# A BI-FOLD APPROACH TO ASSESS THE IMPACT OF LOCKDOWN ON SUPPRESSING COVID-19 SPREAD & SMALL CAP STOCK MARKET MAYHEM IN INDIA

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**Abstract:** *The arrival of nCoV virus took the existence of human race in the toss, thus to slow down the spread of the virus Indian Government imposed a nationwide lockdown. In this paper, we aim to find the liaison between the impacts of lockdown on slowing down the spread of the virus along with the unprecedented blow to the small cap companies enlisted in the stock market. The impact of lockdown model has been assessed by proposing a differential equation based mathematical modelling (SIQR Modelling). Along with that, the stock market effect has been analyzed using a proposed Bi-Directional LSTM model optimized using Genetic Algorithm. In this present research, we have optimized the time-stamp window using genetic algorithm, before passing through the LSTM architecture. The novelty of the paper lies in the bi-fold approach to assess the chaos of the stock* market, under 2 conditional scenarios *i.e.* with and without the lockdown.

***Keywords****: Bi-directional LSTM, Genetic Algorithm, SIQR Modelling, Lockdown, Differential Equation*

## 1. Introduction

In 1720 Plague, followed by Cholera outbreak in 1820, 1920 Spanish Flu; it seems that in every 100 years a pandemic chases the existence of human race and no one has a clue to prevent that. As the famous saying goes, "History repeats itself" and in 2020 we witnessed another pandemic with the name of Novel-Corona Virus (Covid-19). This disease was first identified in December 2019, in Wuhan, China and as the fate would have been it has spread around the globe. The WHO has declared this as a public health emergency on 30th January, 2020 and subsequently the first case of Covid-19 in India has been detected on that day itself. The seriousness and complexity of this pandemic could be assessed by the figure of infected people which is close to million now in India. Moreover, the outbreak of this disease has also spread over 200 countries. The Indian government called for a nationwide lockdown on 24th March 2020, in order to put a bar on the excessive rising of covid cases. This was mainly done in order to buy some time in order to combat the pandemic. This lockdown is a two-sided sword, as on the one side it slowed down the spread of the virus, but on the other hand it took a serious toll on the stock prices, especially companies which come under small cap category

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suffered a huge blow due to the pandemic. The fast decline in the closing price of the companies indicating a huge slump in the production and sale, which will eventually lead to employment layoff and a cumulative result, will be shown in the sharp fall of GDP.

In this paper, we have presented a bi-fold approach to assess the actual impact of lockdown on the small cap market. The effectiveness of the lockdown has been assessed using Susceptible – Infected – Recovered (SIR) model. In this study, we have also incorporated an additional variable to monitor the growth of cases under any accidental mass gathering. Additionally, we have predicted the outcome under circumstantial scenarios *i.e.* with and without lockdown, and subsequent comparative prediction of the stock market has also been simulated.

In the second fold, of our bi-fold model we have proposed a novel *Genetic Algorithm Optimized Bi-Directional LSTM* based for modeling the chaos and volatility of the stock market. All the small cap companies have been enlisted in the BSE indexing which are taken into account for our analysis. As the stock market is a dynamic time series forecasting scenario thus the modeling of the stock price at first we need to map the relationship between input(s) and output(s) variables, generally this model are chaotic and thus we need an effective non-linear predictive model to forecast results. Generally, there are mainly 2 approach to predict time series problem namely, empirical and dynamic approach in chaotic modeling through soft computing technique we will use hybrid approach for modeling.

The LSTM approach is highly effective for time series forecasting as it has the ability to process entire sequences of data in addition to single data points because of the presence of its feedback connections. It can learn the context required for prediction instead of working on pre-specified and fixed context. LSTM also offers flexibility for modeling problems and can very easily process more than one input parameter. The variable which has been taken in the LSTM for forecasting is Closing Value of the company. The decisive modeling for assigning the time-stamp window has been optimized using genetic algorithm, we have iterated for 5 generations and there were 10 offspring per generation and fitness function has been evaluated to consider the best case parent scenario for the mutation of the off springs.

