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Predicting and Controlling Fertility Using Family Planning Methods

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Abstract: Without a real reduction in population fertility rates, developing societies will push for more spending on their infrastructure and more demand for basic services for new-born, and more dependency and crowding, and the attendant ills and various social, economic and cultural problems, which will push these countries towards Directing a large part (if not most) of development revenues to meet the growing population. In general, the importance of this study lies in how to predict fertility rates using the rates of family planning methods (practice rates, years of protection) and to identify the method of neural networks and its accuracy in dealing with fertility data in particular. The study concluded that the prevalence of family planning methods (PR) and protection rate (CYP) are used to estimate and predict the total fertility rate (TFR) very efficiently, and artificial neu6ral networks have reached a high rate and high accuracy in estimating and predicting the total fertility rate (TFR) is highly and reliable (99.6%).

Keywords: Fertility, Total fertility rate (TFR), Prevalence of contraceptive use (PR), Protection rate (CYP), Neural networks, Training algorithms, Prediction accuracy criteria.

1 Introduction

The demographic literature indicates that high population growth rates are not only reflected in the size of the population, but rather extend to their age and gender structure, density and economic, social and geographical distribution. It may also increase the expenditures for securing the basic needs of the population, and may pose many obstacles to the economic, social and political development of countries in general and developing countries in particular, due to the lack of capabilities and capabilities to meet the needs of the population. The challenges arising from overpopulation and its negative effects in terms of absorbing and wasting development revenues, and these changes resulted in these societies becoming more accepting of the idea of fertility regulation, so that these changes formed prominent and influential signs in the reproductive behavior of individuals, especially since this behavior is no longer a behavior Biologically deterministic and absolute, it is a changing behavior and is determined in light of a set of socio-economic and demographic factors, which can affect Indicate the lives, attitudes and attitudes of community members. All of this was reflected in the destruction of many traditional values and attitudes in the same society [1].

It seems that without a real reduction in population fertility rates, developing societies will push for more spending on their infrastructure and more demand for basic services for new-born, more dependency and overcrowding and the attendant ills and various social, economic and cultural problems, which will push these Countries are directing a large part (if not most) of development revenues to meet the growing population. Davies and Black put forward an important model in which they explained the pattern of factors that could have a decisive and direct impact on the reproductive behavior of individuals, and they called them “intermediate variables” that is, they are mediators between social and cultural institutions, and between the level of fertility on the one hand. In this regard, they affirmed that there can be no impact on the level of population fertility, except through one or more of these intermediate variables. As for Bongaarts, [2] it was built on the thought of these two worlds, and reduced a number of direct demographic variables influencing at the level of fertility, it is divided into four variables: “the use of contraceptives, age at marriage, breastfeeding, and abortion, and he called them the approximate variables. It should be noted here, that in this study we will reduce the Bongaarts variables to only one

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variable, which is contraception, which represents the largest weight in controlling fertility, and through it we can estimate and predict the level of fertility. Despite the decline in fertility levels in many societies during the last three decades, they remained far from the desired global fertility levels, even if they achieved some required decline.

2 Research Problems

The research problem crystallizes in how to predict fertility rates using the rates of family planning methods (practice rates, years of protection) and to identify the method of neural networks and its accuracy in dealing with population data in general and fertility data in particular, and this can be determined by answering the following question: How to use the rates of family planning methods (practice rates, years of protection) to predict the fertility rate in different administrative regions using neural networks.

3 Research Objectives

- Using the rates of family planning methods (practice rates, years of protection) to predict the fertility rate in different administrative regions using neural networks.
- Verification of the quality criteria for using the neural network method to predict the fertility rate.

4 Research Importances

The population problem is one of the most important problems facing development policies in the world, and it is sought to deal with it in a manner consistent with the specificity of each country and its level of development, and it is defined as the imbalance between the increase in the population and the development in the volume of resources and services. In educational opportunities, health facilities, job opportunities, or an increase in the economic level, the problem appears clearly - represented by high rates of population increase and rates of development that are not in line with population growth rates - and this in turn leads to a decrease in the standard of living. The importance of the research lies in predicting the fertility rate in the different administrative regions, where there are clear discrepancies in the level of fertility between the regions and governorates of Egypt, in order to effectively intervene in controlling the high fertility according to the characteristics of each region.

5 Research Assumptions

- Prediction and control of fertility using family planning methods.
- Neural networks are one of the best smart methods for estimating and predicting fertility levels.

