International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 5, Issue 8, pp 347-350, August-2021

https://doi.org/10.47001/IRJIET/2021.508076

Projection of Total Fertility Rate (TFR) In the United States of America Using a Machine Learning Approach

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***Abstract* - The United states is among the first world countries which are currently reporting fertility rates below replacement level and this has serious negative consequences in the near future with regards to the availability of youthful labor force, increase in health expenditure and social security costs. In this study, the ANN approach was applied to analyze TFR in the USA. The employed annual data covers the period 1960-2018 and the out-of-sample period ranges over the period 2019-2030. The residuals and forecast evaluation criteria (Error, MSE and MAE) of the applied model indicate that the model is stable in forecasting TFR in the USA. The results of the study indicate that annual total fertility rates in the USA are likely to be around 1.9 births per woman throughout the out-of-sample period. Therefore, the US government is encouraged to promote child bearing especially among women in the 18-30 years age group by providing pro-fertility incentives and reducing the cost of raising children.**

Keywords: ANN, Forecasting, Total fertility rate (TFR).

I. INTRODUCTION

The US fertility rate reached its lowest levels in 2017 (Buckle et al, 2019) and still remains below the replacement fertility level (Hamilton et al, 2018). Birth rates have remained low, however birth rates for women over thirty have been on an upward trend since 1980 while the rate for younger women peaked in the early 1990S (Buckles et al, 2019). The US fertility rate has been decreasing over the years from 3.3 births per woman in 1955 to below replacement level of 1.8 births per woman in 2020 (Worldometer, 2020). The country has recorded a downward trend in infant and under five mortality rates. Infant mortality rate declined from 30.16 infant deaths per 1000 live births in 1950 to 5.48 infant deaths per 1000 live births in 2020. Under five mortality declined from 35.22 deaths per 1000 live births in 1950 to 7.01 deaths per 1000 live births (Worldometer, 2020). The country has consistently reported low IMR and under five mortality over the past decades reflecting the high quality of health care services available for its population. Prediction of fertility rates has not been done by many authors in the USA. Buckles et al (2020) explored the role of changes in unintended births in explaining fertility patterns in the U.S. from 1980 to 2017. The study showed that 35% of the decline in fertility between 2007 and 2016 can be explained by declines in births that were likely unintended, and that this is driven by drops in births to young women. Hamilton et al (2019) predicted future fertility rates using the Bayesian framework using data from England and Wales, the USA, Sweden and France. The results indicated that the former two countries exhibit multi-modality in their fertility rate curves as a function of age, while the latter two are largely uni-modal and forecast performance is found to be comparable to other models identified as producing accurate fertility forecasts in the literature. Based on the Holt's exponential smoothing models, Wang (2018) predicted fertility rates to restore fertility data in China from 2016 and beyond. The study findings revealed that population structure was aging fast, fertility rates continued to decrease to a substantially low level, and three Northeastern provinces displayed notable socioeconomic issues associated with low-fertility trap. Another research done by Vanella et al (2018) proposed a simulation approach for the indirect estimation of age-specific fertility rates (ASFRs) and the total fertility rate (TFR) for Germany via time series modeling of the principal components of the ASFRs. The findings indicated that TFR will increase from 1.6 in 2016 to 1.68 in 2040 and will be between 1.46 and 1.92 with a probability of 75%.

The aim of this study is to project total fertility rate in the USA using a machine learning algorithm. The results of this piece of work are expected to highlight the likely fertility trends in the out of sample period. This will assist in policy making and trigger an appropriate timeous response to the health, education and employment needs of the US population.

II. METHODOLOGY

The Artificial Neural Network (ANN) approach, which is flexible and capable of nonlinear modeling; will be applied in this study. The ANN is a data processing system consisting of a large number of highly interconnected processing elements in architecture inspired by the way biological nervous systems of the brain appear like. Since no explicit guidelines exist for the determination of the ANN structure, 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 annual total fertility rates in USA.

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Data Issues

This study is based on annual total fertility rate (births per woman) in USA for the period 1960 – 2018. The out-of-sample forecast covers the period 2019 – 2030. All the data employed in this research paper was gathered from the World Bank online database.

