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# Modeling and prediction of COVID-19 spread in the Philippines by October 13, 2020, by using the VARMAX time series method with preventive measures

Parikshit Gautam Jamdade [a,*,1], Shrinivas Gautamrao Jamdade [b,1]

[a] PVG's College of Engineering and Technology, Pune, Maharashtra, India
[b] Nowrosjee Wadia College, Pune, Maharashtra, India

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ABSTRACT

COVID-19 outbreak is the serious public health challenge the world is facing in recent days as there is no effective vaccine and treatment for this virus. It causes 257,863 confirmed cases as of September 13, 2020, with 4292 deaths in the Philippines up till now. Understanding the transmission dynamics of the infection is a crucial step for evaluating the effectiveness of control measures. Owing to this, forecasts of COVID-19 cases, deaths, cases per million, and deaths per million are necessary for the Philippines. We examine the characteristics of COVID-19 affected populations based on the data provided by WHO from December 31, 2019, to September 13, 2020. In this paper, forecasts, and analysis of the COVID-19 cases, deaths, cases per million, and deaths per million were presented for 30 days ahead. The projection results are compared with the actual data values and simulated results from the VARMAX time series method. Societal growth is assessed by the median growth rate (MGR). President Rodrigo R Duterte of the Philippines has taken good steps but much more needs to be done. We suggest Philippines governments must rapidly mobilize and make good policy decisions to mitigate the COVID-19 spread. This paper mentions major contributions, current concerns, and challenges during and post COVID-19 epidemic in the Philippines with few non-considered measures to reduce the spread of the COVID-19.

## Introduction

The epidemic of the COVID-19 is increasing day by day severely affecting a large population in the world [1]. Densely populated areas of countries and highly mobile populations are affected mostly showing larger transmission growth [2]. COVID-19 pandemic has damaged human lives and health. It exposes the weak health infrastructure of the countries of the world affecting the world economy. Millions of people have lost their jobs in the past few months. The lower down transmission rate is the most difficult job in the COVID-19 epidemic [3]. WHO declared the spread of COVID-19 as a public health emergency, and the confirmed cases continued to rise globally [4]. Forecasting and analysis of COVID-19 spread is the biggest challenge for forecasters and modelers, as limited data is available to characterize early growth trajectory and its analysis, which enables the countries to respond to the outbreak. There are various statistical models used to forecast the data used for different applications [5–7]. The transmission model is formulated for forecast and analysis of COVID-19 must rely on the total number of infected, total deaths, and prediction of these. This information can be useful to health agencies to make decisions to lower down the spread [8]. Various researchers used numerous models for predictions of the COVID-19 epidemics having large variations in results [9–12]. The impact of immigrants on the dynamics and control of HBV infection is studied by using optimal control theory which provides the best strategies to lower down infectious diseases in the population at the minimal possible cost. Several effective optimal control models for infectious diseases have been developed [13–18]. The FO derivative application is used in the modeling of electrical systems. The dynamics of hepatitis B and E has been modeled using different FO operators with the effect of hospitalizations in [19,20].

The Philippine Department of Health (DOH) confirmed its first case of COVID-19 on January 20, 2020. The Philippines was already declared the Enhanced Community Quarantine (ECQ) in NCR, Region 3 (excluding Aurora), Region 4-A, and the provinces like Pangasinan,

* Corresponding author.
*E-mail address:* parikshit_jamdade@yahoo.co.in (P. Gautam Jamdade).
[1] Present/Permanent Address: Subhadra, S. No. 8+9/18+19, Lane No.2, Below Canal, Near Ganpati Temple, Karvenagar, Pune – 411052, Maharashtra, India.

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Benguet, the Island of Mindoro, Albay, Catanduanes, Antique, Iloilo, Cebu, and Davao del Norte. The enhanced community quarantine (ECQ) involves a temporary suspension of classes, work-from-home, and skeletal or limited workers, and restriction of the population to their homes. It allows only essential services like health care, food supply, medicines, and banking during the ECQ. The doctor-to-patient ratio is poor in the Philippines, having one doctor per 33,000 patients, and one hospital bed is available to every 1121 patients.

Cumulative confirmed case data for the COVID-19 was taken from the WHO site from December 31, 2019, to September 13, 2020. In this study, total COVID-19 cases, total COVID-19 cases per million, total COVID-19 deaths, and total COVID-19 deaths per million are forecasted for 30 days ahead from September 13, 2020, for taking decisions and doing preparation for COVID-19 epidemics.

