GROSS DOMESTIC PRODUCT GROWTH RATE ANALYZING BASED ON PRICE INDEXES, IMPORT AND EXPORT FACTORS

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ABSTRACT

Economic development could be presented by gross domestic product to show how different factors affect the development. Gross domestic product could be affected by different nonlinear factors in positive or negative way. Hence it is suitable to apply artificial intelligence techniques in order to track the gross domestic product variation in depend on the factors. AI techniques require only input and output data pairs in order to catch the output variations based on the input factors. Therefore in this study adaptive neuro fuzzy inference system was applied in order to select the most relevant factors for gross domestic product growth rate. These factors are whole sale price index, consumer price index in urban areas, consumer price index in rural areas, state per capita income, exports, import and industry income. Results shown that the whole sale price index has the highest relevance on the gross domestic product growth rate.

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Introduction

Recently artificial techniques became main instrument for modelling and analyzing of complex nonlinear systems. Their application in every area is widely accepted and acknowledged. One of the potential application of artificial techniques is in social problems like economic development (Marković et al., 2017; Mladenović et al., 2016). Economic development could be analyzed based on different indicators but gross domestic product (GDP) is widely accepted and used indicator to track economic

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development. There are many investigations of GDP according to different input factors (Todorović et al., 2018).

In paper (Jovic, 2019) was investigated the effect of exchange rate pass-through (ERPT) into aggregate import prices and afterwards exchange rate effect on gross domestic product (GDP) was investigated by adaptive neuro fuzzy inference system (ANFIS). GDP per capita is one of the most important indicators of social welfare and all countries try to increase their GDP per capita to contribute to their population’s happiness and well-being, as well as strengthen their nation’s standing in international relations (Tümer, Akkuş, 2018). Expenditures on health care continue to increase substantially, both absolutely and relative to national income, throughout most of the developed world. In study (Mladenović et al., 2016) was analyzed the influence of health care expenditures on the economic growth. Aggregate accounting earnings growth is an incrementally significant leading indicator of growth in nominal GDP (Konchitchki, Patatoukas, 2014). Strong evidence of discontinuities around zero in the distribution of actual minus target GDP growth rates was found in paper (Changjian et al., 2018). The yield curve – specifically the spread between long term and short term interest rates is a valuable forecasting tool. Results presented in paper (Hvozdenska, 2015) confirmed that 10-year and 3-month yield spread has significant predictive power to real GDP growth after financial crisis. The environment that governs the relationships between carbon dioxide (CO2) emissions and GDP changes over time due to variations in economic growth, regulatory policy and technology. The purpose of research (Marjanović et al., 2016) was to develop and apply the Extreme Learning Machine (ELM) to predict GDP based on CO2 emissions.

The main goal of the paper is to present application of adaptive neuro inference system (ANFIS) (Jang, 1993) for GDP analyzing based on input factors influence. The main reason of ANFIS application is strong presence of nonlinear phenomena in the economic problem namely GDP growth rate. There are number of social phenomena like GDP where linearity is exceeded in independent variables (Subic et al., 2007; Kuzman, Prdić, 2018; Prdić, Kuzman, 2019). Economic aspects have different variables and factors which is challenging to analyzing by conventional approaches (Kuzman et al., 2018; Kuzman et al., 2017; Kuzman et al., 2016; Kuzman, Prodanović, 2017; Nedelcu et al., 2015). ANFIS methodology shows good capability to catch and track nonlinearity phenomena since there are multiple parallel operations during training of the ANFIS model. ANFIS technique require only input and output data pairs in order to catch the output variations based on the input factors. In this study ANFIS was applied in order to analyze GDP growth rate based on 7 input factors. These factors are wholesale price index, consumer price index in urban areas, consumer price index in rural areas, state per capita income, exports, import and industry income.

**Materials and methods**

In order to perform GDP analysing and prediction there is need to collect input and output data pairs for ANFIS training process. Table 1 shows used input factors and
output as well. The used input are whole sale price index, consumer price index in urban areas, consumer price index in rural areas, state per capita income, exports, import and industry income. The factors are paired with GDP. After the pairing the ANFIS models are training in order to investigate relationships between inputs and output. All of the data are acquired and arranged based on OECD database for European Union.