6 Data Sources

The study is based on Egypt Demographic Health Survey data from 1980-2014

7 Previous Studies

7.1 Fertility Studies

In a study conducted by Jamal et al. 2012, it aimed to analyze the impact of economic and social factors on fertility levels and to determine the extent to which each of them contributes to reducing total fertility rates using multiple linear regression analysis. The study found that the greater the evidence for human development, the lower the total fertility rate [3].

In a study conducted by Al-Najjar in 2014, it aimed to identify the socio-economic and demographic characteristics affecting the fertility of the woman in the family with a child with a disability, as well as to identify the level of fertility in those families. The study aimed to identify the effect of a disabled child in the family on the desired number of children before and after having a child with a disability, the arrangement of that child and the types of that disability at the level of fertility. The methodology of the study relied on the use of the descriptive and analytical statistical method. Linear regression and logistic regression were used. The study concluded that the woman's age and age at first marriage, whether the child is disabled or not, the woman's educational status, the kinship relationship between the spouses and the woman's work before the first marriage have an impact on the total number of boys in the family. [4]

In a study conducted by Jamal 2014 aimed at comparing the characteristics of the four governorates in terms of social,

economic and demographic terms with high levels of fertility. The study reached to take into account the nature and characteristics of each governorate separately and the nature of the problems facing family planning programs. It also concluded the need to focus on the phenomenon of early marriage, especially in the governorate of Beni Suef. The study also concluded that attention should be paid to health and family planning services in Upper Egypt. [5]

7.2 Studies of Neural Networks

In a study conducted by Al-Maliki in 2017, it aimed to apply the Box and Jenkins method in analyzing time series and predicting the number of accidents and injuries in the Kingdom of Saudi Arabia. One of the results of the study was that the Boxes and Jenkins models are the best ways to predict traffic accidents, and the study emphasizes the use of these models in predicting traffic accidents and their variables [6].

In a study conducted by Safi 2017, it aimed to compare the use of ARIMA models and the neural network model, the uses of applied data from the Palestinian society and simulation data. The data showed linear relationship, and simulation results indicated that modeling using ARIMA produced the most accurate predictions for almost all cases Except for a very small sample, when the size is 10 cases, the predictions using ARIMA were more accurate than the neural network model, and the experimental results of the data showed that the ARIMA models outperform the neural networks model, and thus resulted in more accurate predictions than the neural networks [7].

A study conducted by Adreba and others aimed at comparing the Arima model and the artificial neural network models in predicting stock prices. ARIMA model and neural networks can make good predictions. The prediction model using neural networks showed superiority over the ARIMA model in reality and the actual and expected values of the prediction model in future studies can use a hybrid of smart technologies [8]

8 Uses of Family Planning Methods and Its Relationship to Population Fertility

The variable of contraceptive use is directly responsible for reducing fertility and for the success of family planning programs in most countries of the world. Previous studies confirm that many women in most developing societies cannot use contraceptives before ensuring the birth of at least one child, and this means that the process of contraceptive use The transition from the stage of marriage to the stage of motherhood (bearing the first child) is completely linked to the woman's natural ability to become pregnant and procreate (Fecundability) and to repeat the process of sexual intercourse between spouses (Rodriguez et al 1983), as the results of previous studies in this regard showed that most contraceptive users in Societies of developing countries are among the older women who have spent long periods of marriage, who have a large number of children, and who usually resort to the use of contraceptives in order to stop their excess fertility, and not with the aim of regulating their reproductive behavior, and this explains the marginal and failure of the effect of using contraceptives On the fertility behavior of women in many developing societies [9], but despite this, many demographic studies concluded that the use of contraceptives is considered harmful. The most important means in family planning and reducing the level of marital fertility, especially for couples who aspire to form a small family. [10]

9 Family Planning

Access to safe, voluntary family planning is a human right. Family planning is central to gender equality and women's empowerment, and it is a key factor in reducing poverty. Yet, globally at least 222 million women who want to use safe and effective family planning methods are unable to do so because they lack access to information, services, commodities or the support of their partners or communities. Most of the women with an unmet need for family planning live in 69 of the poorest countries on earth. [11]

9.1 Family Planning in Egypt

Egypt is the most populous country in the Middle East and the third most populous country in Africa. The fertility rate reached 3.1 for the year 2018, and fertility levels are the main determinant of population growth. Fertility rates in Egypt have been on an upward trend since 2006, reaching their highest level in 2014 at 3.5. Fertility rates declined at a slower pace in 2017 (3.4) compared to 2014, but experienced a sharp decline in 2018, reaching 3.1. According to the 2014 Egypt Demographic Health Survey, 16 percent of births in the five-year period preceding the survey accounted for unwanted births at the time of conception. This percentage is slightly higher than the percentage of women who reported an unwanted birth in the 2008 DHS (14%). Of the unwanted births at the time of conception, just over half (8% of all births) were not desired at all.

