FORECASTING COVID-19 CASES IN ETHIOPIA 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

Given that most Ethiopians live in crowded inter-generational households that usually lack running water and other basic sanitary facilities, COVID-19 has a potential to cause mayhem in the country. In this endeavor, the basic ANN technique is applied to analyze daily new COVID-19 cases in Ethiopia. The employed data covers the period 13 March 2020 to 31 October 2020 and the out-of-sample period ranges over the next 6 months, starting from 1 November 2020. The residuals and forecast evaluation criteria (that is; Error, MSE and MAE) of the applied model indicate that the model is stable and acceptable in forecasting daily new COVID-19 cases. The results of the study indicate that daily new COVID-19 cases are likely to continue declining over the period November 2020 to April 2021. This simply suggests that the current preventive and control measures for the pandemic such as quarantining, isolation, treatment, testing, tracing contacts, social distancing, regular and consistent washing of hands and so on; are really working for the Ethiopia. The people in the country are advised not be complacent but rather remain responsible and alert in order to avoid a possibility of a second wave of infections.

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

INTRODUCTION

Currently, the world is facing a deadly pandemic with a new coronavirus SARS-Cov-2 (Severe Acute Respiratory Syndrome Corona Virus Type 2) causing an infectious disease named COVID-19 (Corona Virus Infectious Disease 2019) (Leulseged *et al*., 2020a). COVID-19 was first identified in China on December 2019 and later spread to the entire world and declared to be a pandemic by WHO on March 11, 2020 (WHO, 2020b). The infection basically targets the human respiratory system and is mainly transmitted by respiratory droplets and close contact with an infected person (Rothan & Byrareddy, 2020). Common signs of COVID-19 include fever, shortness of breath and dry coughs. Its uncommon symptoms include muscle pain, mild diarrhoea, abdominal pain, sputum production, loss of smell and sore throat (Wang *et al*., 2020; Hu *et al*., 2020; Tao *et al*., 2020). Most people who are infected with COVID-19 virus experience mild to moderate respiratory illness, and they recover without requiring special treatment (WHO, 2020b; Guan *et al*., 2020). In Ethiopia, the first case of COVID-19 was officially confirmed on March 13 2020, two days after the pandemic was declared (Leulseged *et al*., 2020a, b & c). By 5 August 2020, there were a total of 19875 confirmed cases and 343

deaths. Most of the cases were from the capital city, Addis Ababa; mostly imported cases. However, currently the transmission is classified by WHO as "community transmission" (WHO, 2020a). As of October 5 2020, 79437 cases were identified with 34016 recovered and 1230 deaths. Since the disease transmission dynamics shifted to a community transmission, the number of new cases, those who need critical care and daily deaths are increasing, 292 cases on critical care at different treatment centers in the country on the same day (EFMOH, 2020). Artificial Neural Networks (ANN) are increasingly becoming an important tool in understanding the dynamics of disease transmission and consequently in decision making processes regarding intervention programs for disease control. The main aim of this paper to model and forecast daily new COVID-19 infections in Ethiopia.

LITERATURE REVIEW

Table 1 below is a summary of the selected relevant previous studied done in Ethiopia:

Table 1: Studies Reviewed

Author/s (Year)	Study Period	Method	Key Findings
Deressa & Duresa (2020)	March – August	Compartmental Model	The diseases free and endemic equilibrium points are locally and globally asymptotically stable. A combination of optimal preventive strategies such as public health education, personal protective measures and treatment of hospitalized cases are effective to significantly decrease the number of COVID-19 cases in the country
Abebe (2020)	March – June	Exponential Smoothing Model	Double Exponential Smoothing method was appropriate in forecasting the future number of COVID-19 cases in Ethiopia. COVID-19 cases in Ethiopia are growing exponentially
Alemneh & Tilahun (2020)	March – June	SEIR Model	An integrated strategy effective in controlling the epidemic must apply all control strategies within a short period of time
Argawu (2020)	March – August	OLS Model	Number of new laboratory tests and number of new cases from Addis Ababa city significantly predicted COVID-19 new cases
Maru *et al*. (2020)	March – September	Logistic Regression Model	Having diabetes mellitus, fever and shortness of breath are significant predictors of death in severe COVID-19 patients
Balcha (2020)	March – June	Curve Fitting and Least Squares	COVID-19 cases trending upwards, sharply

		technique	

Source: Literature Review (2020)

METHOD

This research paper applies the multi-layer perceptron neural network type of the ANN approach in order to analyze newly confirmed COVID-19 daily cases. The research article particulary applies the ANN (12, 12, 1) model and chooses the hyperbolic tangent function as the activation function since it generally performs better than other activation functions such as the sigmoid function.

