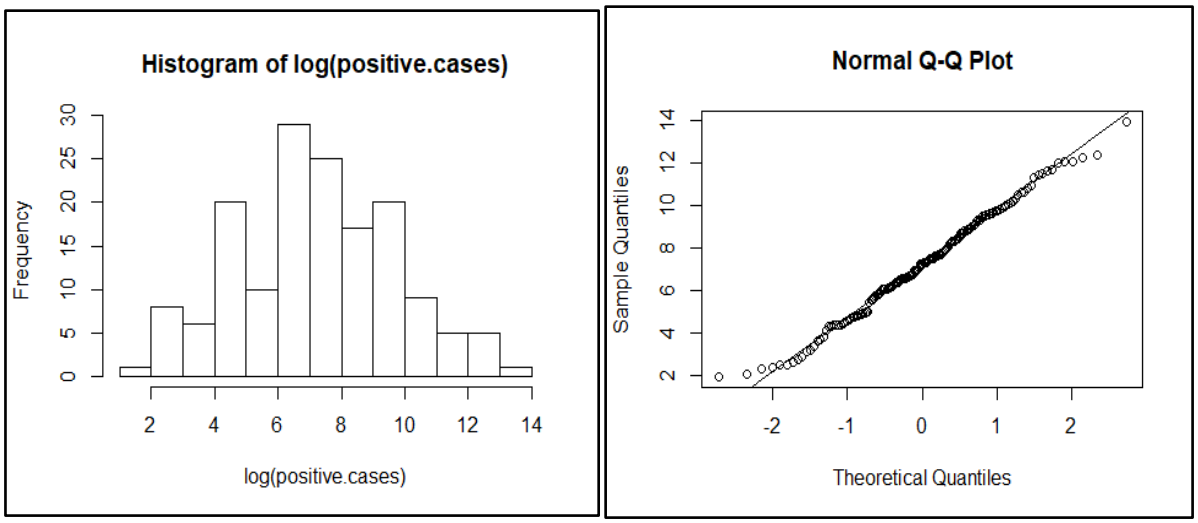
Method and findings

Data analysis was done on the data collected using R programming language.

As variables: number of positive cases and number of deaths have much variations they do not follow normal distribution, we took logarithmic transformation of these variables.Normality of transformed variables is checked using histogram, qq plot and Shapiro – Wilk test.

Normality check fortransformed variable:logarithm of number of positive cases:

Fig.1. Histogram and qq plot of logarithm of number of positive cases



Both the graphs in Fig. 1 suggest that the variable log of number of positive cases is normally distributed.

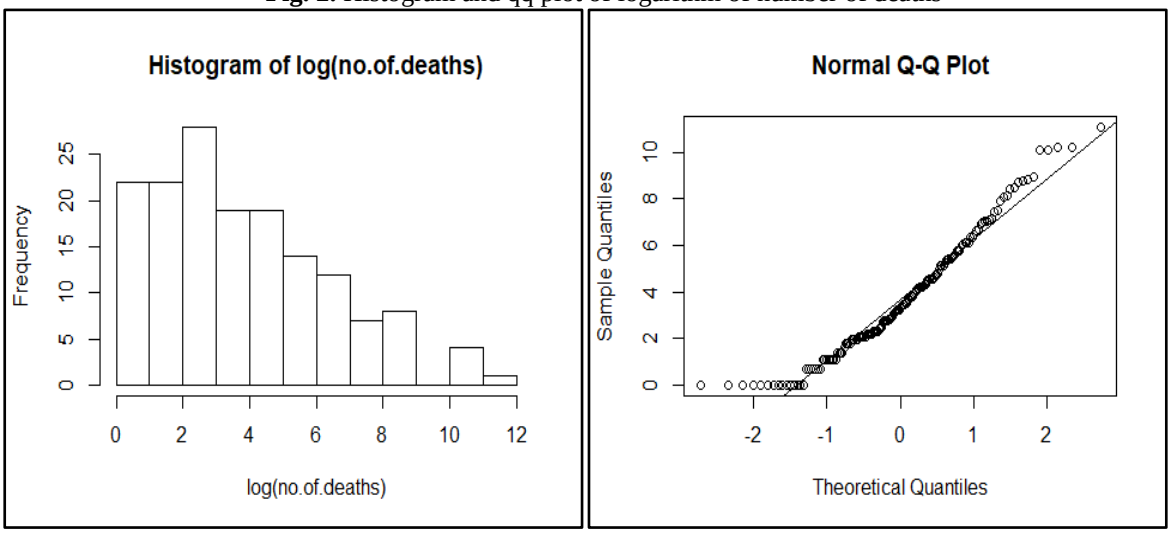
Shapiro-Wilk normality test gave the following results:

