

Forecasting Infant Mortality Rate in Ethiopia Using Artificial Neural Networks

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Abstract - In this piece of work, the ANN approach was applied to analyze infant mortality rate in Ethiopia. The employed annual data covers the period 1966-2020 and the out-of-sample period ranges over the period 2021-2030. The residuals and forecast evaluation criteria (Error, MSE and MAE) of the applied model indicate that the model is stable in forecasting infant mortality rate in Ethiopia. The ANN (12, 12, 1) model predictions suggest that IMR will be around 34/1000 live births per year in the out-of-sample period. Therefore, in line with the policy recommendations, the government is encouraged to intensify maternal and child health surveillance and control programs in order to curb infant mortality in the country.

Keywords: ANN, Forecasting, infant mortality rate.

I. INTRODUCTION

Artificial intelligence (AI) has a great potential for use in public health. Machine learning (ML) is a sub discipline of AI and is defined as the ability of computers to learn through experience. ML algorithms can analyze large amounts of data with accurate results (Zhao et al, 2020; Panch et al, 2018; Makhlysheva, 2018; Weng et al, 2017). ML algorithms have four uses in health 1) interpretation of medical images, prognostics, diagnostics and time series modelling and forecasting (Makhlysheva, 2018). There are four types of ML which are supervised, unsupervised, semi-supervised and re-enforcement learning. In supervised learning the algorithm learns by comparing their own predictions with the sample data that a human supervisor has provided (Weng et al, 2017). When the algorithm finds the hidden structures or patterns in the input data it is then known as unsupervised learning. Semi supervised learning combines the use of a small amount of labelled data with larger amount of unlabeled data. Enhanced or reinforcement learning means that the algorithm is rewarded when it takes the right decision in a given situation. ML algorithms are very useful in time series modelling and forecasting, however they have been under-utilized in low and middle income countries. Algorithms such as ensembles, support vector machine, artificial neural networks, K-nearest neighbors and Bayesian networks have gained tremendous popularity in forecasting problems (Nyoni et al, 2020; Zhao et al, 2020, Weng et al, 2017).

In this paper we aim to model and forecast infant mortality rate in Ethiopia using artificial neural networks. The multilayer perceptron is chosen to predict IMR and the model is composed of 3 layers namely input, hidden and output layers (Zhao et al, 2020, Nyoni et al, 2020; Yan et al, 2018; Kaushik & Sahi, 2018; Fojnica et al, 2016; Zhang, 2003; Kishan, 1997; Patterson, 1995). The findings of the study are expected to detect the likely future trends of infant mortality rate in Ethiopia and facilitate resource allocation for health in order to achieve sustainable development goals by 2030.

II. LITERATURE REVIEW

Islam et al (2020) developed a predictive analytics framework to predict the death rates with high accuracy and to find the significant determinants that cause high child mortality. The framework used an automated method of information gain to rank the information-rich mortality variables for accurate predictions. Ethiopian Demographic Health Survey and Pakistan Demographic Health Survey data sets were used for the validation of the proposed framework. These real-world data sets were tested using machine learning classifiers, such as Naïve Bayes, decision tree, rule induction, random forest, and multi-layer perceptron, for the prediction task. The authors concluded that Naïve Bayes classifier predicts the child mortality rate with the highest average accuracy of 96.4% and decision tree helps in identifying key classification rules covering the factors behind children deaths. In another study, Nyoni & Nyoni (2020) modelled and forecasted infant deaths in Zimbabwe using ARIMA models. The study utilized annual time series data on total infant deaths in Zimbabwe from 1960 to 2018. The optimal model based on AIC was the ARIMA (1, 2, 5) model. The study concluded that the number of infant deaths per year, over the out-of-sample period, would follow a downward trend. In a related study, Nyoni & Nyoni (2020) used monthly time series data on

neonatal deaths cases at Chitungwiza Central Hospital (CCH) from January 2013 to December 2018; to forecast neonatal deaths over the period January 2019 to December 2020 using the Box-Jenkins SARIMA approach. The parsimonious model was found to be the SARIMA (0, 0, 3) (2, 0, 0)₁₂ model and its predictions indicate slow but steady decrease in neonatal deaths at CCH. Khan et al (2019) modelled and forecasted infant mortality rates of Asian countries in the perspective of GDP. Secondary data of IMR and GDP (PPP) from 1980 to 2015 was analyzed and forecast was done from 2016 to 2025. AR (1) was found to be suitable for all the countries except Japan and Nepal for which ARIMA (1, 1, 1) model was appropriate based on FMSE and FRMSE.