## Material and methods

### Mathematical model

To understand the COVID-19 epidemic, we need accurate data of confirmed cases of the infected people. But some infected people may not have symptoms, as well as people who do not carry laboratory tests and those who are misdiagnosed. In such scenarios, confirmed COVID-19 cases are only a fraction of the total infected peoples. So, model parameters cannot be accurately calculated from the COVID-19 data resulting in non-accurate predictions. Due to this normal distribution model is used. The mean, standard deviation, skewness, and kurtosis of COVID-19 data are calculated and analyzed.

The Normal distribution CDF (Cumulative Density Function) is

$$F(V) = \varphi\left(\frac{V-\mu}{\sigma}\right) = \frac{1}{2}\left[1 + erf\left(\frac{V-\mu}{\sigma\sqrt{2}}\right)\right] \tag{1}$$

The Normal distribution PDF (Probability Density Function) is

$$f(V) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(V-\mu)^2}{2\sigma^2}} = \frac{1}{\sigma}\varphi\left(\frac{V-\mu}{\sigma}\right) \tag{2}$$

where μ is the sample mean and σ is the standard deviation of COVID-19 data.

The CDF of the COVID-19 data provides information about the fraction of time or probability that the COVID-19 data has a particular value or lower than a particular value which is useful for determining the COVID-19 data parameters and their variations. Fig. 1 shows the PDF and CDF plots for total COVID-19 cases with upper and lower bounds (95% CI) while Fig. 2 shows the PDF and CDF plots for total COVID-19 deaths with the upper and lower bounds. Also Fig. 3 shows the PDF and CDF plots for total COVID-19 cases per million with upper and lower bounds with Fig. 4 showing the PDF and CDF plots for total COVID-19 deaths per million with upper and lower bounds.

The PDF observed from Fig. 1a to 4a shows that the most fraction of net total COVID-19 cases, net total COVID-19 deaths, net total COVID-19 cases per million, and net total COVID-19 deaths per million expected in the Philippines are about 49000, 1000, 300, and 5 respectively. The CDF observed from Fig. 1b to 4b shows that net total COVID-19 cases, net total COVID-19 deaths, net total COVID-19 cases per million, and net total COVID-19 deaths per million greater or equal to 80% in the Philippines are 100000, 1800, 800, and 18 respectively.

### VARMAX time series method

The VARMAX time series method stands for Vector Autoregressive Moving Average with an exogenous time series method. It is used as an epidemic model for the evaluation of infectious disease spread and used for forecasting.

A simple algorithm for determining the VARMAX model is given below. Let consider a k-variate time-series $Y_t$ induced by linearly mixed stochastic and controlled inputs:

$$\varphi(B)y_t = \beta(B)x_t + \vartheta(B)a_t, t = 1, ...., T,$$

$$\Re^{k\times k} \ni \varphi(B) = I - \varphi_1 B - ..... - \varphi_p B^p,$$

$$\Re^{k\times k} \ni \theta(B) = I - \theta_1 B - ..... - \theta_q B^q,$$

$$\Re^{k\times m} \ni \beta(B) = \beta_0 + \beta_1 B + ...... + \beta^{r-1} B^{r-1},$$

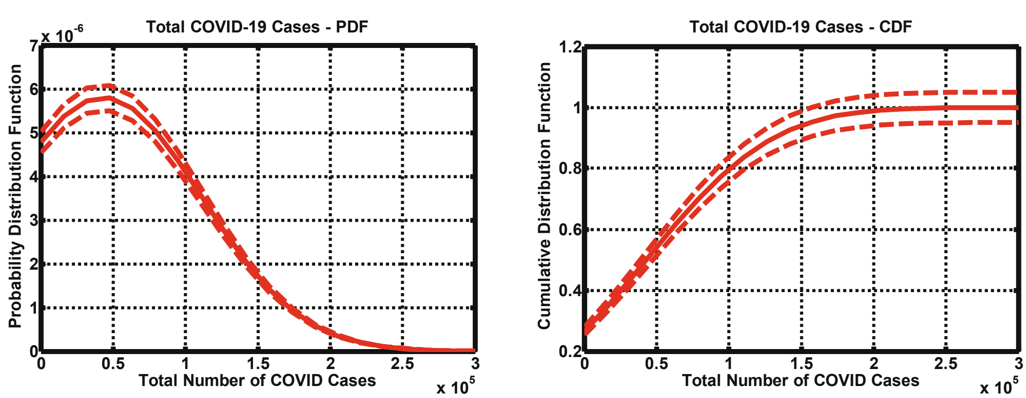
$$\{y_t, a_t\} \in \Re^{k\times 1}, x_t \in \Re^{m\times 1},$$

$$a_t \sim NID(0, \Omega). \tag{3}$$

We assume that the model is stationary and invertible. Eq. (3) is solved by Ordinary Least Squares (OLS). For this, we introduce the following definitions:

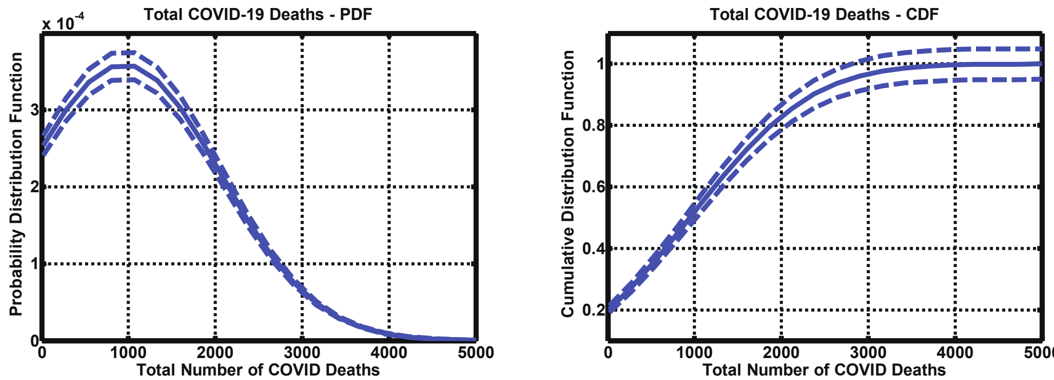
$$\Re^{n\times k} \ni y = \begin{bmatrix} y_{11}\cdots y_{1k} \\ \cdots\cdots \\ \cdots\cdots \\ y_{n1}\cdots y_{nk} \end{bmatrix},$$

$$\Re^{n\times k} \ni a = \begin{bmatrix} a_{11}\ldots a_{1k} \\ \cdots\cdots \\ \cdots\cdots \\ a_{n1}\ldots a_{nk} \end{bmatrix},$$



