PREDICTION OF COVID-19 CASES IN BOLIVIA USING ARTIFICIAL NEURAL NETWORKS

*Dr. Smartson. P. NYONI[1], Thabani NYONI[2], Tatenda. A. CHIHOHO[3]

[1]ZICHIRe Project, University of Zimbabwe, Harare, Zimbabwe
[2]Department of Economics, University of Zimbabwe, Harare, Zimbabwe
[3]Department of Economics, University of Zimbabwe, Harare, Zimbabwe
**Corresponding Author*

ABSTRACT

During the recent global urgency, scientists, clinicians and healthcare experts around the globe keep on searching for accurate and reliable COVID-19 forecasting models to support in tackling the deadly and highly infectious disease. In this research paper, the ANN approach was applied to analyze COVID-19 daily cases in Bolivia. The employed data covers the period March 11, 2020 – October 31, 2020 and the out-of-sample period ranges over the period November 2020 to April 2021. The residuals and forecast evaluation criteria (Error, MSE and MAE) of the applied ANN (12, 12, 1) model indicate that the model is stable in forecasting daily COVID-19 cases in Bolivia. The results of the study indicate that COVID-19 daily cases were, in general, likely to increase over the out-of-sample period. The Bolivian government, through the ministry of health, should continue to implement COVID-19 control and prevention measures such as isolation, quarantine, testing and tracing, face-mask wearing, sanitization of hands and so on., in line with WHO standards.

Keywords: - *ANN, COVID-19, Forecasting*

INTRODUCTION & BRIEF OVERVIEW

Escalating at a rapid pace, COVID-19 has emerged as a global pandemic. The virus, thought to be migrated from bats, started transmission in Wuhan, the capital of Hubei, China (Huang *et al*., 2020). The COVID-19 outbreak is considered a serious disease due to its high permeability and contagiousness (Tolksdorf *et al*., 2020). COVID-19 affects various people in different ways. Over 80% of COVID-19 patients develop mild to moderate illness and recover without hospitalization (WHO, 2020). Fever, dry cough and tiredness are the most common symptoms of COVID-19. Very few patients will present with symptoms such as chest pain, loss of speech or movement, as well as shortness of breath (Del & Malani, 2020; Wang *et al*., 2020). There are no specific treatments or vaccines for COVID-19: however, there are many ongoing clinical trials evaluating potential treatments. People can prevent the infection by washing hands, staying home, face-mask wearing, social distancing and so on., as recommended by the World Health Organization (WHO) (Alakus & Turkoglu, 2020). The first case of COVID-19 in Bolivia was reported on March 11, 2020. Today, Latin America has become the new epicenter for the spreading of COVID-19, with especially alarming cases in Brazil, Mexico, Ecuador, Peru and Chile. Bolivia, in its own right, is a particularly concerning country due to the high percentage of

the population living on a basis of informal economy (Shih *et al*., 2020), recent political events leading to exacerbated polarization and a deficient healthcare system (Penafiel & Ramirez-Avila, 2020). Despite the fact that the COVID-19 pandemic is now widely analyzed using predictive modelling techniques, it is ironical to note that forecasting studies focusing Bolivia are limited, with just a few papers such as Penafiel & Ramirez-Avila (2020) being noticeable. Using Tsallis' proposal for determining the occurrence of a peak, and also the Susceptible-Infected-Recovered-Asymptomatic-Symptomatic and Dead (SIRASD) compartmental model, Penafiel & Ramirez-Avila (2020); determined a range of probable peak dates and also examined several social distancing scenarios during the epidemic. The study established that electoral scenarios would largely affect the epidemic's dynamics in a catastrophic manner. In this paper, we apply the Artificial Neural Network (ANN) model to forecast daily new COVID-19 cases in Bolivia. Our intention is to try and complement government efforts in the fight against the pandemic. The results of the study are also expected to ease the strain on the fragile Bolivia healthcare system by predicting the future trends of the infections in the country.

METHODOLOGY

This paper applies the multi-layer perceptron neural network type of the ANN approach in order to predict COVID-19 cases in Bolivia. The study actually applies the ANN (12, 12, 1) model and chooses the more efficient hyperbolic tangent function as the activation function. The research is based on newly confirmed daily COVID-19 cases (reffered to as the BX series in this study) for all age groups in Bolivia. The data covers the period March 11, 2020 to October 31, 2020 while the out-of-sample forecast covers the period November 2020 to April 2021. All the data employed in this paper was gathered from the COVID-19 data repository prepared by the CSSE at JH University.

