FORECASTING THE TOTAL FERTILITY RATE IN ALBANIA USING NEURAL NETWORKS

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Abstract: Fertility is the main determinant of population growth rate. Almost all over the world the births rate is decreased. The age and size of a population mainly depend on birth rates, so it is important for the policymakers to know whether fertility decline is slowing, accelerating or reversing. The performance of fertility in Albania is of particular interest for the significant differences before and after the year 1990. The aim of this study is to observe the trend, model and predict the fertility using one of the intelligent methods such as artificial neural network. A time series model is fitted in a multilayer perceptron neural network to forecast the Total Fertility Rate (TFR) in Albania. In the end we will make a comparison of this study results with the results of a study which we have done before for the same problem using ARIMA model.

Key words: *TFR, ANN, Time Series, modeling***.**

Literature Review

Marijana Zekic showed that NN accuracy mostly ranges from 70%-80%. NNs outperform statistical methods for a 5%-20% higher accuracy.

Monica Adya and Fred Collopy found that nineteen studies (86%) produced the results favorable to forecasting and prediction through neural network (NN). In those papers NN outperformed alternative approaches.

A. Bhatt and K.Vaisla have proved that NN can predict very well with proper inputs, data, right number of layers and neurons. Meanwhile, the forecasting ability of statistical techniques decreases as the series become complex. Therefore, NN can be used as a better alternative technique for forecasting.

Gjonca and Falkingham (2001), researched the fertility transition in Albania from 1950 to 1990. The results demostrate that the number of births is declining due to the emancipation of women in society and improvement in child mortality.

Introduction

Forecasting time series is an important discipline in different areas. Conventional approaches such as ARMA, ARIMA, exponentional smoothing have been used for a long time in time series forecasting. Most of the problems are non-linear. So it is important to use non-linear methods to model and forecast their future values. The need for modeling non-linear problems has made us to use the intelligent technique of artificial neural network. Other studies and experience have shown a successful forecasting using this technique.

ANN are computer units connected together such that each neuron can transmit and receive signals from each other. They are based on the human brain which get knowledge through learning. They are searching and optimizing methods, which optimize complex and non-linear systems. Ann are extremely versatile and do not require formal specification of the model such as Bilinear, Threshold Autoregressive and Generalized Autoregressive Conditional Heteroskedastic. It is a less sensitive method to error term assumptions. It tolerates noise, chaotic components, is adaptable to the large dataset, flexible, nonlinear, can adjust seasonality and the linear trend of a time series based on the fact that ANN are capable of modeling any arbitrary function.

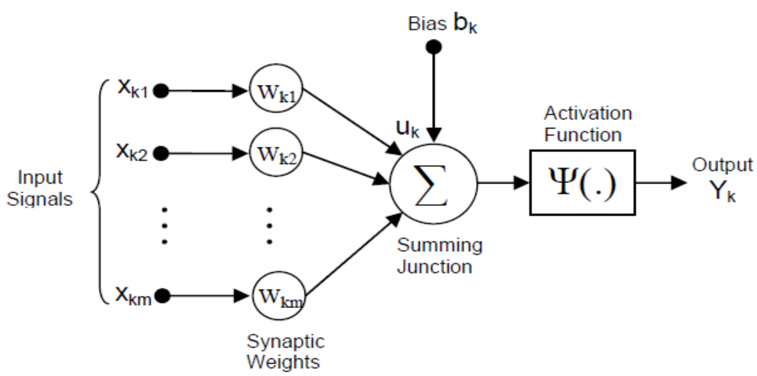


Fig.1 The mathematical model of a Feed-forward Multilayer Back-propagation network.