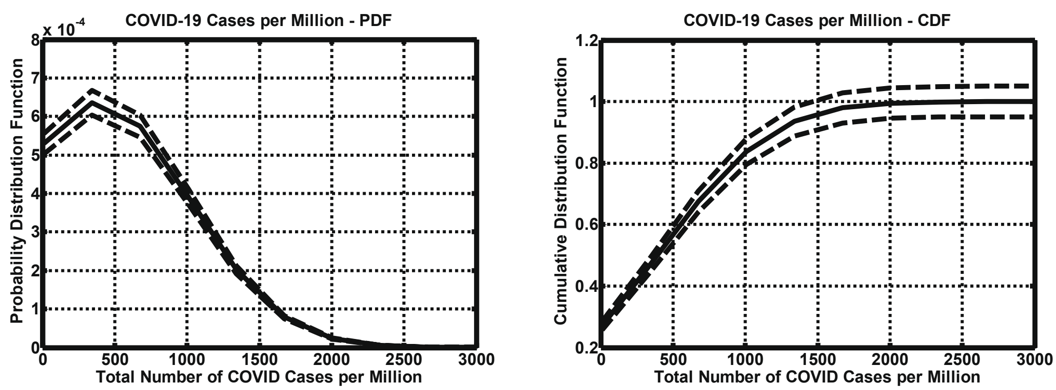

a                                                  b

**Fig. 1.** a, PDF and b, CDF plot for total COVID-19 cases with upper and lower bounds.



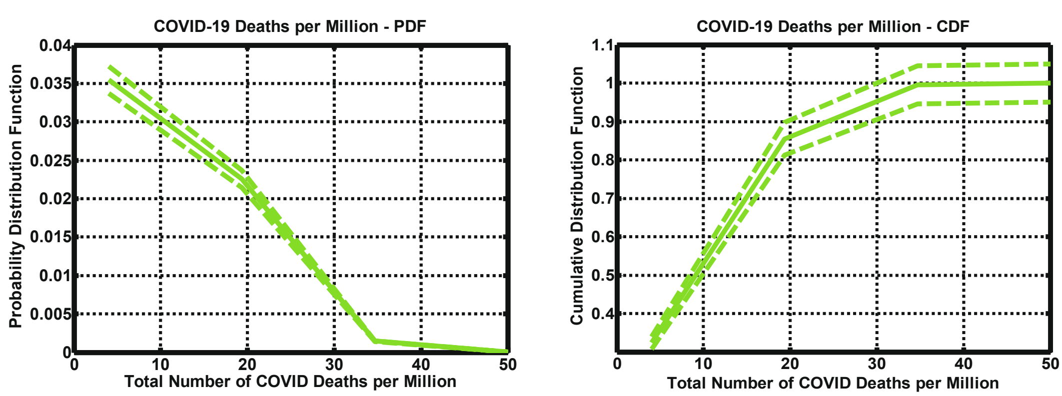

a b

**Fig. 2.** a, PDF and b, CDF plot for total COVID-19 deaths with upper and lower bounds.




a b

**Fig. 3.** a, PDF and b, CDF plot for total COVID-19 cases per million with upper and lower bounds.




a b

**Fig. 4.** a, PDF and b, CDF plot for total COVID-19 deaths per million with upper and lower bounds.

$$\Re^{n\times m}\ni X=\begin{bmatrix}X_{11}\ldots X_{1k}\\ \ldots\ldots\\ \ldots\ldots\\ X_{n1}\ldots X_{nk}\end{bmatrix}$$

Let:

$$\Re^{n\times kp}\ni Y=\left(By,B^2y,\ldots\ldots,B^py\right),$$

$$\Re^{n\times kq}\ni A=\left(Ba,B^2a,\ldots\ldots,B^qa\right),$$

$$\Re^{n\times rm}\ni X=\left(x,Bx,\ldots\ldots,B^{r-1}x\right),$$

$$\Re^{n\times(k(q+p)+rm}\ni U=(-A,Y,X),$$

$$\Re^{qk\times k}\ni\theta=\left(\theta_1,\ldots\ldots,\theta_q\right)^T,$$

$$\Re^{pk\times k}\ni\varphi=\left(\varphi_1,\ldots\ldots,\varphi_p\right)^T,$$

$$\Re^{rm\times k}\ni\beta=\left(\beta_0,\beta_1,\ldots\ldots,.\beta_{r-1}\right)^T,$$

$$\Re^{(k(q+p)+rm)\times k}\ni\delta=\left(\theta_1,\theta_2,\ldots..,\theta_q,\varphi_1,\varphi_2,\ldots\ldots\varphi_p,\beta_0,\beta_1,\ldots\ldots,.\beta_{r-1}\right)^T,$$

We now separate the current and past elements of y, and $a_t$ in Eq. (3):

$$y_t-(\varphi_1B+\varphi_2B^2+\ldots+\varphi_PB^p)y_t=(\beta_0+\beta_1B+\ldots+\beta_{r-1}B^{r-1})x_t+a_t-(\theta_1B+\theta_2B^2+\ldots+\theta_qB^q)a_t,$$

or, equivalently,

$$y_t^{'}-\left(By_t^{'},B^2y_t^{'},\ldots,B^py_t^{'}\right)\begin{bmatrix}\varphi_1^{'}\\ \varphi_2^{'}\\ .\\ .\\ .\\ \varphi_p^{'}\end{bmatrix}=\left(x_t^{'},Bx_t^{'},\ldots,B^{r-1}x_t^{'}\right)\begin{bmatrix}\beta_0^{'}\\ \beta_1^{'}\\ .\\ .\\ .\\ \beta_{r-1}^{'}\end{bmatrix}+a_t^{'}-\left(Ba_t^{'},B^2a_t^{'},\ldots,B^qa_t^{'}\right)\begin{bmatrix}\theta_1^{'}\\ \theta_2^{'}\\ .\\ .\\ .\\ \theta_q^{'}\end{bmatrix}\quad(4)$$

Using the above definitions we may reformulate Eq. (5) as follows:

$$y-Y\varphi=X\beta+a-A\theta\Rightarrow y=-A\theta+Y\varphi+X\beta+a$$
$$=(-A,Y,X)\begin{pmatrix}\theta\\ \varphi\\ \beta\end{pmatrix}+a,$$

$$y=U\delta+a\quad(5)$$

The model orders are estimated by the algorithm consisting of two major stages. In stage 1, the optimal lag orders for yt, xt, and at are calculated. In stage 2 the optimal lag orders are used as fixed values in an iterative calculation of the system matrices $Ø_i$, $\theta_j$, and $\beta_k$.

Stage 1. Estimating p, q, and r.

Stage 1, consists of two steps. In Step 1, we calculate optimal lag orders for the endogeneous and exogenous vectors, i.e. the parameters s and r. In Step 2, we decompose s into the lag order p for the endogeneous vector and the lag order q for the residual process.

Step 1. Determining the (s, r) order.