III. FINDINGS OF THE STUDY

ANN Model Summary

Table 1: ANN model summary

Variable	U
Observations	47 (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	0.247104
MSE	0.015320
MAE	0.103315

Residual Analysis for the Applied Model

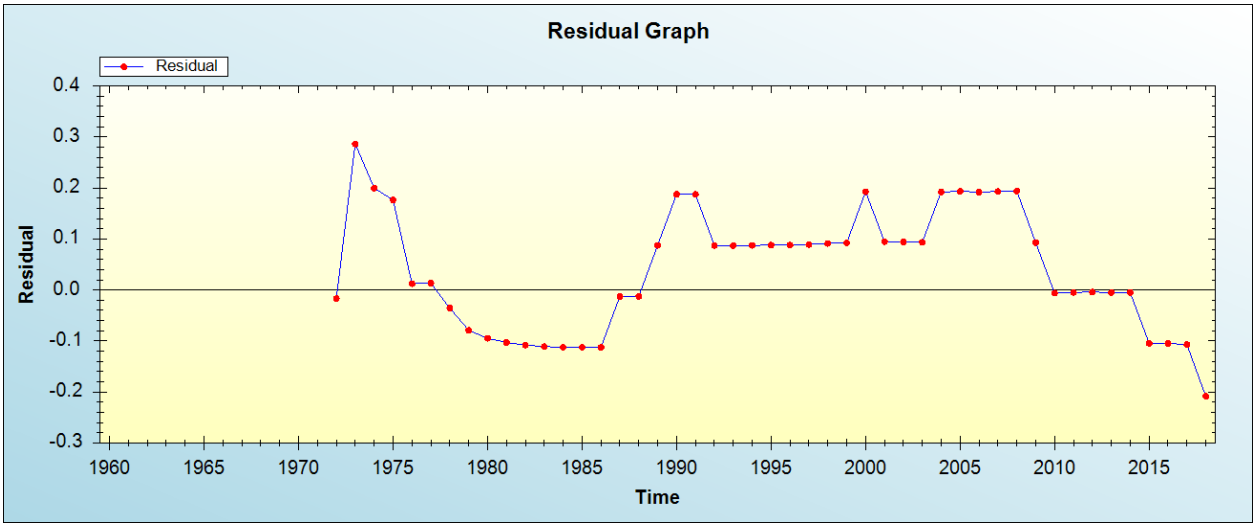

Figure 1: Residual analysis

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In-sample Forecast for U

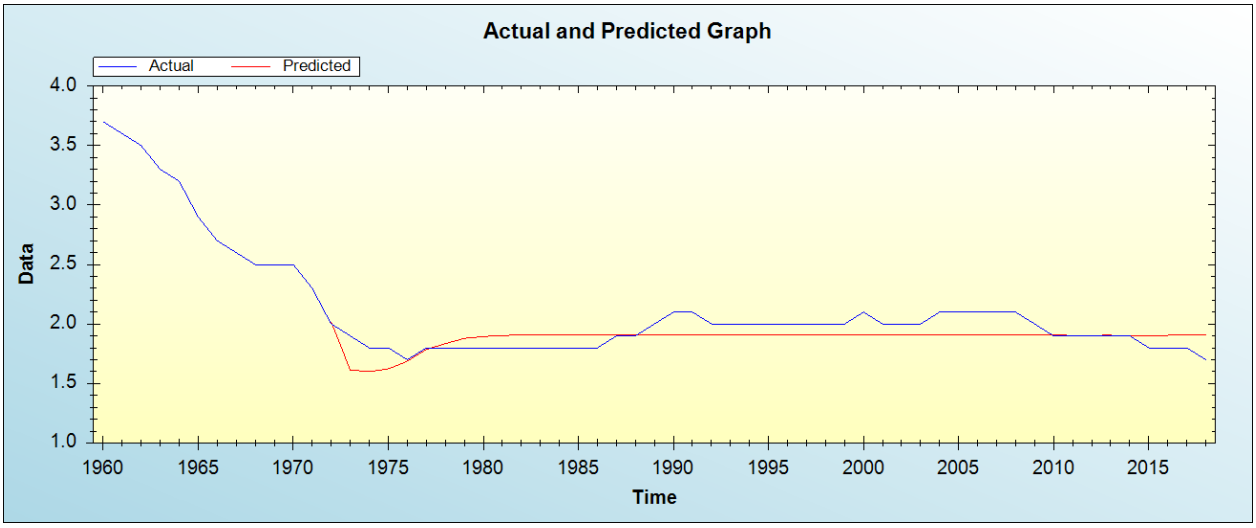

Figure 2: In-sample forecast for the U series

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

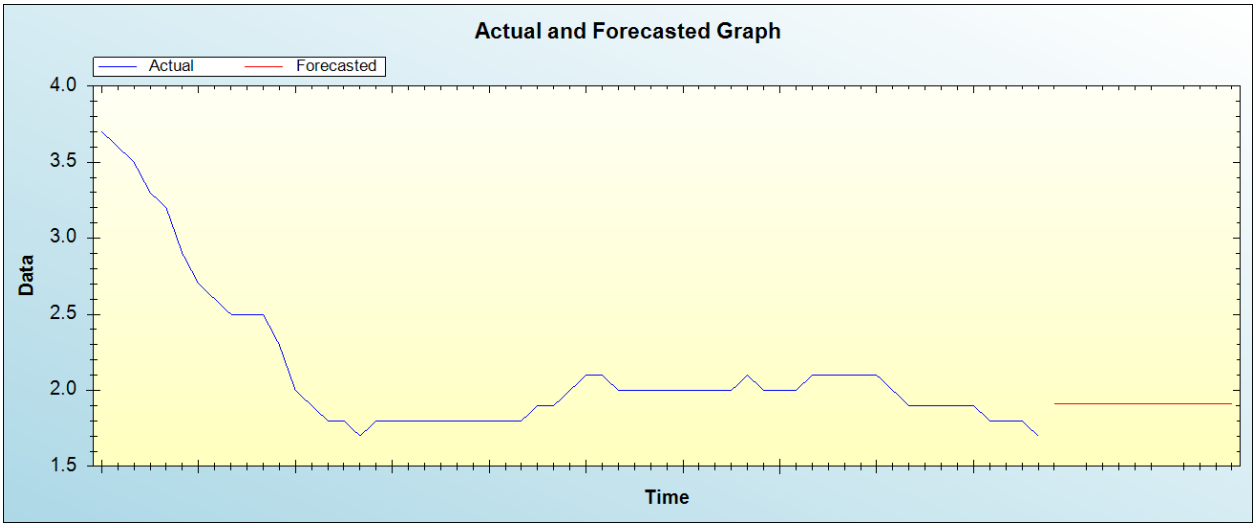

Figure 3: Out-of-sample forecast for U: actual and forecasted graph

Out-of-Sample Forecast for U: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted TFR values
2019	1.9092
2020	1.9102
2021	1.9111
2022	1.9112
2023	1.9120
2024	1.9114
2025	1.9120
2026	1.9125
2027	1.9117
2028	1.9121
2029	1.9119
2030	1.9111

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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 annual total fertility rates in USA are likely to be around 1.9 births per woman throughout the out-of-sample period.

IV. CONCLUSION & RECOMMENDATIONS

The US government has done very well in preventing adverse maternal and child health outcomes as this is reflected by consistently low maternal, infant and child mortality rates. The country has witnessed fertility transition over the years and TFR currently is below replacement level, however births rates for women over thirty years is on an upward trend. In this study we proposed a machine learning algorithm to project total fertility rate for the US. The findings indicated that annual total fertility rates in USA are likely to be around 1.9 births per woman throughout the out-of-sample period. Therefore, the US government is encouraged to continue to promote child bearing especially among women in the 18-30 years age group by providing pro-fertility incentives and reducing the cost of raising children.

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Citation of this Article:

Dr. Smartson. P. NYONI, Tatenda. A. CHIHOHO, Thabani NYONI, "Projection of Total Fertility Rate (TFR) In the United States of America Using a Machine Learning Approach" Published in *International Research Journal of Innovations in Engineering and Technology - IRJIET*, Volume 5, Issue 8, pp 347-350, August 2021. Article DOI https://doi.org/10.47001/IRJIET/2021.508076

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