Data Issues

This study is based on newly confirmed COVID-19 daily cases (reffered to as series X in this study) for all age groups in Ethiopia. The data covers the period 13 March 2020 to 31 October 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 2: Descriptive statistics

Mean	Median	Minimum	Maximum
412.74	203.00	0.0000	1829.0
Std. Dev.	C.V.	Skewness	Ex. kurtosis
452.33	1.0959	1.0363	0.36980

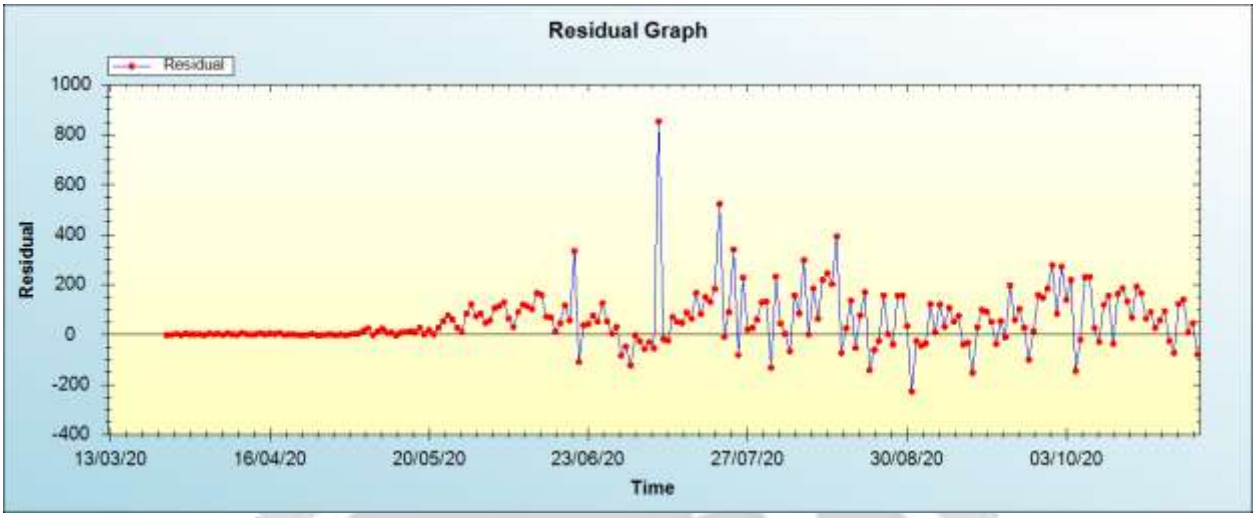
ANN MODEL SUMMARY FOR COVID-19 DAILY CASES IN ETHIOPIA

Table 3: ANN model summary

Variable	X
Observations	221 (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	0.121994
MSE	15365.987528
MAE	77.911592