For each combination of s = 0, 1, … and r = 1, 2 , … , we:

(i) Build the matrices, $Y_s$, $X_r$ and

$$W=(Ys,Xr)\in\Re^{n\times(ks+rm)},$$

(ii) Estimate the model

$$y=W\gamma+e,$$

e.g. with OLS, which gives

$$\gamma=(W^{'}W)^{-1}W^{'}y\in\Re^{kp+rm}$$

$$e=y-W\gamma,$$

$$\sum e=cov\ (e_t).\quad(6)$$

(iii) Calculate the AIC information criterion

$$AIC=ln\left|\sum e\right|+\frac{2\ (s+r)\ (k+m)^2}{2}.\quad(7)$$

Here we select the combination (s, r) which minimizes AIC. This gives an estimate of the true order r of the X matrix. In calculating the OLS estimates γ we can use a method of adding/deleting variables.

Let the matrix of residuals e, obtained for the chosen (s, r) order, a(0). These residuals are then used to estimate the orders p and q and a new parameter vector δ as following way:

Step 2. Determining the (p, q) order.

We note that the residuals a(0) of Step 1 remain unchanged in all regressions of Step 2. For each combination of p = 0, 1,… and q = 0, 1,… around the reference point s = p + q, we:

(i) Build the matrices $Y_p$ as above,

$$A_q(0)=(Ba(0),B^2a(0),\ldots..,B^qa(0)),$$

and

$$U(0)=(-A_q(0),Y_p,X_r).$$

(ii) Estimate the model

$$y=U(0)\ \delta(1)+e$$

With OLS,

$$\delta(1)=(U^{'}(0)\ U(0))^{-1}U^{'}(0)y,$$

$$e=y-U^{'}(0)\delta(1),$$

$$\sum e=cov\ (e_t).\quad(8)$$

(iii) Estimate the Schwartz-Rissanen (SR) criterion

$$SR = ln\left|\sum e\right| + (p+q+r)\ (k+m)^2\frac{lnn}{n}. \quad (9)$$

We then choose that combination (p*, q*) which minimizes SR and set

$$a(1) = e(p^*, q^*).$$

Next, let j = 1 and proceed to Step 2 of stage 2.

When j = 1 the parameter values are inherited from stage 1.

Stage 2. Iterative estimation of model parameter values, given the optimal lag orders p, q, and r.

Step 1. Calculating the iteration

$$a_t(j) = y_t - \sum_{i=1}^{p}\varphi_i(j)y_{t-i} + \sum_{i=1}^{q}\theta_i\ (j)a_{t-i}(j) - \sum_{i=0}^{r-1}\beta\ _i(j)x_{t-i},\ t = 1,\ 2, \ldots\ldots, n. \quad (10)$$

Step 2. Calculating new parameter estimates.

Let

$A_q(j) = (Ba(j), B^2a(j), \ldots., B^q a(j))$ and

$$U(j) = (-A_q(j), Y_p, X_r).$$

Then estimate

$$y = U(j)\ \delta(j+1) + a(j+1). \quad (11)$$

Using OLS, where

$$\delta(j) = (\theta_1(j), \ldots\ldots, \theta_q(j), \varphi_1(j), \ldots\ldots., \varphi_p(j), \beta_0(j), \ldots\ldots, \beta_{r-1}(j))^T.$$

Step 3. Check for convergence.

If

$|\delta(j+1) - \delta(j)|\ >\ \varepsilon,\ \varepsilon > 0$, some convergence criterion, then let

$j = j + 1$ and go to Step 1.

else let

$$\delta = \delta\ (j+1),$$

$$\delta = (\theta_1, \ldots\ldots, \theta_q, \varphi_1, \ldots\ldots., \varphi_p, \beta_0, \ldots\ldots, \beta_{r-1})^T$$

and stop.

In this study, variable $X_t$ represents the COVID-19 cases, COVID-19 deaths, COVID-19 cases per million, and COVID-19 deaths per million.

Fig. 5 shows the forecasted plots using the VARMAX time series method a, COVID-19 cases, b, COVID-19 deaths, c, COVID-19 cases per million, and d, COVID-19 deaths per million which were used to determine. The trend of the respective forecasted data values is represented by the red color line while blue color lines represent upper and lower bounds in those values. These forecasted values are added with current data values that present the total forecasted COVID-19 data parameter values for 30 days ahead.

## Results and findings

For forecasting, the VARMAX time series method is used. Currently, on September 13, 2020, total COVID-19 cases are 257,863 in the Philippines. 30-day ahead forecasts show, with the above cases there will be an average addition of COVID-19 cases are 375,000 in the Philippines. Then total cumulative COVID-19 cases after 30 days will be 632863. In the Philippines, on September 13, 2020, the total COVID-19 cases per million are 2353.171. 30-day ahead forecasts show, with the above cases there will be an average addition of COVID-19 cases per million are 3500 in the Philippines. So the resulting total cumulative COVID-19 cases per million will be 5853 in the Philippines after 30 days.