The prevalence of family planning methods increased, from 48 percent in 1991 to 59 percent live births per woman in 1988 to 3 in 2008 and then increased again in 2014. The government has attributed the high rate of contraceptive use to efforts to

inform women about health services. However, the 2014 Demographic Health Survey found that one in eight married women required family planning at the time of the survey. According to 2014 data, the unmet need for family planning in Egypt is 12.6%. According to the same survey, only 30% of women were advised about family planning methods after childbirth. Lack of information can put women at risk of an unwanted pregnancy soon after a previous delivery, which can carry health risks and cause complications and death during pregnancy. Birth spacing remains a challenge, especially among young mothers, as in general about 20% of births occur within 24 months of the previous delivery.

The overall level of teenage pregnancy (aged 15-19) has been on a slow but steady upward trend, from 9% in 2005 to 10% in 2008 and finally 11% in 2014, 7% of teenage girls are already mothers, and 4% are pregnant with their first child, according to the 2014 Demographic Health Survey. As for the unmet need for family planning methods, which includes women of childbearing age who did not use family planning methods but who want to postpone the next child (spacing) or stop childbearing altogether (specify). According to the 2014 Egypt Population Survey, we find that 13% of married women in Egypt is considered to have an unmet need for family planning methods. About a third of this need is represented in the desire to postpone the next child, and the rest is to determine the number of births. It was found that 23% of unused women are linked to reasons for using the method; 12% for fear of side effects and 21% for other health considerations. As for the opposition in use - whether it was from the respondent herself or her husband - it was the cause of 5% of cases of lack of intention to use, and I think that more work should be done on these in the next stage to increase the rate of use of family planning methods in Egypt. [12]

10 Using the Rates of Family Planning Methods (Prevalence Rate, Protection Rate) to Predict the Fertility Rate

In this part, we discuss the use of neural networks on annual data for the prevalence of family planning method (PR) and protection rate (CYP) for the period from 1984 to 2014.

11 Data Description

The data presented in Table (1) are annual data for each of the total fertility rate (TFR), the prevalence rate of family planning methods (PR), the protection rate (CYP) for the period from 1984 to 2014. We assume annual data for the prevalence of family planning methods (PR) and protection rate (CYP) for the period from 2015 to 2020, in order to predict the total fertility rate (TFR).

Table 1. Protection rate during the period 1984 – 2020

Year	TFR	PR	CYP	Year	TFR	PR	CYP
1984	5.3	24.2	18	2003	3.2	60	55.74
1985	4.93	29.55	26.39	2004	3.48	54.71	49.88
1986	4.86	30.87	27.63	2005	3.1	59.2	58.02
1987	4.78	32.2	28.86	2006	3.33	57.36	52.35
1988	4.9	30.3	25.62	2007	3.25	58.69	53.59
1989	4.63	34.84	31.34	2008	3	60.3	53.74
1990	4.55	36.17	32.57	2009	3.1	61.34	56.06
1991	4.47	37.49	33.81	2010	3.02	62.66	57.3
1992	4.4	37.8	38.08	2011	2.95	63.99	58.54
1993	4.32	40.14	36.28	2012	2.87	65.31	59.77
1994	4.25	41.47	37.52	2013	2.8	66.64	61.01
1995	4.1	47.6	51.39	2014	3.5	58.5	53
1996	4.09	44.12	39.99	2015		68.54	53.48
1997	4.02	45.44	41.23	2016		69.83	53.76
1998	3.9	47.1	41.75	2017		70	54.04
1999	3.86	48.09	43.7	2018		70	54.32
2000	3.6	47.9	37.9	2019		70.5	54.6
2001	3.71	50.74	46.17	2020		71	54.89
2002	3.5	56.1	47.46				

Neural networks are known as models of artificially intelligent neural networks, which are flexible non-linear functions where they do not require the availability of restrictive assumptions about the relationship between dependent and independent variables and treat non-parametric or small-sized data and do not require dependency to the normal distribution with a high degree of accuracy, in addition to their accuracy with regard to parameter data.