FINDINGS OF THE STUDY

DESCRIPTIVE STATISTICS

Table 1: Descriptive statistics

Mean	Median	Minimum	Maximum
603.22	460.00	0.0000	2036.0
Std. Dev.	C.V.	Skewness	Ex. kurtosis
554.16	0.91867	0.73861	-0.50081
5% Perc.	95% Perc.	IQ range	Missing obs.
3.0000	1708.6	889.00	0

ANN MODEL SUMMARY FOR COVID-19 DAILY CASES IN BOLIVIA

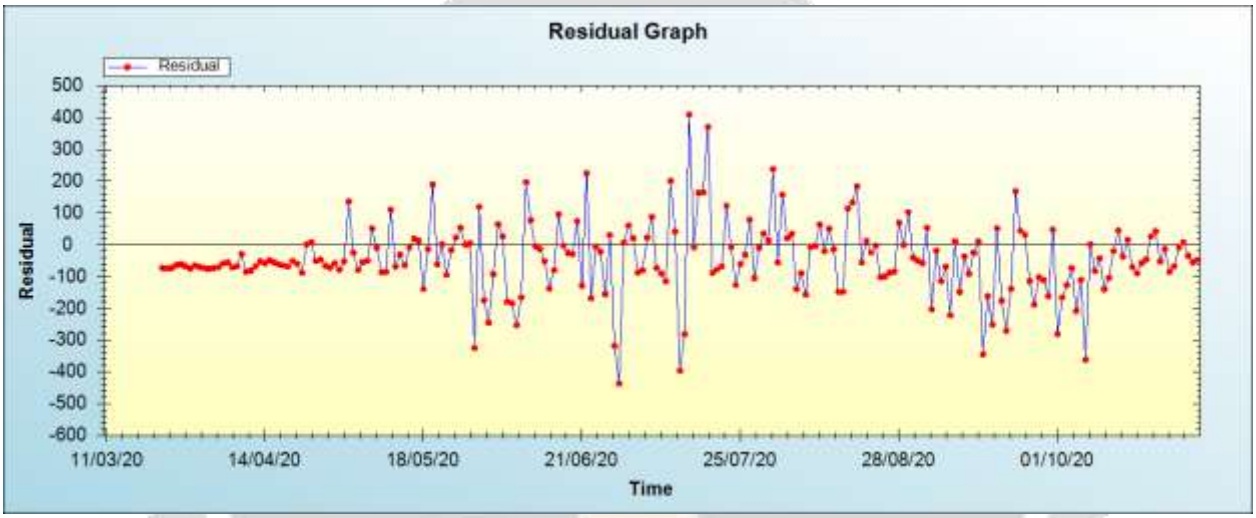
Table 2: ANN model summary

Variable	BX
Observations	223 (After Adjusting Endpoints)
Neural Network Architecture:	
Input Layer Neurons	12
Hidden Layer Neurons	12
Output Layer Neurons	1

Activation Function	Hyperbolic Tangent Function
Back Propagation Learning:	
Learning Rate	0.005
Momentum	0.05
Criteria:	
Error	0.107146
MSE	14688.069375
MAE	89.794660