W = 0.99146, p-value = 0.4755

Here the value of p = 0.4755 > 0.05, we can say that the variable log of positive cases is normally distributed.

Normality check for transformed variable logarithm ofnumber of deaths

Fig. 2. Histogram and qq plot of logarithm of number of deaths



Both the graphs in Fig. 2 suggest that the variable log of number of deaths is not normally distributed.

Shapiro-Wilk normality test gave the following results:
W = 0.95362, p-value = 4.691 e-05
Here the value of p = 4.691 e -05 < 0.05, we can say that the variable log of number of deaths is not normally distributed.

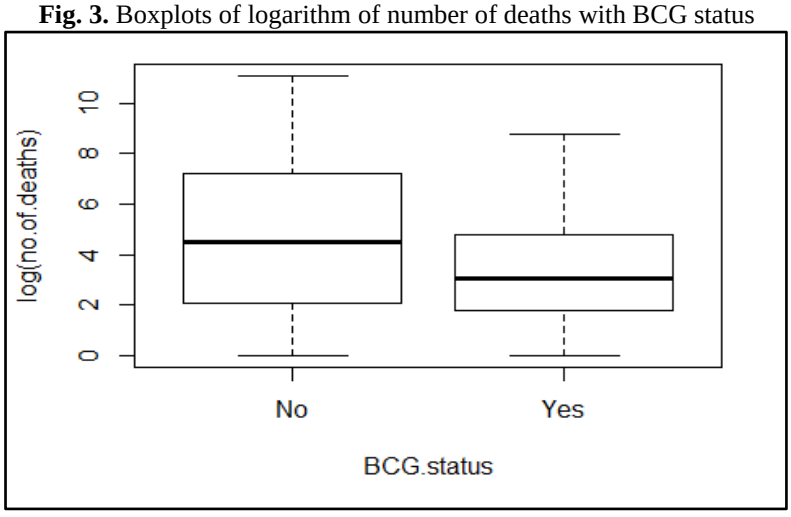
Effect of BCG on number of deaths

Table 2*: Summary statistics of log of number of deaths in countries with and without BCG vaccination*

	Countries without BCG vaccination program	Countries with BCG vaccination program
Number of countries	43	113
Mean	4.608774	3.381844
Standard deviation	3.352526	2.230468

To test whether there is significant difference in number of deaths due to BCG vaccination in country, we will use Box-plot test and Non-parametric test.

Fig. 3. Boxplots of logarithm of number of deaths with BCG status



The box plot in Fig. 3 suggests that the average number of deaths in countries where BCG vaccination is not mandatory is almost same to countries where BCG vaccination ismandatory.

The above result is again strengthened bythe following Non-parametric test.

H_o: There is no significant difference betweenaverage number of deaths in countries where BCG vaccination program is mandatory and in countries where it was not
H_1: There is significant difference between average number of deaths in countries where BCG vaccination program is mandatory and in countries where it was not

The R output gave the following result:

Wilcoxon rank sum test

W = 2903, p-value = 0.06

As p-value > 0.05, we conclude there is no significant difference between average number of deaths in countries where BCG vaccination program is mandatory and in countries where it was not at 5% level of significance.