The paper is structured as; Sect. II contains the literature review of the articles, followed by SIQR modeling in Sect III. Sect. IV contains the Genetic Algorithm and LSTM Modeling and forecasting and our proposed algorithm model. In Sect V we have presented a comparative study of the impact of lockdown on the stock market, and finally Sect. VI contains concluding remarks and future scope of study.

## 2. Literature Review

The pandemic outbreak has affected every aspect of industry, and the stock market for small cap companies are no exception. Duan et al. [1] came up with their study

showing the medium sized enterprises which play a pivotal role in the economic welfare of china have suffered the blow, as a result of which the reopening stat of China's stock market showed a dip of 3%. Moreover, Goldman Sachs also predicted of a contraction of global GDP by 2.5% [2]. Another study by Ramelli & Wagner [3] shows policy impacted the stock movement. Adda [4] in their study showed how an infectious disease can have their impact in the stock movement, and on that light they showed how to allocate the limited resources to limit the spread. Hang [5] shows that the relation between the underlying dynamics of share market and the informatics blockage. Lee & Brahmasrhee [6] showed the relationship between the stock price exchange and the macro-economic variables like inflation, exchange rate etc. They tested their model in both short and long term run, and it returned a positive relation incase of short run modeling. Baker et al. [7] showed the role of covid-19 and impact of that in recent stock market up-downs. They also compared the outcomes comparing with other virus outbreaks like SARS, Ebola etc. Ozili & Arun [8] analyzed the impact of covid-19 on global economy through the light of fiscal monetary policy implementations. Osagie et al. [9] showed the relation of covid-19 impact nigeria's stock market and prescribed policy which can heal the situation, major model used in this study are Quadratic GARCH and Exponential GARCH model. Study of Hyn-Jung [10] showed the rollercoaster ride of economy of South-Korea during this unpredicted time. Saad *et al.* [11] proposed a multilayer model to predict the stock outcomes the architecture is made up of 3 ANN layers, along with time-delay, probabilistic modeling, and RNN layers. Kuo *et al.* [12] proposed a GA optimized fuzzy logic based model to predict the outcome. Huarng and Yu *et al.* [13] proposed a neural network based fuzzy time series to predict the outcomes. Kwon *et al.* [14] proposed a GA optimized ANN model to predict the stock prices. The genetic algorithms have been used to assign the weights of the nodes of ANN. Hsu *et al.* [15] created a three layer hybrid model to predict the prices; it was created by merging backpropagation neural network, feature selection and optimized using genetic algorithm. Adhikari and Agarwal [16] proposed another hybrid model by combining random walk model along with ANN. Considerable amount of work have been carried out in different sectors like economy, agriculture etc. but none have assessed the impact due to lockdown on the stock market dynamics along with that none of the work uses state of the art deep learning models to predict the outcome in this pandemic situation. The novelty of our work is considerable as we proposed a novel LSTM based architecture to predict the impact under conditional scenarios of lockdown. The confluence of the two models increases the contribution of this paper.

## 3. SIQR Dynamic Modeling

The spread of epidemic study is generally done using SIQR modeling, which was introduced by Kermack & McKendrik. In this modeling approach we divide the entire population into partial groups and study the contagion and spread of the

disease across the groups using the parameter of rate of change of size of these groups. In this section we propose our dynamic model to predict the spread of Covid-19 across the nation. The spread of this virus followed an exponential growth rate and creating a massacre around the globe. The aim in this section is to forecast the path of daily infected cases and to measure the extent of epidemic in India.

The entire population is assumed to be $N$ and it has been normalized to 1 for better assessment. The different categories in which we have divided are as follows. Susceptible $S$, Infectious $I$, Quarantine $Q$, Removed (either recovered or deceased). The total number of active cases is being denoted by $C$, and it's the sum of Infectious and Removed *i.e.* $C = I + R$.