Residual Analysis for the ANN model

Figure 1: Residual analysis



In-sample Forecast for BX

Figure 2: In-sample forecast for the BX series

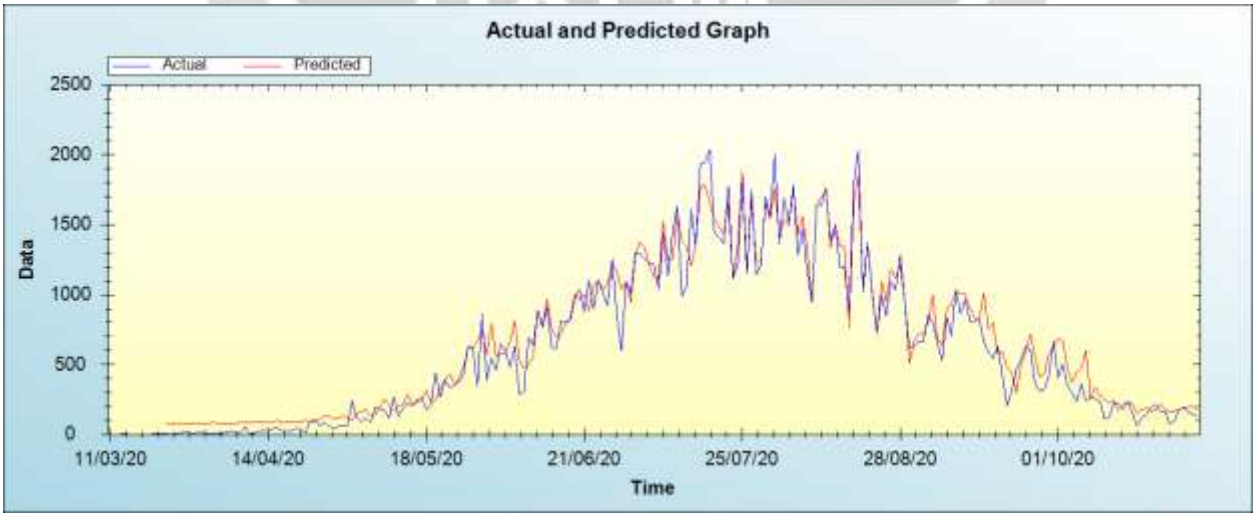
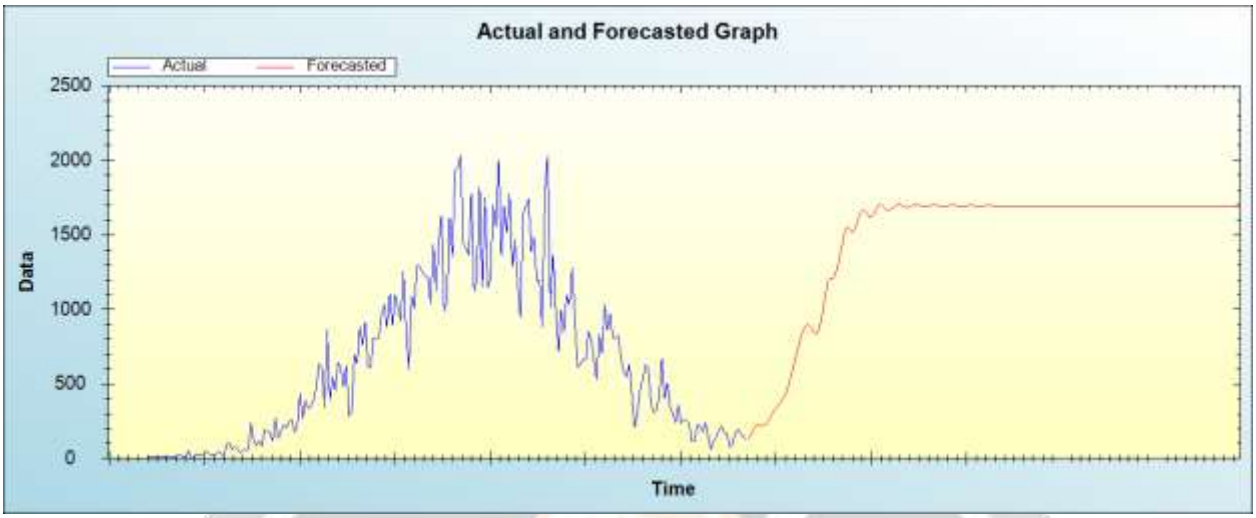


Figure 2 shows the in-sample forecast for BX series.

Out-of-Sample Forecast for BX: Actual and Forecasted Graph

Figure 3: Out-of-sample forecast for BX: actual and forecasted graph



Out-of-Sample Forecast for BX: Forecasts only

Table 3: Tabulated out-of-sample forecasts

Day/Month/Year	Forecasts
01/11/20	134.7546
02/11/20	170.2522
03/11/20	209.9588
04/11/20	226.4284
05/11/20	215.3256
06/11/20	226.9410
07/11/20	229.5016
08/11/20	245.4214
09/11/20	284.3058
10/11/20	316.1507
11/11/20	337.7373
12/11/20	359.1849
13/11/20	387.6010

14/11/20	416.8203
15/11/20	457.9623
16/11/20	523.9159
17/11/20	590.8905
18/11/20	661.4916
19/11/20	741.9048
20/11/20	810.4225
21/11/20	865.7888
22/11/20	893.5334
23/11/20	897.6205
24/11/20	875.1358
25/11/20	842.4363
26/11/20	837.0007
27/11/20	882.2087
28/11/20	972.6936
29/11/20	1094.4153
30/11/20	1187.9300
01/12/20	1209.9355
02/12/20	1212.2320
03/12/20	1247.2385
04/12/20	1320.6055
05/12/20	1415.1129
06/12/20	1504.7471
07/12/20	1551.7216
08/12/20	1538.1992
09/12/20	1515.2690