There are several articles which suggest that "Countries with national program of whole population BCG vaccination appear to have a lower incidence and death rate from Covid-19". Our results suggest that in the absence of a specific vaccination against Covid-19, population-based BCG vaccination do not have any role in reducing the impact of this disease.

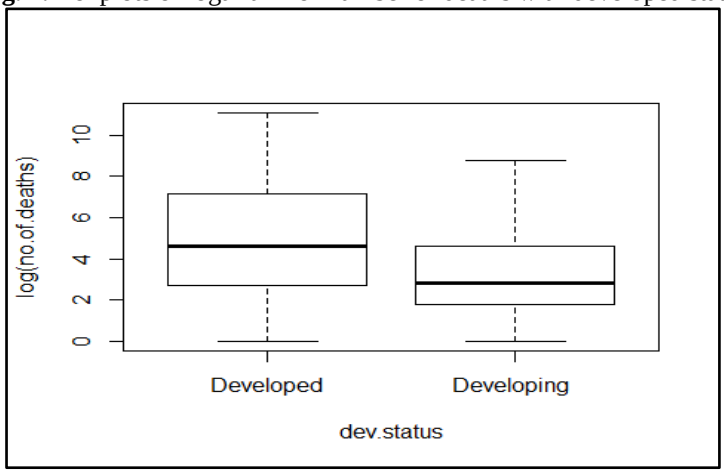
Effect of developing status of country on number of deaths

Table 3: *Summary statistics of log of number of deaths in developed and developing countries*

	Developed Countries	Developing Countries
Number of countries	46	110
Mean	4.880451	3.234775
Standard deviation	3.146740	2.231364

To test whether there is significant difference in number of deaths due to developing status of the country, we will use Box-plot test and Non-parametric test.

Fig. 4. Boxplots of logarithm of number of deaths with developed status



The box plot in Fig. 4 suggests that the average number of deaths in countries with developed status is higher compared to countries with developing status.

The above result can be verified using Non-parametric test.

H0: There is no significant difference in the average number of deaths in developed and developing countries
H1: There issignificant difference in the average number of deaths in developed and developing countries

The R output gave the following result:

Wilcoxon rank sum test

W = 3310, p-value = 0.002

Here p-value< 0.05, we can conclude that there is significant difference in number of deaths due to developing status at 5%level of significance.
This indicates that even though the developed countries have good infrastructure and other medical facilities but they might not be serious on the effect of such corona virus and did not take necessary steps intime like lock down of sufficient period of time and this may be one of the important factors for large number of death.

Regression model

We have used regression analysis to model number of deaths due to Covid – 19. For this we took data of all countries affected by COVID – 19. Out that, we removed countries where there were no deaths due to COVID – 19 and also countries for which BCG vaccination data was not available. Finally, we had data for 156 countries. We have considered the variables like population, number of positive cases, BCG.status and development status as independent variable and number of deaths as dependent variable for these 156 countries.

We have used R programming language to fit the regression model. The development status of the country was not a significant variable. After removing that variable, the R output of final fitted model is given below.

```
Coefficients:
##                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)       -5.94744    0.65307  -9.107 4.56e-16 ***
## log(Population)    0.29133    0.05447   5.349 3.20e-07 ***
## log(positive.cases)  0.79651    0.04250  18.741  < 2e-16 ***
## BCG.statusYes      -1.00378    0.21121  -4.752 4.62e-06 ***


Residual standard error: 0.9868 on 152 degrees of freedom
## Multiple R-squared:  0.8625, Adjusted R-squared:  0.8598
## F-statistic: 317.7 on 3 and 152 DF,  p-value: < 2.2e-16
```