The rate of change of these quantities has been showed using differential forms and they are denoted as $\frac{dS}{dt}, \frac{dI}{dt}, \frac{dQ}{dt}, \frac{dR}{dt}$ respectively. The equations of this model are shown below:

$$\frac{dS}{dt} = -\frac{\beta_t S}{N} I \quad (1)$$

$$\frac{dI}{dt} = \sigma E - \gamma I \quad (2)$$

$$\frac{dQ}{dt} = \frac{\beta_t S}{N} I - \sigma E \quad (3)$$

$$\frac{dR}{dt} = \gamma_r i \quad (4)$$

$$\frac{dD}{dt} = d\gamma I - \tau D \quad (5)$$

$$\frac{dC}{dt} = \sigma E \quad (6)$$

$$\frac{dC_n}{dt} = N_m \quad (7)$$

Where,

$\gamma = Infectious\ period\ time$
$\gamma_r = Relation\ between\ infected\ population\ and\ infected\ one$
$\sigma = Mean\ Latent\ Period$
$d = Proportion\ of\ severe\ cases$
$\tau = Mean\ duration\ of\ public\ reaction\ time$
$N_m = Fraction\ of\ population, infected\ due\ to\ accidental\ mass\ gathering$
$\beta_t = Transmission\ rate$

The transmission rate is governed by the factor $\alpha$ which is the government policies or measures to curb the spread pandemic. The function of transmission rate is represented by Eq. 8.

$$\beta_t = \beta_0(1 - \alpha)\left(1 - \frac{D}{N}\right)^k \quad (8)$$

Table 1, shows the parametric values which have been taken into consideration while modeling the SIQR epidemic model.

| Parameter | Description | Value |
|---|---|---|
| $N_0$ | Initial Population | 130 Crore |
| $S_0$ | Initial Susceptible Population | $0.9N_0$ (constant) |
| $E_0$ | Exposed Population for each infected | $24I_0$ (assumed) |
| $I_0$ | Initial State of Infected Person | 4 |
| $\alpha$ | Lockdown and Other Action Strength | varied |
| $k$ | Intensity of People's Reaction | 1117 (constant) |
| $\sigma^{-1}$ | Latent Period (mean) | 3 days |
| $\gamma^{-1}$ | Infectious period (mean) | 6 days |
| $d$ | Ratio of severe cases | 0.26 |
| $\tau^{-1}$ | Duration of public reaction (mean) | 12 days |

***Table 1: Parametric Values used in our Model***

### 3.1. Simulation Results

In this section, the results of our mathematical modeling have been presented. The parametric values which have been used to asses our model should be treated as an average value for India. The initial value of transmission rate $\beta_0$ in our model is taken as 0.50. In first case we have assumed there would be no lockdown across the country. In this case the value of α is taken as 0.8 as there is no government intervention and the situation is normal.

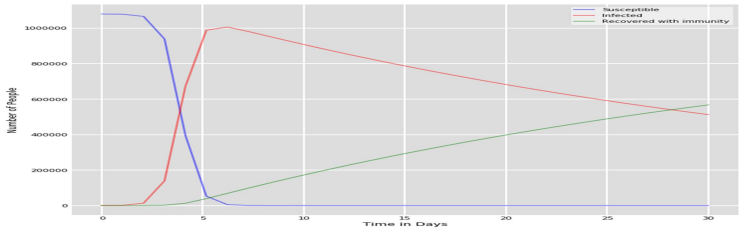


Figure 1: Potential Covid-19 Scenario in India if there would be no lockdown and social distancing, initial date taken 14th March, 2020

In the next scenario we have simulated the covid-19 spread across India with social distancing and lockdown. In this case the α value taken was very small near to 0.2. Lower value indicates there are stronger restrictions of lockdown across the country. In Fig. 5 we have presented the scenario with lockdown.