10/12/20	1539.3878
11/12/20	1602.4474
12/12/20	1650.0898
13/12/20	1667.6294
14/12/20	1654.5833
15/12/20	1626.3810
16/12/20	1618.2995
17/12/20	1643.6338
18/12/20	1682.3680
19/12/20	1704.7596
20/12/20	1698.3156
21/12/20	1676.1961
22/12/20	1665.9995
23/12/20	1671.7505
24/12/20	1684.9271
25/12/20	1700.6092
26/12/20	1706.6158
27/12/20	1698.1935
28/12/20	1685.7016
29/12/20	1682.9394
30/12/20	1688.9698
31/12/20	1696.1656
01/01/21	1700.7475
02/01/21	1701.2374
03/01/21	1697.0335
04/01/21	1691.4573

05/01/21	1690.5991
06/01/21	1694.2826
07/01/21	1698.0431
08/01/21	1699.1704
09/01/21	1698.1841
10/01/21	1696.2609
11/01/21	1694.3240
12/01/21	1694.0597
13/01/21	1695.8409
14/01/21	1697.7520
15/01/21	1697.9699
16/01/21	1696.9981
17/01/21	1696.0408
18/01/21	1695.5352
19/01/21	1695.6153
20/01/21	1696.3416
21/01/21	1697.1779
22/01/21	1697.2445
23/01/21	1696.6251
24/01/21	1696.1068
25/01/21	1696.0435
26/01/21	1696.2299
27/01/21	1696.5194
28/01/21	1696.8061
29/01/21	1696.8242
30/01/21	1696.5281

31/01/21	1696.2527
01/02/21	1696.2667
02/02/21	1696.4359
03/02/21	1696.5648
04/02/21	1696.6278
05/02/21	1696.6134
06/02/21	1696.4967
07/02/21	1696.3731
08/02/21	1696.3808
09/02/21	1696.4861
10/02/21	1696.5566
11/02/21	1696.5541
12/02/21	1696.5248
13/02/21	1696.4839
14/02/21	1696.4416
15/02/21	1696.4433
16/02/21	1696.4936
17/02/21	1696.5326
18/02/21	1696.5237
19/02/21	1696.4963
20/02/21	1696.4801
21/02/21	1696.4727
22/02/21	1696.4751
23/02/21	1696.4940
24/02/21	1696.5125
25/02/21	1696.5085

26/02/21	1696.4909
27/02/21	1696.4821
28/02/21	1696.4843
01/03/21	1696.4886
02/03/21	1696.4944
03/03/21	1696.5007
04/03/21	1696.4998
05/03/21	1696.4914
06/03/21	1696.4860
07/03/21	1696.4885
08/03/21	1696.4928
09/03/21	1696.4946
10/03/21	1696.4955
11/03/21	1696.4952
12/03/21	1696.4921
13/03/21	1696.4894
14/03/21	1696.4905
15/03/21	1696.4933
16/03/21	1696.4943
17/03/21	1696.4937
18/03/21	1696.4931
19/03/21	1696.4923
20/03/21	1696.4913
21/03/21	1696.4916
22/03/21	1696.4930
23/03/21	1696.4937

24/03/21	1696.4931
25/03/21	1696.4925
26/03/21	1696.4924
27/03/21	1696.4922
28/03/21	1696.4923
29/03/21	1696.4928
30/03/21	1696.4932
31/03/21	1696.4929
01/04/21	1696.4925
02/04/21	1696.4924
03/04/21	1696.4925
04/04/21	1696.4926
05/04/21	1696.4927
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26/04/21	1696.4927
27/04/21	1696.4926
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29/04/21	1696.4926
30/04/21	1696.4926