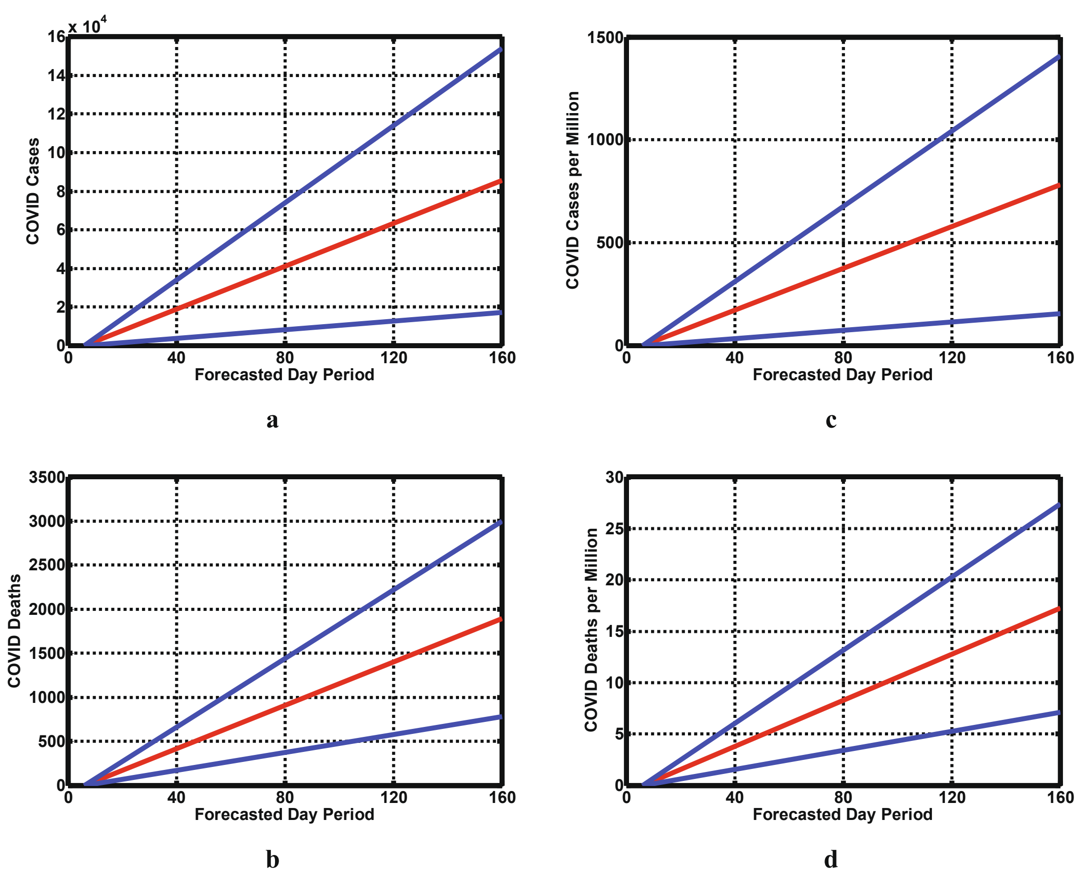



**Fig. 5.** Forecasted Plots using VARMAX Time Series Method a, COVID-19 cases, b, COVID-19 deaths, c, COVID-19 cases per million, and d, COVID-19 deaths per million.

**Table 1**
Actual and Forecasted COVID-19 Parameters.

| | Actual Values | | Simulated Values | | Percentage Error | | Forecasted Values | |
|---|---|---|---|---|---|---|---|---|
| Dates | 2020–08-19 | 2020–09-02 | 2020–08-19 | 2020–09-02 | 2020–08-19 | 2020–09-02 | 2020–09-30 | 2020–10-13 |
| Cases | 169,213 | 224,264 | 158,054 | 240,732 | −7 | 7 | 500,631 | 632,863 |
| Deaths | 2687 | 3597 | 2873 | 3396 | 6 | −6 | 5330 | 6632 |
| Cases per Million | 1544.181 | 2046.558 | 1446 | 2184 | −7 | 6 | 4595 | 5853 |
| Deaths per Million | 24.521 | 32.825 | 26 | 31 | 5 | −7 | 48 | 60 |