$$U_K = \sum_{j=1}^{m} W_{kj} X_{kj}$$

$$Y_K = \Psi(U_K + b_K)$$

Learning model

1. Calcualate the error gradient for the neurons in the output layer:

$$\delta_k(p) = y_k(p)\big(1 - y_k(p)\big)e_k(p)$$

where $e_k(p) = y_{d,k}(p) - y_k(p)$

2. Calculate the weight corrections

$$\Delta w_{jk}(p) = \alpha y_j(p)\delta_k(p)$$

3. Update the weights at the output neurons:

$$w_{jk}(p+1) = w_{jk}(p) + \Delta w_{jk}(p)$$

4. Calculate the error gradient for the neurons in the hidden layer:

$$\delta_j(p) = y_j(p)(1 - y_j(p)) \sum_{k=1}^{l} \delta_k(p) w_{jk}(p)$$

5. Calculate the weight corrections:

$$\Delta w_{ij}(p) = \alpha x_i(p) \delta_j(p)$$

6. Update the weights at the hidden neurons:

$$w_{ij}(p+1) = w_{ij}(p) + \Delta w_{ij}(p)$$

Application

The data are with monthly frequency, from 1990 to 2013, in Albania. It is observed that this time series becomes stable last years (2006-continue).

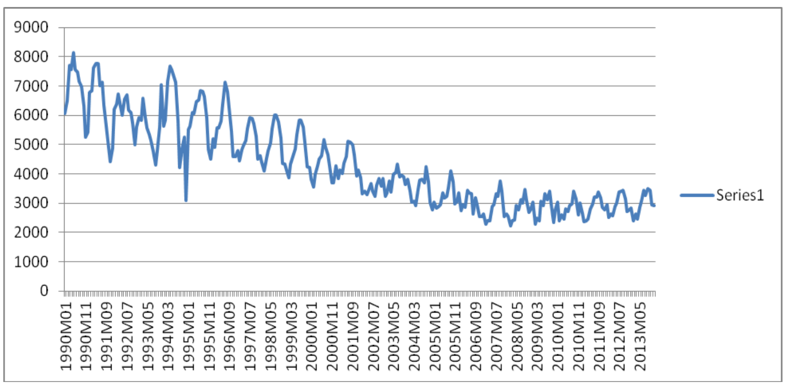


Fig. 2 The TFR series graph of 1990-2013 years

The fertility graph shows that before 1990 there are 6 children per woman and this got low levels last years falling in 2 children per woman.

The transition from high to low fertility rates takes place in three phases:

- The first phase is marked by stable and high fertility with a birth rate of six or seven children for each woman.
- The second phase is marked by the transition from high to low fertility. The fertility rate falls to five children per woman.
- The third phase is marked by low fertility. The fertility rate falls below the level of 2.1 children.

Steps in designing a neural network forecasting model

1. Analysis

- Data partition method: Random
- Data partition results:

197 records to Training set (68.64%)

45 records to Validation set (15.68%)

45 records to Test set (15.68%)

2. Prepocessing

This is the phase in which we minimize noise, highlight important relations to eradicate and destroy variable distributions. We normalize the data using a logistic function according to:

$$Y_{sigmoid} = \frac{1}{1 + e^{-x}}$$

This transformation normalizes the data and guarantee us the values are in [0,1] interval.

3. Network Design
    - The first network architecture has three layers, the first layer has one input, the second has two computational neurons and the third has one neuron - Network architecture: [1-2-1].
    - The hidden layer activation function is Logistic
    - The error function is Sum-of-squares
    - The activation function is Logistic

4. Search the best network architecture

    We use a search method which is heuristic search. With the classic selection method, a neural network with the smallest error on the validation data is selected from other neural networks. The fitness criteria is Test error. There are five network architectures verified