III. METHODOLOGY

The Artificial Neural Network (ANN), which we intend to apply in this study; is a data processing system consisting of a huge number of simple and highly interconnected processing elements resembling a biological neural system. It has the capability of learning from any data-set to describe the nonlinear and interaction effects with great accuracy. No strict rules exist for the determination of the ANN structure hence the study applies the popular ANN (12, 12, 1) model based on the hyperbolic tangent activation function. This paper applies the Artificial Neural Network (ANN) approach in predicting infant mortality rates in Ethiopia.

Data Issues

This study is based on annual infant mortality rates in Ethiopia for the period 1966 – 2020. The out-of-sample forecast covers the period 2021 to 2030. Infant mortality rate, which is simply a proxy for infant deaths; for the purposes of this study, is defined as the number of infants dying before reaching one year of age, per 1000 live births in a given year. All the data employed in this paper was gathered from the World Bank.

IV. FINDINGS OF THE STUDY

ANN Model Summary

Table 1: ANN model summary

Variable	R
Observations	43 (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	0.017831
MSE	1.187407
MAE	0.826305

Residual Analysis for the Applied Model

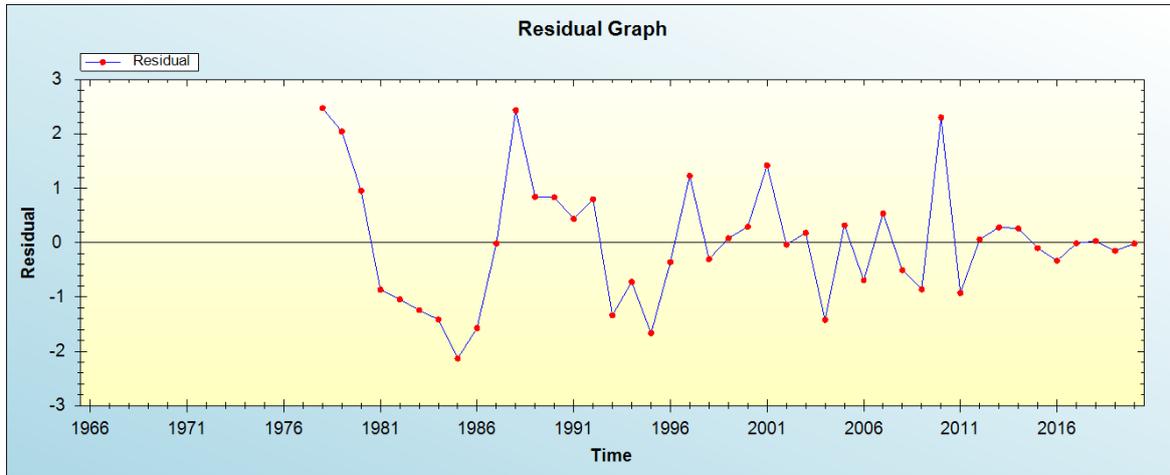


Figure 1: Residual analysis

In-sample Forecast for R

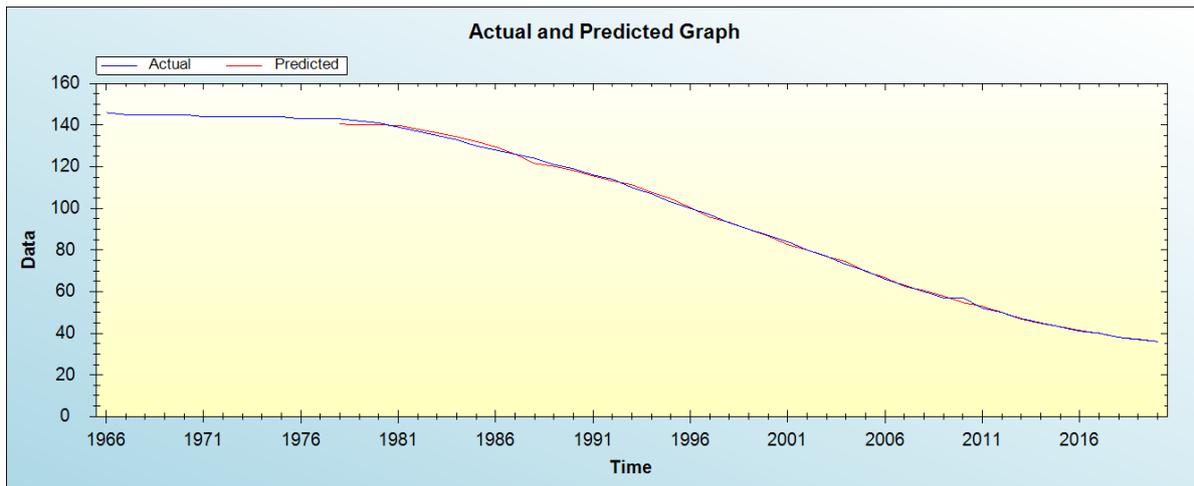


Figure 2: In-sample forecast for the R series

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

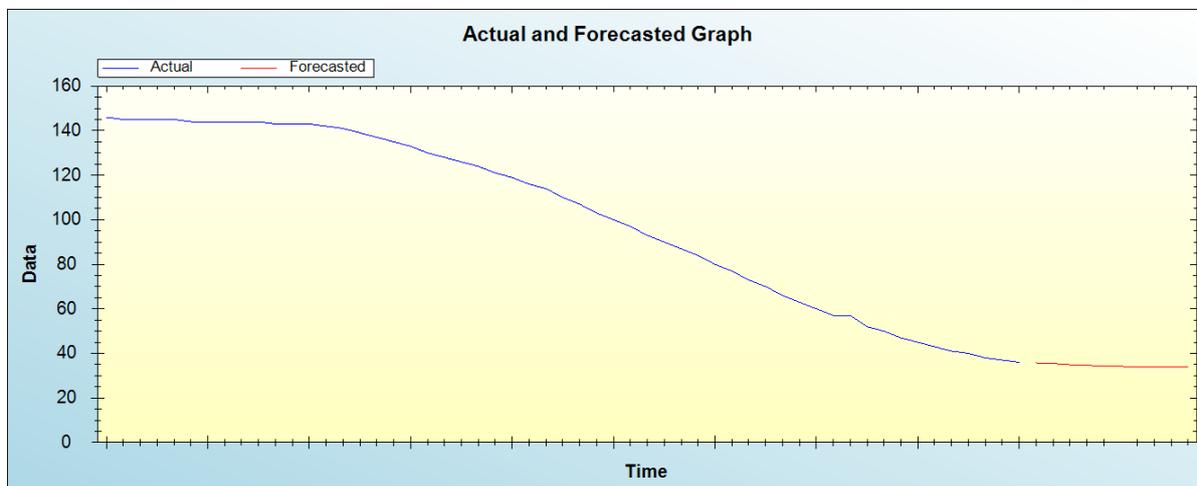


Figure 3: Out-of-sample forecast for R: actual and forecasted graph

Out-of-Sample Forecast for R: Forecasts only

Table 3: Tabulated out-of-sample forecasts

Year	Forecasts
2021	35.7756
2022	35.5163
2023	34.9272
2024	34.6603
2025	34.3151
2026	34.1890
2027	34.0075
2028	33.9696
2029	33.8955
2030	33.7671