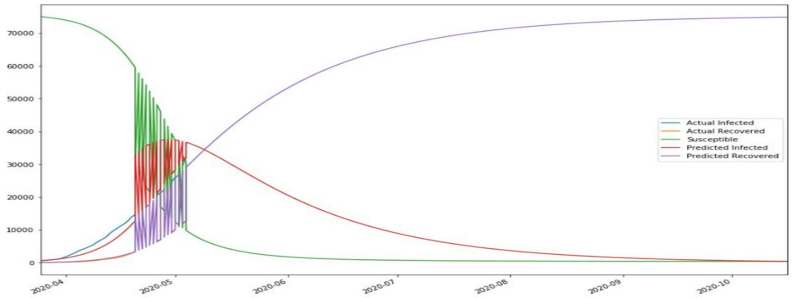


Figure 2: Infected Scenario in India if there would be lockdown and social distancing

## 4. Genetic Algorithm Optimized Bi-Directional LSTM Modeling for Chaotic Nature of Stock Market

The stock market is a complex, evolutionary, and non linear dynamical system. The stakes price in the market fluctuate at a rapid pace, and predicting this dynamic chaotic nature is very much difficult. The variations are mostly noisy, non-stationary and chaotic governed by many factors in a country ranging from corporate statements to government policies. Most of this governing factors are linguistic in nature thus we can easily apply our fuzzy based logic into this with a varying range of probabilities to buy, hold, or sell.

### 4.1. Modeling the Chaotic Nature of Stock Market

The system or the fluctuations of the stock market can be represented using eq. 1.

$$y(k+n) = F(y(k), U) \quad (1)$$

Where,

$n = Order\ of\ the\ process$
$F = Multiple\ Composite\ Function$
$U = Control\ Actions$

The stock price will move up from $y(k)$ to $y(k+n)$ in $(n)$ steps. Thus representing the eq.1 in explicit form (refer eq. 2).

$$U = G\big(y(k), y(k+n)\big) \quad (2)$$

Through eq.2 we can explicitly map $G$ with the predictive model, the final estimator is given in eq. 3

$$U' = G'\big(y(k), y_d(k+n)\big) \quad (3)$$

### 4.2. LSTM Modeling

Long Short-Term Memory algorithm thus came up with filling up the drawback of RNN algorithm by introducing the concept of gates which are capable of remembering the outputs states. The LSTM architecture diminishes the major problem of the RNN architecture *i.e.* the vanishing gradient descent problem. It minimized the error in the process by adding the constant error flow term through the hidden cells but not through the activation function. In LSTM architecture there are 4 gates through which the memory allocation occurs. Mainly forget gate $f$, input gate $i$, input modulation gate $g$ and the output gate. The forget gate used to process the output of the last state $h_{t-1}$ it mainly used to remove or forget the irrelevant data which are present in the information which have been passed through the model. The activation function which is majorly used in the forget gate is the sigmoid function.

$$f_t = \sigma(W_f.[h_{t-1}, x_t] + b_f) \quad (4)$$

$$i_t = \sigma(W_i.[h_{t-1}, x_t] + b_f) \quad (5)$$

$$C'_t = tanh(W_i.[h_{t-1}, x_t] + b_C) \quad (6)$$

$$C_t = f_t \times C_{t-1} + i_t \times C_t \quad (7)$$

$$o_t = \sigma(W_0.[h_{t-1}, x_t] + b_0) \quad (8)$$

$$h_t = o_t \times tan\, h(C_t) \quad (9)$$

## 4.3. Genetic Algorithm

GA is a nature inspired algorithms and this is a kind of heuristic algorithm which are being used widely. GA is used for solution search or for optimizing technique. Each GA is being operated on the population of artificial chromosomes, and the model will iterate till the best fitness is not obtained for a subsequent generation.

### *4.3.1. Chromosome Encoding*

A GA has chromosomes which are basically, solution representations in string format for a particular problem. A particular position or the index of the chromosome is known as *gene* and the letter which is present at that particular position or index is known as allele. The general solution space for a GA is around $2^{100} - 10^{30}$ individuals.