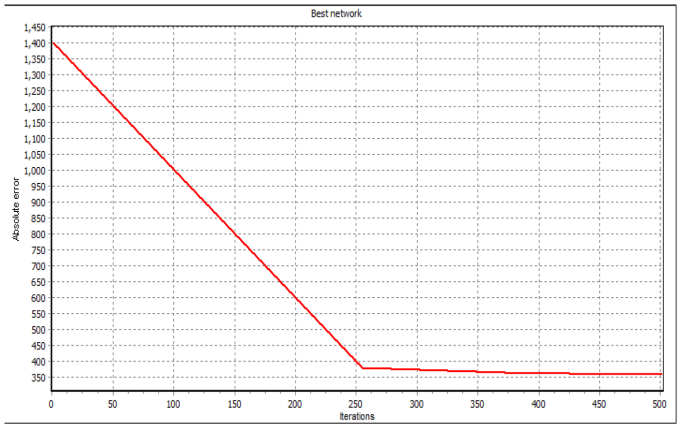
    [1-1-1] fitness: 0.004373

    [1-7-1] fitness: 0.004589

    [1-4-1] fitness: 0.004432

    [1-5-1] fitness: 0.004771 had the best fitness

    [1-6-1] fitness: 0.004617



Correlation	0.948984
R-Squared	0.890844

Fig. 3 The performance of absolute error

5. Training
   We use the training algorithm Quick Propagation. The number of iterations is 501.

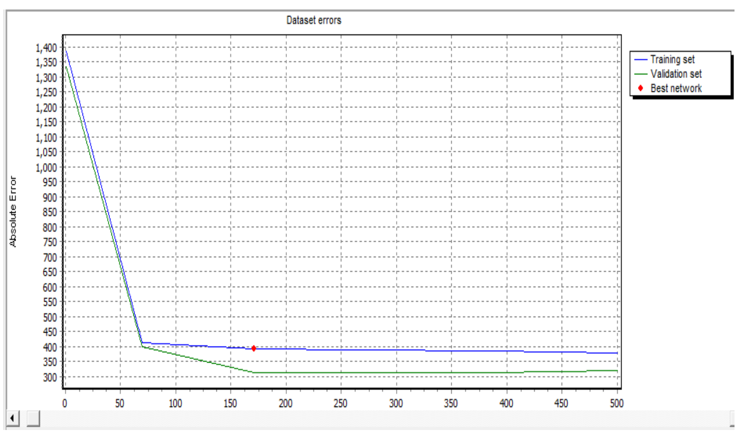


Fig. 4 The performance of dataset errors

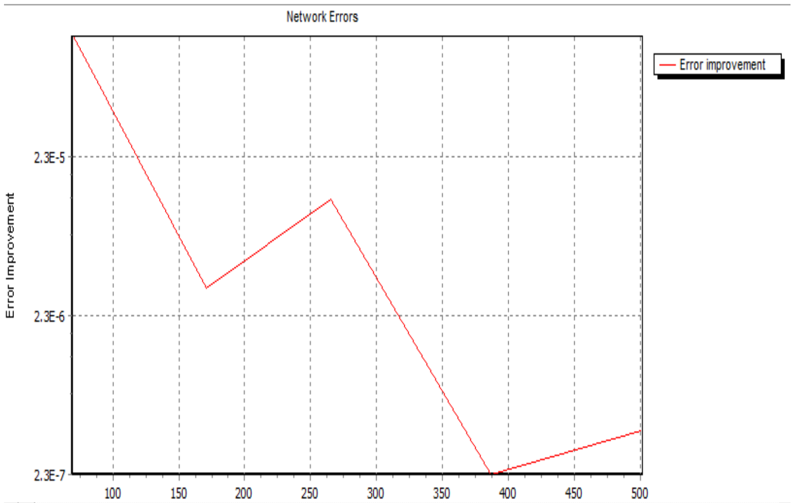


Fig. 5 The performance of error improvement

6. Testing

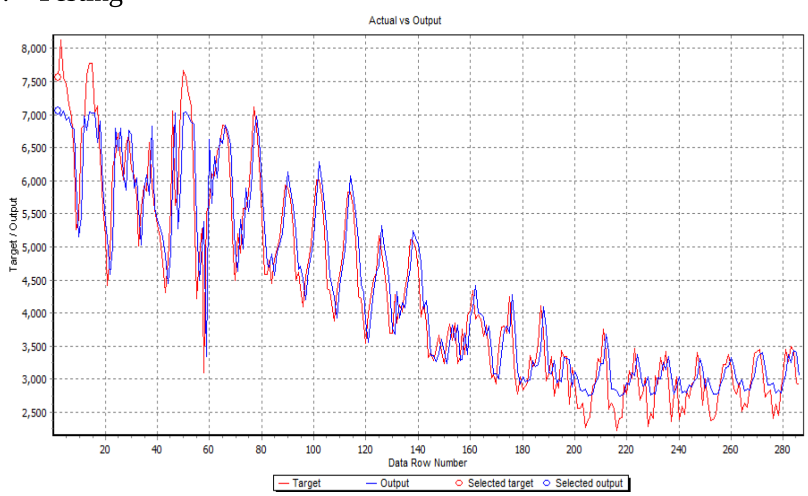


Fig. 6 The curbe of actual outputs vs the curbe of target outputs

Summary

	Target	Output	AE	ARE
Mean:	4282.449123	4334.687819	355.306723	0.087696
Std Dev:	1465.808262	1371.430771	301.650767	0.077388
Min:	2222	2737.304309	1.503652	0.000506
Max:	8130	7056.115228	2294.512821	0.741122

Correlation: 0.948862
R-squared: 0.884499

Fig. 7 The table with all the parameters: mean, standard deviation, minimal, maximal, correlation and R-squared.

Conclusions

- It has been an overall decrease of birth's number in Albania.
- Neural network offer several potential advantages rather than alternative methods, mainly ARIMA time series models, dealing with problems concerning nonlinear data which do not follow a normal distribution.
- Statistical approaches make some assumptions, which are sometimes found unrealistic. Also, statistical population forecast procedures cannot deal with the intrinsic chaos.
- Correlation between actual and predicted fertility is high both in training and the test phase.
- However, the network needs further improvements. The limits in prediction accuracy or in space complexity are some of the elements that should be improved.