Residual Analysis for the ANN model

Figure 1: Residual analysis



In-sample Forecast for X

Figure 2: In-sample forecast for the X series

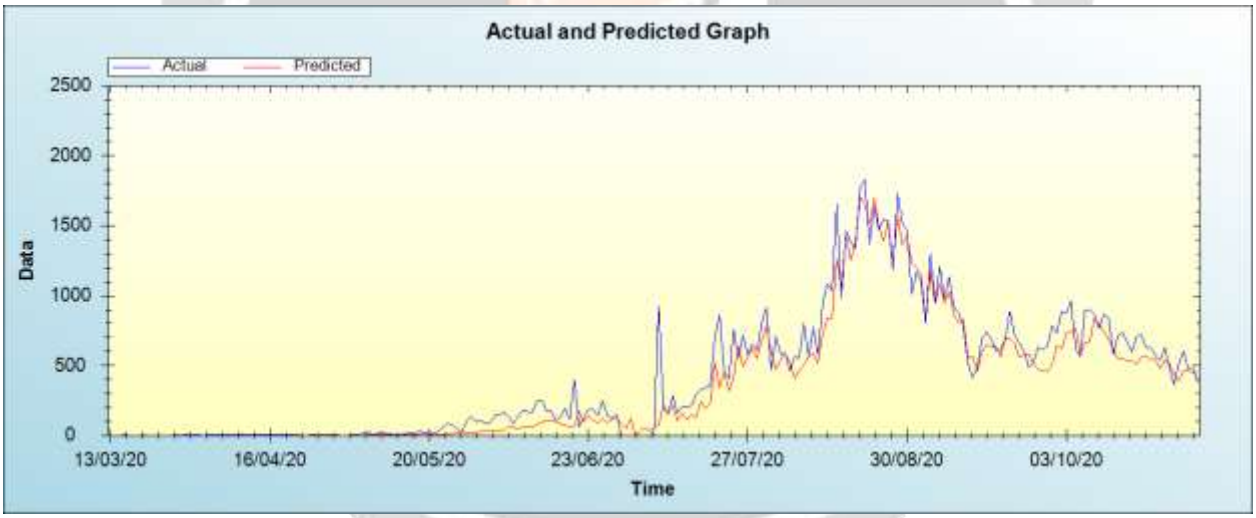
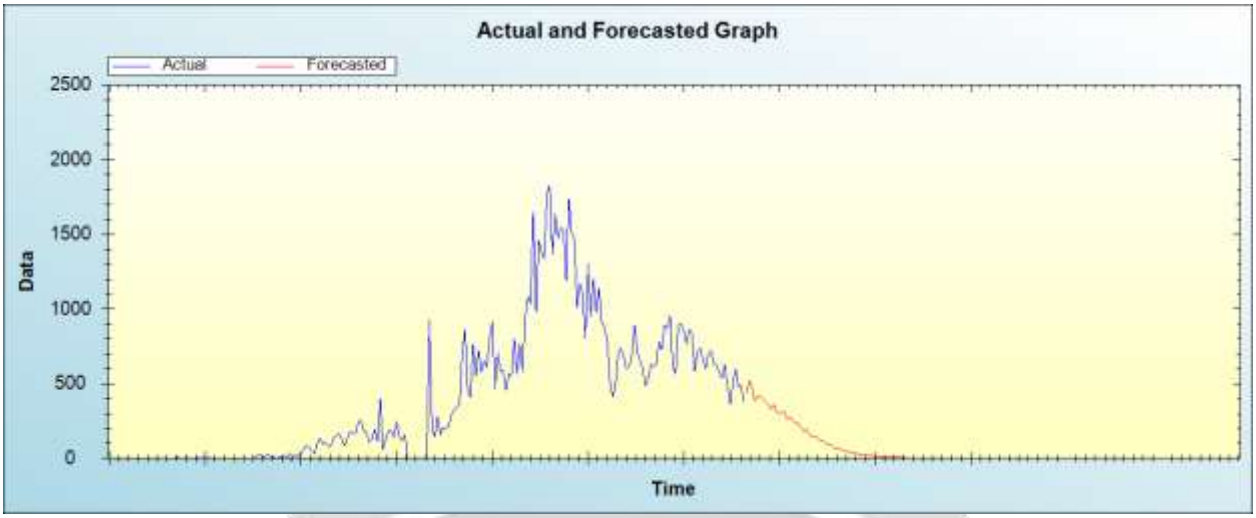


Figure 3 shows the in-sample forecast for X series.

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

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



Out-of-Sample Forecast for X: Forecasts only

Table 4: Tabulated out-of-sample forecasts

Day/Month/Year	Forecasts
01/11/20	442.4559
02/11/20	522.4975
03/11/20	468.5259
04/11/20	381.7249
05/11/20	413.5085
06/11/20	410.6181
07/11/20	394.6169
08/11/20	374.8203
09/11/20	361.4582
10/11/20	330.6525
11/11/20	364.6860
12/11/20	313.0451
13/11/20	296.4143
14/11/20	317.7375
15/11/20	306.5853