### *4.3.2. Fitness Function*

The fitness can be defined as the strength of the chromosomes for a particular problem statement. As this algorithm is being inspired from biological concept, thus the chromosome can be referred as genotype and the solution which is associated with that particular problem statement is the phenotype. The aim of the algorithm is to maximize the count of 1's in a string of length n.

### *4.3.3. Selection*

The fitness function in the GA acts a discriminator to detect the quality of solutions which are being created by the chromosomes, and selection parameter of GA is made to use the value of fitness function to assess the recombination of genes to create a better generation. In simple words, we can say that function with higher fitness will have higher chance of recombination to create the new generation rather than a lower fitness function chromosome.

### *4.3.4. Recombination*

As the selection criteria is more biased towards more fit chromosomes thus only the fit chromosomes are being recombined and evolve to give better results. There are mainly 2 types of recombination *viz.* genetic crossover and mutation. The

genetic crossover is a nondeterministic crossover in nature and each of them occurs with some probabilities. The selected chromosome undergoes recombination and a random number is being generated [0,1] with uniform probability and then it's being compared with pre-determined crossover rate and if it's lower than that then parent will be unchanged in recombination and if higher then crossover operator is being applied.

### *4.3.5. Evolution*

The GA algorithm iterates until and unless the stopping criteria is being reached. After recombination a new generation is being created and it also undergoes similar process to evolve. A widely used evolutionary technique is used called *replacement-with-elitism.* Here there is an almost complete replacement of the wide population in the successor population; this model ensures that highest fitness doesn't get lost in the next generation. [14]

### *4.3.6. Proposed Algorithm*

**Algorithm: GA Optimized Bi-Directional LSTM Architecture**
**Input:** Open Value of Stock Price
**Output:** Prediction of target variable with optimized value of time-stamp which have been passed in LSTM Architecture with highest fitness of evolution

```
Begin
        All Combination of Time Window Size generated
         if (fitness ! = max)
           {
                      for (fitness = 0; fitness < next generation fitness; fitness +
+)
                          {
                          next gen = max (prev. gen fitness)
                          crossover occurs
                          next gen created
                          }
               break;
               evolved time − stamp window passed through bi −
directional LSTM Architecture
              Result
           }
End
```

### *4.3.7. Model Evaluation and Results*

We have implemented the hybrid model; at first we have optimized the time-stamp window for the LSTM architecture. As this is a regression problem we have used RMSE value at each generation to obtain the fitness function value. In table 2 we have shown the RMSE value for each step.

| Number of Windows | Number of Units | RMSE Score |
|---|---|---|
| 36 | 2 | 0.0183 |
| 56 | 8 | 0.0266 |
| 60 | 9 | 0.1381 |
| 49 | 9 | 0.1492 |
| 29 | 10 | 0.1588 |

***Table 2: Fitness Score for Optimized Dataset***

The time-stamp was taken as the optimized value where the RMSE score was the least, then the architecture is being passed through the bi-directional LSTM architecture, and its model evaluation metrics is given in table 3, and figure-3.

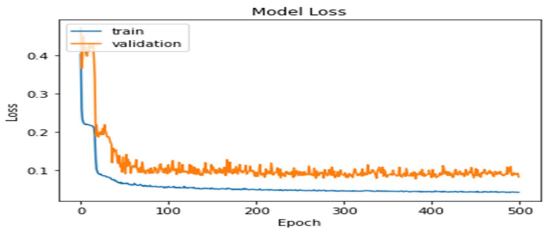


Figure 3: Model Loss Curve for Genetic Algorithm Optimized Bi-Directional LSTM Model