**Table 2**
Upper and lower bound (±5%) of Forecasted COVID-19 parameters.

| | Forecasted Values on 2020-09-30 | | Forecasted Values on 2020-10-13 | |
|---|---|---|---|---|
| | Upper Bound | Lower Bound | Upper Bound | Lower Bound |
| Cases | 525,663 | 475,599 | 664,506 | 601,220 |
| Deaths | 5597 | 5064 | 6964 | 6300 |
| Cases per Million | 4825 | 4365 | 6146 | 5561 |
| Deaths per Million | 50 | 46 | 63 | 57 |

On September 13, 2020, total COVID-19 deaths were 4292 in the Philippines. 30-day ahead forecasts show, with the above cases there will be an average addition of COVID-19 deaths of 2340 in the Philippines. Total cumulative COVID-19 deaths after 30 days will be 6632 in the Philippines. In the Philippines, on September 13, 2020, total COVID-19 deaths per million are 39.167. 30-day ahead forecasts show, with the above deaths there will be an average addition of COVID-19 deaths per million are 20.625 in the Philippines. Then total cumulative COVID-19 deaths per million after 30 days will be 60 in the Philippines.

These forecasts are useful for real-time preparation for anticipating the required number of hospital beds and other medical resources needed to prepare in the coming days. Table 1 presents the comparison between actual, already simulated COVID-19 data, and percentage errors, with forecasted values while Table 2 presents the upper and lower bound (±5%) values of forecasted COVID-19 data parameters.

Many researchers with the help of doubling rate as a tool try to access the measures of COVID-19 spread in terms of the time period (days). But doubling the rate becomes ineffective for countries having a large population as the infected population becomes large like the USA, India, Russia, and Brazil, etc. To access societal growth, we are using a median growth rate (MGR) where growth is expressed in terms of the time period which was determined by time (days) taken to have value 1.5 times that of the previous number of COVID-19 cases. In the case of the Philippines currently, MGR is 17 days.

## Discussion

Here discussion was presented based on the results involving the impact of control measures taken by the Philippine, major contribution, current concerns, and challenges of the COVID-19 epidemic with control measures.

### *Impact of control measures taken by the Philippine*

In the world, various countries are taking steps and measures to counter the COVID-19 epidemic (B. Krishnakumar and S. Rana, 2020; M. L. Holshue et al., 2020; Q. Li et al., 2020) by considering various types of parameters (Zhao, S., Musa, et al. 2020). President Rodrigo R Duterte issued Proclamation 922 on March 8, declaring a state of national emergency due to the COVID-19 epidemic in the Philippines. On March 13, 2020, Enhanced Community Quarantine (ECQ) was announced which was initially limited to the National Capital Region (NCR). Due to community transmission, it is extended to the entire Philippines. In the Philippine land, sea, and air transportation were banned but essential services were allowed. It involves medical drugs and goods, sanitation operations, and emergency cases. People were directed to work from home instead of from the workplace with the use of online communications and business transactions to avoid gathering in offices. The Philippines gave special powers to provide public and private hospitals with additional support like the purchase of additional equipment and to engage temporary additional doctors and staff.

DOH of the Philippines has directed five new sub-national laboratories operating alongside the Research Institute for Tropical Medicine. These are San Lazaro Hospital, Baguio General Hospital & Medical Center for Luzon, Vicente Sotto Memorial Medical Center for Visayas, and Southern Philippines Medical Center for Mindanao. Two additional laboratories now in the operating set-up are Western Visayas Medical Center and Bicol Public Health Laboratory. The University of the Philippines-National Institutes of Health is now testing overflow samples from the Research Institute for Tropical Medicine. With the help of WHO and the Research Institute for Tropical Medicine, DOH started five more laboratories in private tertiary hospitals starting on March 21, 2020. These are St. Lukes Medical Center - Global City, Makati Medical Center, The Medical City, St. Lukes Medical Center - Quezon City, and Chinese General Hospital. Owing to control measures in the Northern Luzon Ilocos region, Bicol, Mimaropa, and Cagayan Valley provinces, the COVID-19 epidemic has lowered down with fewer new cases reported.

In the case of the Philippines, total cumulative COVID-19 cases are rising day by day showing major concerns but their recovery rate is also increasing showing good effect of control measures. Due to the COVID-19 epidemic commercial and industrial sectors are fully or partly closed in the country causing a lesser job with a lesser amount of salary and cash flow. This issue can turn into lower GDP growth. As per our observation country may face a post-COVID-19 economic recovery problem i.e. GDP growth as the biggest challenge.