16/11/20	260.6973
17/11/20	275.6603
18/11/20	248.0999
19/11/20	239.3566
20/11/20	231.2625
21/11/20	203.5158
22/11/20	179.9920
23/11/20	198.1190
24/11/20	159.2949
25/11/20	144.7886
26/11/20	150.2991
27/11/20	134.3898
28/11/20	115.5881
29/11/20	121.3121
30/11/20	97.6951
01/12/20	93.8781
02/12/20	92.2915
03/12/20	72.5142
04/12/20	63.9985
05/12/20	69.2368
06/12/20	51.7406
07/12/20	47.2264
08/12/20	48.3238
09/12/20	39.1802
10/12/20	35.6796
11/12/20	36.6294

12/12/20	27.4018
13/12/20	26.7310
14/12/20	26.5870
15/12/20	19.6068
16/12/20	18.0748
17/12/20	18.8579
18/12/20	13.9013
19/12/20	13.2555
20/12/20	13.3261
21/12/20	10.3686
22/12/20	10.1218
23/12/20	10.1633
24/12/20	7.6483
25/12/20	7.6710
26/12/20	7.6159
27/12/20	5.8096
28/12/20	5.6781
29/12/20	5.7132
30/12/20	4.5129
31/12/20	4.5255
01/01/21	4.4773
02/01/21	3.7000
03/01/21	3.7693
04/01/21	3.7316
05/01/21	3.1242
06/01/21	3.1859

07/01/21	3.1459
08/01/21	2.7217
09/01/21	2.7490
10/01/21	2.7206
11/01/21	2.4414
12/01/21	2.4843
13/01/21	2.4539
14/01/21	2.2657
15/01/21	2.3075
16/01/21	2.2848
17/01/21	2.1450
18/01/21	2.1741
19/01/21	2.1545
20/01/21	2.0584
21/01/21	2.0780
22/01/21	2.0623
23/01/21	1.9988
24/01/21	2.0174
25/01/21	2.0049
26/01/21	1.9615
27/01/21	1.9765
28/01/21	1.9672
29/01/21	1.9361
30/01/21	1.9463
31/01/21	1.9387
01/02/21	1.9175

02/02/21	1.9249
03/02/21	1.9190
04/02/21	1.9049
05/02/21	1.9110
06/02/21	1.9066
07/02/21	1.8970
08/02/21	1.9016
09/02/21	1.8983
10/02/21	1.8916
11/02/21	1.8947
12/02/21	1.8922
13/02/21	1.8876
14/02/21	1.8899
15/02/21	1.8880
16/02/21	1.8850
17/02/21	1.8867
18/02/21	1.8853
19/02/21	1.8833
20/02/21	1.8846
21/02/21	1.8835
22/02/21	1.8821
23/02/21	1.8830
24/02/21	1.8822
25/02/21	1.8813
26/02/21	1.8819
27/02/21	1.8813

28/02/21	1.8807
01/03/21	1.8812
02/03/21	1.8808
03/03/21	1.8804
04/03/21	1.8807
05/03/21	1.8804
06/03/21	1.8801
07/03/21	1.8803
08/03/21	1.8801
09/03/21	1.8799
10/03/21	1.8801
11/03/21	1.8799
12/03/21	1.8798
13/03/21	1.8799
14/03/21	1.8798
15/03/21	1.8797
16/03/21	1.8798
17/03/21	1.8797
18/03/21	1.8797
19/03/21	1.8797
20/03/21	1.8797
21/03/21	1.8796
22/03/21	1.8797
23/03/21	1.8796
24/03/21	1.8796
25/03/21	1.8796

26/03/21	1.8796
27/03/21	1.8796
28/03/21	1.8796
29/03/21	1.8796
30/03/21	1.8796
31/03/21	1.8796
01/04/21	1.8796
02/04/21	1.8796
03/04/21	1.8796
04/04/21	1.8796
05/04/21	1.8796
06/04/21	1.8796
07/04/21	1.8796
08/04/21	1.8795
09/04/21	1.8796
10/04/21	1.8795
11/04/21	1.8795
12/04/21	1.8795
13/04/21	1.8795
14/04/21	1.8795
15/04/21	1.8795
16/04/21	1.8795
17/04/21	1.8795
18/04/21	1.8795
19/04/21	1.8795
20/04/21	1.8795