The main results of the study are shown in table 1. It is clear that the model is stable as confirmed by evaluation criterion as well as the residual plot of the model shown in figure 1. It is projected that infant mortality in Ethiopia is likely to remain around 34% per year over the next decade.

V. CONCLUSION AND POLICY RECOMMENDATIONS

Preventing infant mortality remains one of the main objectives of the health ministry in Ethiopia. The Ethiopia government remains committed to ending preventable deaths infants in the country. The study used annual data to analyze the trends of infant mortality in Ethiopia. The applied model is the ANN model. In order to make sure that infant mortality in the country significantly declines, the government of Ethiopia ought to consider the following policy suggestions:

- i. The Ethiopian government should continue to encourage mothers to breast-feed their babies adequately.
- ii. There is need for all Ethiopian child-bearing women to be vaccinated against common illnesses.
- iii. There is need to prevent birth defects in Ethiopia.
- iv. The government of Ethiopia should address preterm birth, low birth-weight and their outcomes.
- v. The government of Ethiopia should also ensure adequate access to pre-pregnancy and prenatal care.
- vi. There is need to educate, especially, mothers on the importance of creating a safe infant sleep environment in the country.
- vii. Healthcare providers in Ethiopia need to use newborn screening activities in order to detect hidden conditions.

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Citation of this Article:

Dr. Smartson. P. NYONI, Thabani NYONI, "Forecasting Infant Mortality Rate in Ethiopia Using Artificial Neural Networks" Published in *International Research Journal of Innovations in Engineering and Technology - IRJIET*, Volume 5, Issue 3, pp 647-651, March 2021. Article DOI <https://doi.org/10.47001/IRJIET/2021.503112>