Neural networks are similar and similar to traditional statistical models in common use, but there are differences with regard to some conventions. Independent variables are called inputs, dependent variables are called training or target values, and predicted values are called outputs and estimation are called training, teaching or self-organization, and the parameters are called weights, and their values are always positive and their sum. equals one, and in order to apply it to the data:

- The data was processed and the network trained on this data, meaning that the network learns and recognizes the data and the relationships between the various variables.
- A program was used to design the neural network and train it accordingly, and a criterion was set to finish the training, which is not to notice any change in the mean error. The statistical criteria are the sum of the squares of error MSE and the mean relative error MEP.
- The neural network of the available data was used at a rate of (100%) for training and (0%) for testing.
- The network inputs represented the number of values of the three independent variables, and the outputs represented the dependent value, and by applying to the data:
- The statistical analysis showed the significance of the relationship between outputs and inputs using the F-test at the level of significance of 0.000, the degree of accuracy is 99.6%, and the efficiency of the division is correct Classification 100%.
- The efficiency of the correct division reached 100%, which is a high percentage indicating the relative importance of the independent variables. By comparing the aforementioned statistical criteria, it appears that the neural network has been highly trained, and with the continued training and stability of the network, which means that the neural network has learned and trained appropriately.
- The figures show the network training outputs, as it becomes clear that the network has been trained through the function layer activation hidden functions, and 4 hidden neurons were estimated for the model, and it was clear that the model was able to explain the phenomenon in question, and the above-mentioned figures show that there are neurons whose weights are less from zero.

Using statistical criteria, it can be concluded without a doubt that the neural network was actually trained to an excellent degree, while the process of training the network continued to decline until it reached its minimum and stabilized, which means that the neural network has already learned and trained properly and well. It should be noted that there was no significant improvement in the performance of the neural network when some of its internal specifications were changed. In addition, when these specifications were changed, it was found that all scenarios took more time in the training process. We did not notice the effect of changing these specifications on the network performance through the previously mentioned statistical criteria, and the following figures and tables are presented for the network training outputs and their relative weights. [13]

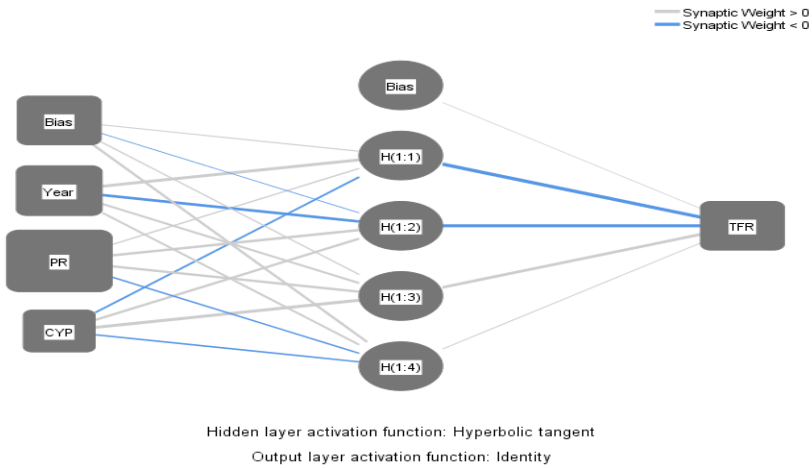

Fig. 1: Network Training Outputs.

From the previous figure, it is clear that the network was trained through the hidden layer activation function, also, 4 hidden neurons of the model were estimated, it is also clear from the previous figure that the model was able to explain the phenomenon in question, as it is also clear that there are neurons whose weights are less than zero.

Using statistical criteria, it is undoubtedly concluded that the neural network has already been trained in an excellent way. As the network training process continues, the decline continues until it reaches its lowest level and stabilizes, which means that the neural network has already learned and trained properly and well. It should be noted that there was no significant improvement in the performance of the neural network when changing some of its internal specifications, in addition to that, when these specifications were changed, it was found that all scenarios took more time in the training process. We did not notice the effect of a change in these specifications on the performance of the network through the previously mentioned statistical criteria. [13].The following table (2) and figure (2) show the network training outputs and their relative weights.

Table 2: Relative Importance.