21/04/21	1.8795
22/04/21	1.8795
23/04/21	1.8795
24/04/21	1.8795
25/04/21	1.8795
26/04/21	1.8795
27/04/21	1.8795
28/04/21	1.8795
29/04/21	1.8795
30/04/21	1.8795

Table 2 are the descriptive statistics of the series, X. The average daily new case volume is 413 cases for the period under study; with a maximum number of cases having been 1829 cases. The summary of the applied model is shown in table 3: the error, MSE and MAE indicate that the model is acceptable. Furthermore, figure compliments this fact because the residual analysis tells us that the model is stable also. The in-sample predictions are shown in figure 2 while figure 3 and table 4 show out-of-sample forecasts. What is clear is that COVID-19 cases are likely to continue declining sharply in Ethiopia over the out-of-sample period. By early 2021, the country could possibly win the war against the pandemic, holding other things constant. The results of this study are quite reasonable and acceptable especially given the government's response to the pandemic. Various control and preventive measures were put in place urgently as soon as the first case was confirmed, for example, travel restrictions, isolations, quarantining, wearing of masks, social distancing and so on. All these strategies have been shown to work in controlling the spread of the virus and hence there is need for a continued implementation of these control and preventive strategies.

CONCLUSION & RECOMMENDATIONS

The outbreak of COVID-19 is a global health and economic security threat with staggering cumulative incidence worldwide (Mohammed *et al*., 2020; Bogoch *et al*., 2020; Wu *et al*., 2020), and has apparently caused massive damage on the Ethiopian economy (Bogale *et al*., 2020; Geda, 2020a & b; Demiessie, 2020; Beyene *et al*., 2020). In fact, economic growth has already been lowered by 1%, 1.5% and 2.5% globally, in Africa and in Ethiopia, respectively (Vos *et al*., 2020; Kapata *et al*., 2020; Jimma, 2020). However we still recommend the following: people in the country should continue to avoid close contact with the sick, continue to avoid touching the eyes, nose and mouth with unwashed hands, consistent washing of hands, wearing of masks, social distancing, seeking medical advice as early as possible in case of need and so on amongst other guidelines set by the WHO. This will go a long way in controlling the pandemic.

REFERENCES

[1] Abebe, T. H. (2020). Forecasting the Number of Coronavirus (COVID-19) Cases in Ethiopia Using Exponential Smoothing Time Series Model, *medRxiv*, pp: 1 – 12.

[2] Alemneh, H. T., & Tilahun, G. T. (2020). Mathematical Modeling and Optimal Control Analysis of COVID-19 in Ethiopia, *medRxiv*, pp: 1 – 33.

[3] Argawu, A. S. (2020). Regression Models for Predictions of COVID-19 New Cases and New Deaths Based on May/June Data in Ethiopia, *medRxiv*, pp: 1 – 14.

[4] Balcha, A. A. (2020). Curve Fitting and Least Square Analysis to Extrapolate for the Case of COVID-19 Status in Ethiopia, *Advances in Infectious Diseases*, 10: 143 – 159.

[5] Beyene, L. M., Ferede, T., & Diriba, G. (2020). The Economy-wide Impact of the COVID-19 in Ethiopia: Policy and Recovery Options, Working Paper No. 3, Ethiopian Economics Association (EEA).

[6] Bogale, M., Kelkay, S., & Mengesha, W. (2020). COVID-19 Pandemic and Tourism Sector in Ethiopia, *Horn of Africa Journal of Business and Economics (HAJBE)*., Special Issue 1, pp: 1 – 9.

[7] Bogoch, I. I., *et al*. (2020). Pneumonia of Unkown Aetiology in Wuhan, China: Potential for International Spread via Commercial Air Travel, *Journal of Travel Medicine*, 27 (2): 1 – 6.

[8] COVID-19 Repository By the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University.

[9] Demiessie, H. G. (2020). COVID-19 Pandemic Uncertainty Shock Impact on Macroeconomic Stability in Ethiopia, MPRA Paper No. 102625, Munich, Germany.

[10] Demiessie, H. G. (2020). COVID-19 Pandemic Uncertainty Shock Impact on Macroeconomic Stability in Ethiopia, MPRA Paper No. 102625, Munich, Germany.