### *Major contribution during COVID-19 epidemic*

Major contributions during the COVID-19 epidemic done by the Philippines are

- President Rodrigo R Duterte's leadership take a good decision for curbing the spread
- Timely response from President Rodrigo R Duterte resulted in lowering of transmission of COVID-19
- Strong lockdown implemented by President Rodrigo R Duterte
- Economic policies related to industries directed by President Rodrigo R Duterte
- Public support created by President Rodrigo R Duterte

### *Current concerns during COVID-19 epidemic*

Major concerns during the COVID-19 epidemic faced by the Philippines are

- Lack of science advisory structures
- Nationwide community spread

- Saving of people who have medical problems
- Sequential lifting of lockdown without spreading of COVID-19
- Lack of funds locally and centrally throughout the country
- Poor food distribution chain in the Philippines
- Lack of rapid people and food transfer infrastructure
- The critical shortage of medical personal, protective equipment (PPE)
- Lack of medical research and diagnostic laboratories
- Lack of medical educational infrastructures like medical colleges and universities
- Lack of science advisory group for emergencies situations
- Limited budget for human and material resources
- Lack of big special infectious disease hospitals

*Challenges post COVID-19 epidemic*

Major post-COVID-19 epidemic challenges will be faced by the Philippines are

- Post-COVID 19 economic recovery i.e. GDP growth
- Jobs curtailment need to be taken care
- Migration of labors from the urban area to rural area due to lack of job
- Attracting tourist in the Philippines
- Development of funds locally and centrally throughout the country
- Development of new big hospitals for future disasters
- Building good food distribution chain to curb disasters
- Lack of rapid people and food transfer infrastructure
- Building large health infrastructure to mitigate health disasters
- The building of a science advisory group for emergencies to mitigate effects

Our observations show few non-considered measures can also reduce the spread of the COVID-19 within family clusters, residential compounds, areas, cities, and regions in Philippine are

1] The Philippines should build and develop a sound science advisory body and group for emergencies involving field experts and researchers rather than the political party's representatives.
2] Distribution of basic needs like drinking water, bread, milk, common medicines, and food packages to the resident at a lower rate or free
3] Providing and arranging additional resources to combat the COVID-19 epidemic depending on mathematical and statistical modeling.
4] No home visitor's policy.
5] Special hospitals for infectious diseases
6] Increased health budget
7] Increased a budget for welfare and safety of peoples
8] Price freeze control on household goods
9] Strengthening of school and college medical services, hygienic practices, and mental health

COVID-19 outbreak is a serious public health challenge to the world. In this paper, transmission dynamics of the infection are performed using the VARMAX time series model which shows that the effectiveness of control measures is necessary to lower down the COVID-19 cases, deaths, cases per million, and deaths per million in the Philippines. The comparison between the simulated and the actual data values shows a good match from the VARMAX time series method. The societal growth is assessed by the median growth rate (MGR) shows serious concerns in the Philippines to take immediate steps and good policy decisions to mitigate the COVID-19 spread. Few mentioned non-considered measures can help to reduce the spread of the COVID-19.

## Conclusions

Mathematical modeling is a tool for analyzing, assessing, and predicting the scale and time course of COVID-19 epidemics, and evaluating the effectiveness of public health measures and policies. In the present work, we use a VARMAX time series method to analyze the dynamics of COVID-19. The model is further used to estimate the parameters of COVID-19 like net the total COVID-19 cases, net total COVID-19 deaths, net total COVID-19 cases per million, and net total COVID-19 deaths per million using the reported infected cases documented in the Philippines from December 31, 2019, to September 13, 2020. The ordinary least squares algorithm is used for parameter estimation. The findings show that the model simulated infected values are in good agreement with the reported COVID-19 infected cases. As per the VARMAX time series method, on October 13, 2020, net the total COVID-19 cases, net total COVID-19 deaths, net total COVID-19 cases per million, and net total COVID-19 deaths per million after 30 days will be 632863, 6632, 5853, and 60 respectively in the Philippines. In the case of the Philippines, the median growth rate of COVID-19 spread is 17 days. These forecasts are beneficial for real-time preparation for anticipating the required number of hospital beds and other medical resources needed to prepare in the coming days. This paper mentions major contributions, current concerns, and challenges during and post COVID-19 epidemic in the Philippines. Few non-considered measures, if implemented in the Philippines, will reduce the spread of the COVID-19.

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All authors have read and agreed to this version of the manuscript.

## CRediT authorship contribution statement

**Parikshit Gautam Jamdade:** Conceptualization, Formal analysis, Investigation, Methodology, Software, Writing - original draft, Writing - review & editing. **Shrinivas Gautamrao Jamdade:** Conceptualization, Writing - original draft, Writing - review & editing.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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