Independent Dimensional	Relative Importance
Year	0.306
PR	0.563
CYP	0.131

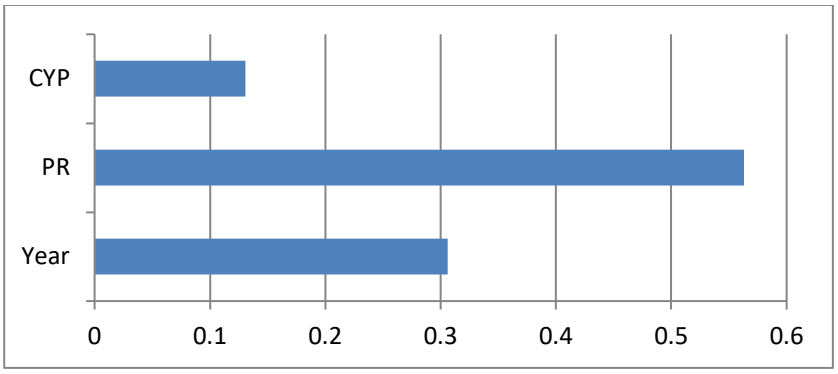

Fig.2: Relative Importance.

It is clear from table (2) and figure (2) that the variables that represent the model inputs vary in terms of their importance in the interpretation of the dependent variable (total fertility rate TFR), Where the second variable PR represents the most important variable as it has an absolute importance rate, Also, the CYP variable is the least important variable.

In order to complete the image, the results of the neural networks method must be compared with some traditional methods and other data mining methods available with the SPSS Modeler 14.2 system. Figure (3) shows the results of the network training that shows the relationship between the actual values and the estimated values of the total fertility rate, and explains the relationship at a degree of 99.6%, that is, a high and reliable degree.

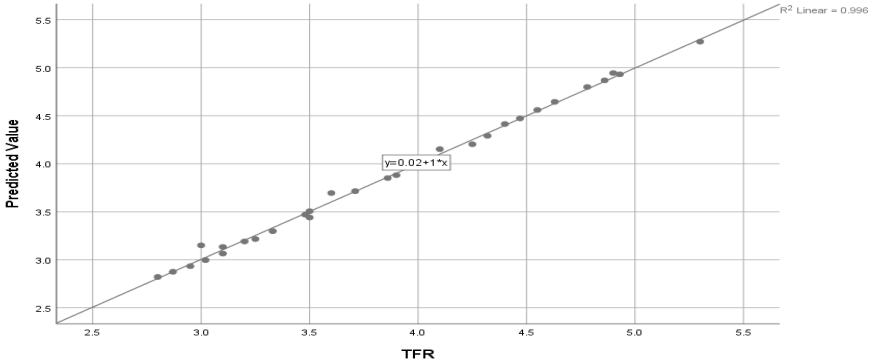

Fig.3: The Outputs of the Network Training.

12 Criteria for Accurate Prediction of the Neural Network Model

The quality of the estimated results depends on the predictive performance strength of the unrestricted error correction model, so it must be ensured that this model has good predictability during the estimate time period, so some statistical criteria have been used that appear in table (3) below

Table 3: Statistical Criteria to Measure the Model's Predictability.

Criterion	Coefficient of Determination (R^2)	Mean Absolute Error (MAE)	Root Mean Squared Error (RMSE)	Mean Absolute Percentage Error (MAPE)	Theil index of significance (TS)	Theil Coefficient (TC)	Chi-Square
Value	0.996	0.045	0.073	1.370	0.000	0.009	1.000

From the previous table (3), the following is noted: -

- (R^2) means the coefficient of determination and It is the ratio between the regression sum squares to the total sum squares, therefore, the more the number of explanatory variables in the model increases, accordingly the sum of the regression squares and therefore the value of the determination coefficient, therefore, we must take into account the resulting decrease in degrees of freedom due to the addition of any explanatory variable to the regression equation, which would make the bias value to the higher. this can be achieved by using an alternative formula for the coefficient of determination called "adjusted coefficient of determination" (ACD) which denoted by the symbol of $(\bar{R}^2)$ and calculated as follows:

$$\bar{R}^2 = 1 - (1 - R^2).\left(\frac{n-1}{n-k}\right) \qquad (1)$$

where,

n →The sample size (length of the time series),

k → The number of explanatory variables in the model.

It is clear from equation No. 1 that if $(k > 1)$, then $(R^2 > \bar{R}^2)$ which means that the more explanatory variables in the model, the greater the value of $(\bar{R}^2)$ is less than the value of (R^2). It is also noted that the value of $(\bar{R}^2)$ can take a negative value even though (R^2) is always a non-negative value. If it occurs that, the value of $(\bar{R}^2)$ is negative then it is rounded to zero, in which case the estimated model is not suitable and it must be reformulated.