- The error is almost equal to zero in the test phase. These give a qualitative support to the non-linear ANN as a modeling method for fertility in Albania.

Reference

1. Michael Negnevitsky (2005): Artificial Intelligence, A guide to Intelligent Systems – second edition.

2. Mirza Rizwan Sajid, Fauzia Maqsood and Mehwish Rani (2011): Determinants of Fertility: A neural Network Approach. Middle-East Journal of Scientific Research, Vol.8 Number 2.

3. Mahendran Shitans and Yung Lerd Ng (2015): Forecasting the Total Fertility Rate in Malaysia with ARIMA. Pak. J. Statist. 2015 Vol. 31(5), 547-556

4. Mathias Lerch (2011): Fertility decline in Albania: interplay with societal crisis and subsequent consolidation. Population Association of America Meeting 2011, Washington DC, Session 141: Fertility and Social, Economic, and Political Instability.

5. G. Peter Zhang and Douglas M. Kline (2007): Quarterly time-Series forecasting with neural networks.

6. R.J.Frank, N.Davey, S.P.Hunt: Time series prediction and neural networks.

7. Muhammad Zakria, Muhammad Yaseen, Faqir Muhammad and Sajid Mahmood (2013):Modeling fertility patterns of Pakistan during 1984-2007. Pak. J. Statist. 2013 Vol. 29(4), 479-486
8. Jamal Abdul Nasir,Munir Akhtar, M.H. Tahir (2009): Reproductivity and age specific fertility rates in Pakistan after 1981. Pak. J. Statist. 2009 Vol. 25(3), 251-263

9. Goutami Bandyopadhyay and Surajit Chattopadhyay (2008): An artificial neural net approach to forecast the population of India.

10. Iebeling Kaastra, Milton Boyd (1996): Designing a neural network for forecasting financial and economic time series.