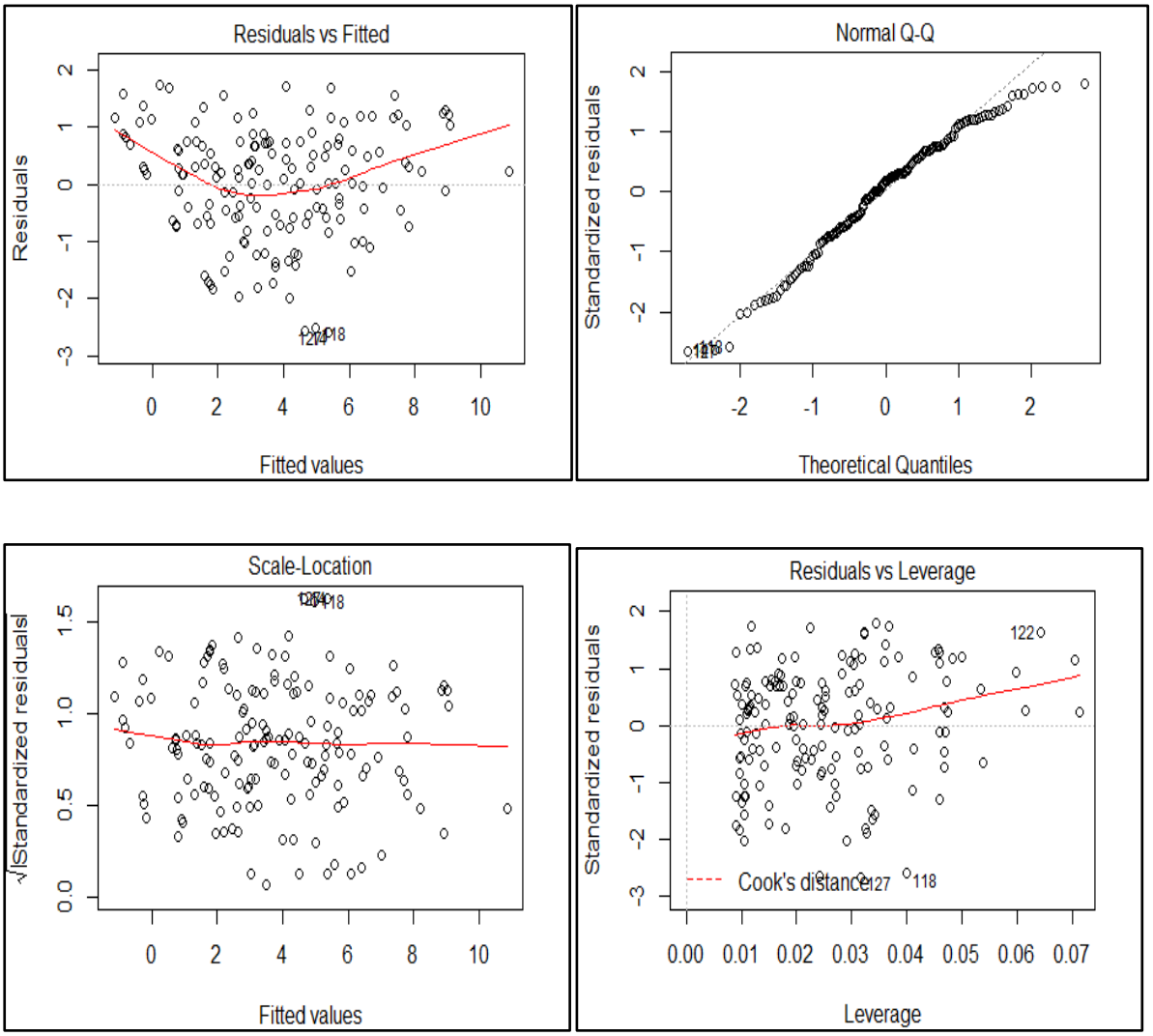
The above output suggest that log (Population), log(positive.cases)and BCG.status are significant variables for predicting the dependent variable log(no. of deaths).
Also, Adjusted R – squared = 0.8598 which shows that the model is the good fit. The fitted model is given below:

Model:

Log (no. of deaths) = -5.94744 + 0.29133 * log (Population)
+ 0.79651 * log(positive.cases)
–1.00378 *(BCG.status)

The model validation can be done by the four different graphs shown in Fig. 5. The graphs suggest that model is a good fit satisfying the required assumptions

Fig. 5: *Graphs for Model validation*



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