- (MAE) means the Mean Absolute Error and it is calculated as follows [14]:

$$\text{MAE} = \frac{1}{n}\sum_{i=1}^{n}|\hat{y}_t - y_t| \qquad (2)$$

- (RMSE) means the Root Mean Squared Error and it is calculated using the following equation:

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(\hat{y}_t - y_t)^2} \qquad (3)$$

- (MAPE) means the Mean Absolute Percentage Error and it is calculated as follows:

$$\text{MAPE} = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{\hat{y}_t - y_t}{y_t}\right| \qquad (4)$$

- (TS) means the index of significance and it is obtained through compensation in the following relationship:

$$TS = \frac{\sum_{i=1}^{n}(y_t - \hat{y}_t)}{MAE} \quad (5)$$

where,

$\hat{y}_t \rightarrow$ The estimated value of the dependent variable in the time period t,

$y_t \rightarrow$ The actual value of the dependent variable in the time period t,

$n \rightarrow$ The number of cases or the sample size.

- (TC) means Thiel Coefficient and it is calculated using the following equation:

$$TC = \sqrt{\frac{\sum(df - da)^2}{\sum(da)^2}} \quad (6)$$

where,

da → The actual change in the value of the dependent variable,

df → The change in the expected (predicted) value of the dependent variable.

- Finally, the value of Chi–Square is calculated according to the following equation:

$$\chi^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i} \quad (7)$$

where,

$O_i \rightarrow$ *is the observed frequency (actual value),*

$E_i \rightarrow$ is the expected frequency (expected value).

Usually, chi–square analysis is used to study the relationship between two descriptive variables from a double table which shows the extent of correlation between the two variables. From Table No. (3) we can say that the proposed structural model (based on prediction accuracy criteria) explains the relationship with a degree of 99.6%, that is, a high and reliable degree. By applying the equation to predict the new values

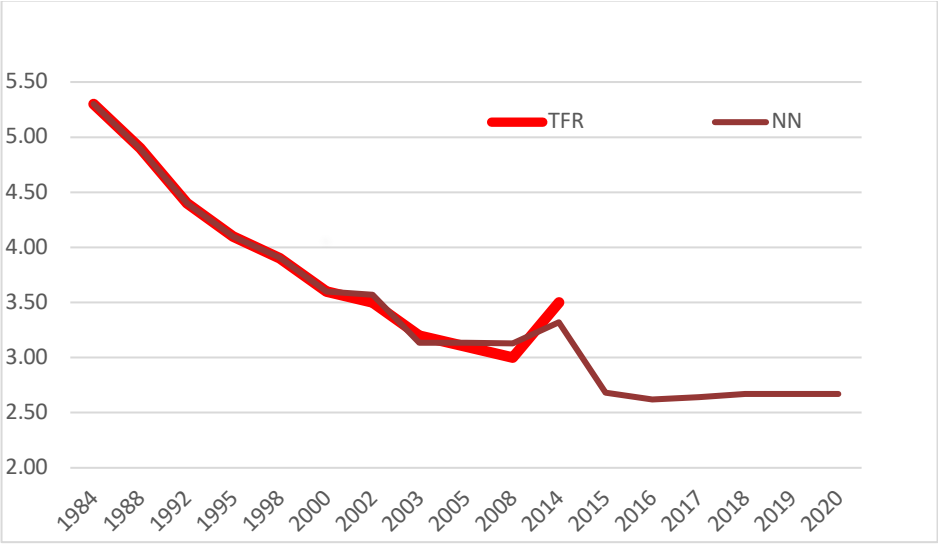

Fig. 4: Estimation and Prediction of TFR Values using Artificial Neural Networks.

Results and Conclusion

- Using family planning prevalence rate (PR), protection rate (CYP), total fertility rate (TFR) can be estimated and predicted.
- Artificial neural networks have reached a high and high rate of accuracy in estimating and predicting the total fertility rate (TFR) with a high and reliable degree (99.6%).
- The use of the neural network model in classification, and drawing plans, both long-term and short-term, due to the speed and accuracy of this model in the data.
- By estimating the fertility rate in the different administrative regions, effective intervention can be made to enhance the use of family planning methods and the need to ensure that they reach all women.
- Safe and voluntary use of family planning enables us to control fertility, and is essential to women's well-being and independence.
- Work should be done to expand awareness of family planning programs to raise the demand for them, and the service provided must be sustainable and of high quality, in order to achieve results.

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