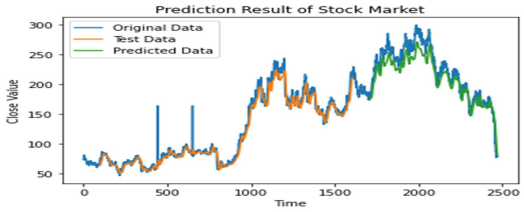


Figure 4: Prediction of our Proposed Model

| Model | RMSE |
|---|---|
| GA Optimized Bi-Directional LSTM Modelling | 0.16889 |

***Table 3: RMSE Score for Proposed Architecture***

## 5. Relative Study of Impact of Lockdown on Stock Market

In the previous 2 sections, we have established our models for lockdown estimation and stock price predictability separately, and in this section we aim to give study on the effectiveness of lockdown on stock market movement.

$H_0$: There is a significant positive effect of lockdown on stock prices (Small Cap)

$H_1$: There is a significant negative effect of lockdown on stock prices (Small Cap)

In order, to test our hypothesis we have used p-value test, and the result for that is given in table-4.

| Event | P-Value | Confidence Level |
|---|---|---|
| Effect of lockdown on Stock Price | 0.0058 | 95% |

***Table 3: P-value for our Model Hypothesis***

The hypothesis result is suggestive that there is a significant effect; the effect can be explained due to extremely lower production level for around 3 months along with that even after unlock 1.0, 2.0 there are covid protocols which have to be followed resulting in lower workforce and lower production.

Now, we present a comparative prediction of stock prices under 2 scenarios then we will give a relative study to assess the level of impact.

| Month | Predicted Average Covid-19 Cases[2] | Predicted Average Stock Price for Apollo Tyre (Small Cap) under Lockdown Scenario[3] | Predicted Average Stock Price for Apollo Tyre (Small Cap) under No Lockdown Scenario |
|---|---|---|---|
| October* | 80,0000 | 72.68 | 128.45 |
| November* | 42,0000 | 73.96 | 134.58 |
| December * | 10,0000 | 74.66 | 132.89 |
| January* | 5,0000 | 74.01 | 135.22 |

***Table 4: Predicted Values, *denotes predicted outcome***

From, table-4 it's evident that the lowering of covid cases has also resulted in massive slump in stock return prices. Whereas according to our model the average return under no lockdown scenario is high where the average difference is of Rs. 55, where the average high of this stock is Rs. 200 under best scenario. Along with that the fact which should be kept in mind is, if there would be no lockdown scenario, the death toll could be way higher and those figures could have changed in a long run. Correlation coefficient between the covid-19 cases and stock return has been showed in table-5, and it shows a high negative correlation in between them. Which suggests with the decrease of cases, and ease of lockdown there is an increase of stock returns, which also says that the lockdown affected the stock return of small cap companies severely.

| *Correlation Value* | Covid Cases under Lockdown Scenario |
|---|---|
| Stock Return under Lockdown Scenario | -0.8943 |

***Table 5: Correlation Value between Stock Return and Covid Cases under Lockdown Scenario***

[2] Outcome of 2nd wave of Covid-19 haven't been considered in this case. (SIQR Model), and death toll under no lockdown haven't been considered.

[3] All Figures are in Rupees, predicted using our Proposed GA and LSTM Architecture.

## 6. Conclusion and Future Scope of Study

In this study we aimed to find the liaison between the impact of lockdown on restraining covid-19 cases and the blow it gave to the small cap stock markets. We have proposed a bi-fold model in this study where in the first section we have estimated the growth of covid-19 cases under lockdown and no lockdown scenario and in the second stage we have proposed a hybrid genetic algorithm based bi-directional LSTM architecture which will predict the outcome of stock prices. Through the model evaluation metrics we can clearly see the performance of our proposed model is superior. Further, we have assessed the relative impact of lockdown on return prices along with that we saw a negative correlation among the said variables in our study, thus reaching to our concluding remark that lockdown have heavily affected the stock return, but on the other hand we also saw that if lockdown haven't been imposed then the death toll could be sky high and apparently looking good stock market would be crashed by now.

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