Figure 4: Out-of-sample forecasts – in graphical form

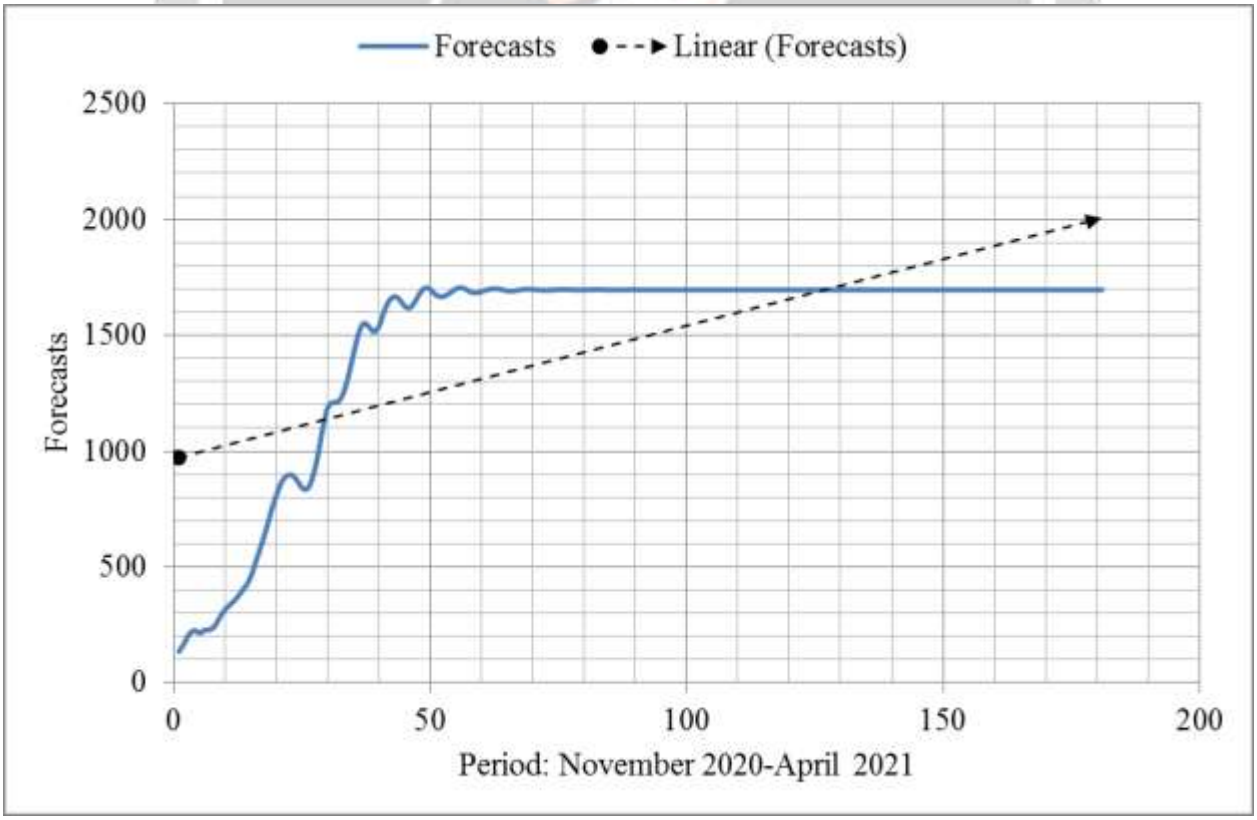

Table 1shows the descriptive statistics of the series, BX, under consideration. Worthy to note is that the average number of infections per day has been as high as 603 cases over the period under study while the maximum was as high as 2036 cases. The summary of the model is shown in table 2 above. The model is checked for stability using figure 1 and we find that the residuals are as close to zero as possible, implying that the model is acceptably stable. Figure 2 shows the in-sample forecast graph while figures 3 & 4 and table 3 basically show out-of-sample predictions. The study found out that daily COVID-19 cases in Bolivia will continue to rise from the estimated 135 cases on November 1, 2020 to an equilibrium level of approximately 1696 cases per day, sometime around January 17, 2021. Our study also shows that this equilibrium level shall, generally, be in existence throughout the out-of-sample period. The fitted trend line in figure 4 further confirms that generally COVID-19 cases are on the rise in Bolivia. The results of this study are consistent with previous studies such as Penafiel & Ramirez-Avila (2020) who already warned of a possible rise in COVID-19 infections in the country, especially if the pandemic coincides with the 2020 presidential elections in the country.

CONCLUSION & RECOMMENDATIONS

COVID-19 is an epidemic that spreads quickly. For this reason, it has very catastrophic effects in many areas worldwide. Therefore, it is vital to forecast daily COVID-19 cases as quickly as possible in order to plan ahead on how to restrain the spread of the disease. In this piece of work, we attempt to model and forecast COVID-19 daily cases in Bolivia. We applied the basic ANN (12, 12, 1) model and found out that COVID-19 daily cases were, in general, likely to increase over the out-of-sample period. The Bolivian government, through the ministry of health, should continue to implement COVID-19 control and prevention measures such as isolation, quarantine, testing and tracing, face-mask wearing, sanitization of hands and so on., in line with WHO guidelines. This will go a long way in controlling the pandemic in the country.

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