[11] Deressa, C. T., & Duresa, F. G. (2020). Modeling and Optimal Control Analysis of Transmission Dynamics of COVID-19: The Case of Ethiopia, *Alexandria Engineering Journal*, pp: 1 – 14.

[12] Dong, E., *et al*. (2020). An Interactive Web-based Dashboard to Track COVID-19 in Real Time, *Lancet Infectious Diseases*, 20 (5): 533 – 534.

[13] EFMOH (2020). National COVID-19 Daily Report, *EFMOH*, Addis Ababa.

[14] Geda, A. (2020a). The COVID-19 Damage on the Ethiopian Service Sector: A Supplement Using Google Search Trend "Big Data", *Department of Economics*, Addis Ababa University.

[15] Geda, A. (2020b). The Macroeconomic and Social Impact of COVID-19 in Ethiopia and Suggested Direction for Policy Response, *Department of Economics*, Addis Ababa University.

[16] Guan, W. J., *et al*. (2020). Clinical Characteristics of Coronavirus Diseases 2019 in China, *New England Journal of Medicine*, 382 (18): 1708 – 1720.

[17] Hu, Z., *et al*. (2020). Artificial Intelligence Forecasting of COVID-19 in China, *medRxiv*, pp: 1 – 16.

[18] Jimma, E. (2020). COVID-19 Probable Impacts on Ethiopian Agriculture and Potential Mitigation and Adaptation Measures: No Food, No Health, No Life, *medRxiv*, pp: 1 – 27.

[19] Kapata, N., *et al*. (2020). Is Africa Prepared for Tackling the COVID-19 (SARS-CoV-2) Epidemic: Lessons From Past Outbreaks, Ongoing Pan-African Public Health Efforts, and Implications for the Future, *International Journal of Infectious Diseases*, 93 (233): 1 – 12.

[20] Leulseged, T. W., *et al*. (2020a). Determinants of Time to Convalescence Among COVID-19 Patients at Millennium COVID-19 Care Center in Ethiopia: A Prospective Cohort Study, *medRxiv*, pp: 1 – 16.

[21] Leulseged, T. W., *et al*. (2020b). Duration of Supplemental Oxygen Requirement and Predictors in Severe COVID-19 Patients in Ethiopia: A Survival Analysis, *medRxiv*, pp: 1 – 15.

[22] Leulseged, T. W., *et al*. (2020c). COVID-19 Disease Severity and Determinants Among Ethiopian Patients: A Study of the Millennium COVID-19 Care Center, *medRxiv*, pp: 1 – 13.

[23] Maru, E. H., *et al*. (2020). Predictors of Death in Severe COVID-19 Patients at Millennium COVID-19 Care Center in Ethiopia: A Case-Control Study, *medRxiv*, pp: 1 – 15.

[24] Mohammed, H., *et al*. (2020). Containment of COVID-19 in Ethiopia and Implications for Tuberculosis Care and Research, *Infectious Diseases of Poverty*, 9 (131): 1 – 8.

[25] Rothan, H. A., & Byrareddy, S. N. (2020). The Epidemiology and Pathogenesis of Coronavirus Disease (COVID-19) Outbreak, *medRxiv*, pp: 1 – 21.

[26] Tao, Z., *et al*. (2020). A New Coronavirus Associated With Human Respiratory Disease in China, *medRxiv*, pp: 1 – 14.

[27] Vos, R., Martin, W., & Laborde, D. (2020). How Much Will Global Poverty Increase Because of COVID-19, *International Food Policy Research Institute*, pp: 1 – 28.

[28] Wang, Y., *et al*. (2020). Abnormal Respiratory Patterns Classifier May Contribute to Large-scale Screening of People Infected With COVID-19 in an Accurate and Unobtrusive Manner, *medRxiv*, pp: 1 – 15.

[29] WHO (2020a). Coronavirus Disease (COVID-19) Situation Report, *WHO*, Geneva.

[30] WHO (2020b). Director General's Opening Remarks at the Media Briefing on COVID-19, *WHO*, Geneva.

[31] Wu, J. T., Leung, G. M., & Leung, K. (2020). Nowcasting and Forecasting the Potential Domestic and International Spread of the 2019-nCoV Outbreak Originating in Wuhan, China: A Modeling Study, *The Lancet*, 395 (10225): 689 – 697.