Table 1. Input and output factors

| in 1: Whole sale price index | in 2: Consumer price index – Urban | in 3: Consumer price index – Rural | in 4: State Per Capita Income | in 5: Export | in 6: Import | in 7: Industry income | output: Gross Domestic Product |
|-----------------------------|----------------------------------|----------------------------------|----------------------------|--------------|--------------|------------------|--------------------------------|
| 80.02                       | 24.12                            | 30.12                            | 105                        | 4153         | 62367        | 50950            | 286566                      |
| 85.02                       | 25.35                            | 34.35                            | 133                        | 7128         | 85156        | 53550            | 329567                      |
| 88.02                       | 42.35                            | 48.35                            | 192                        | 9465         | 87077        | 69640            | 368800                      |
| 99.02                       | 50.35                            | 59.35                            | 267                        | 12814        | 87774        | 81360            | 405707                      |
| 105.02                      | 64.35                            | 73.35                            | 338                        | 15849        | 95101        | 108520           | 454014                      |
| 115.02                      | 76.35                            | 82.35                            | 416                        | 24383        | 101937       | 124950           | 488921                      |
| 127.02                      | 84.35                            | 92.35                            | 491                        | 32517        | 106792       | 127770           | 532374                      |
| 137.02                      | 97.35                            | 104.35                           | 548                        | 39963        | 107921       | 154930           | 557097                      |
| 142.02                      | 108.35                           | 114.35                           | 617                        | 24535        | 90122        | 171020           | 606603                      |
| 149.02                      | 123.35                           | 129.35                           | 688                        | 26660        | 94372        | 182740           | 645436                      |
| 154.02                      | 135.35                           | 142.35                           | 744                        | 29635        | 103076       | 209900           | 672222                      |
| 171.02                      | 143.35                           | 152.35                           | 822                        | 36860        | 125864       | 226330           | 694027                      |
| 166.37                      | 161.35                           | 167.35                           | 899                        | 39198        | 127785       | 229150           | 720810                      |
| 178.87                      | 170.35                           | 176.35                           | 967                        | 42547        | 128482       | 197910           | 744859                      |
| 181.83                      | 179.35                           | 186.35                           | 1022                       | 45581        | 135809       | 230670           | 784955                      |
| 199.34                      | 193.35                           | 200.35                           | 1074                       | 54166        | 142646       | 242230           | 824655                      |
| 225.31                      | 210.2                            | 219.2                            | 1151                       | 62300        | 147500       | 259640           | 866113                      |
| 263.91                      | 251.09                           | 260.09                           | 1350                       | 81500        | 209400       | 230930           | 898394                      |
| 277.73                      | 256.95                           | 263.95                           | 1269                       | 89700        | 224075       | 255065           | 918879                      |
| 303.41                      | 302.79                           | 311.79                           | 1373                       | 97900        | 238750       | 272645           | 961097                      |
| 333.72                      | 314.31                           | 322.31                           | 1376                       | 106100       | 253425       | 313385           | 998466                      |
| 346.28                      | 330.07                           | 335.07                           | 1827                       | 114300       | 268100       | 338030           | 1031660                     |
| 381.53                      | 357.26                           | 366.26                           | 2510                       | 141800       | 290700       | 342260           | 1063491                     |
| 419.16                      | 389.75                           | 399.75                           | 2719                       | 181200       | 298900       | 295400           | 1229030                     |
| 451.74                      | 416.34                           | 425.34                           | 3141                       | 216900       | 385100       | 365800           | 1449271                     |
| 493.78                      | 455.34                           | 459.45                           | 3321                       | 317303       | 465527       | 486600           | 1703392                     |
| 536.16                      | 491.68                           | 498.19                           | 3688                       | 412993       | 522638       | 580500           | 2014567                     |
| 613.25                      | 572.27                           | 572.04                           | 3966                       | 538988       | 535921       | 606500           | 2156190                     |
ANFIS network has five layers as it shown in Figure 1. The main core of the ANFIS network is fuzzy inference system. Layer 1 receives the inputs and convert them in the fuzzy value by membership functions. In this study bell shaped membership function is used since the function has the highest capability for the regression of the nonlinear data.
Bell-shaped membership function is defined as follows:

\[ \mu(x) = \text{bell}(x; a_i, b_i, c_i) = \frac{1}{1 + \left(\frac{x - c_i}{a_i}\right)^{2\beta_i}} \]  

(1)

where \( \{a_i, b_i, c_i\} \) is the parameters set and \( x \) is input.

Second layer multiplies the fuzzy signals from the first layer and provides the firing strength of as rule. The third layer is the rule layers where all signals from the second layer are normalized. The fourht layer provides the inference of rules and all signals are converted in crisp values. The final layers summarized the all signals and providied the output crisp value.

Performances of the proposed models are presented as root means square error (RMSE), Coefficient of determination (R²) and Pearson coefficient (r) as follows:

1) RMSE

\[ RMSE = \sqrt{\frac{\sum_{i=1}^{n} (P_i - O_i)^2}{n}}, \]  

(2)
2) Pearson correlation coefficient (r)

\[ r = \frac{n \left( \sum_{i=1}^{n} O_i \cdot P_i \right) - \left( \sum_{i=1}^{n} O_i \right) \cdot \left( \sum_{i=1}^{n} P_i \right)}{\sqrt{\left( n \sum_{i=1}^{n} O_i^2 - \left( \sum_{i=1}^{n} O_i \right)^2 \right) \cdot \left( n \sum_{i=1}^{n} P_i^2 - \left( \sum_{i=1}^{n} P_i \right)^2 \right)}} \]  

(3)

3) Coefficient of determination (R^2)

\[ R^2 = \left( \frac{\sum_{i=1}^{n} \left( O_i - \bar{O} \right) \cdot \left( P_i - \bar{P} \right)}{\sum_{i=1}^{n} \left( O_i - \bar{O} \right) \cdot \sum_{i=1}^{n} \left( P_i - \bar{P} \right)} \right)^2 \]  

(4)

where \( P_i \) and \( O_i \) are known as the experimental and forecast values, respectively, and \( n \) is the total number of dataset.

**Results**

GDP growth rate sensitivity is analysed based on factors influence. The influence is estimated according the RMSE values with ANFIS network. Figure 2 shows GDP sensitivity based on 7 input factors. As can be seen the factors with the smallest RMSE after training process has the highest impact on GDP. In other words the GDP is the most sensitive after input 1 (Whole sale price index) variation as can be seen in Figure 2. On the other hand GDP has least sensitivity for input 6 (Import).

**Figure 2. Factors influence on GDP**

![Figure 2. Factors influence on GDP](source: Authors’ calculations)
Numerical RMSE values after training and checking of ANFIS network is listed in Table 2 for the single factors influence. Furthermore if one combine two factors in same time corresponding results are presented in Table 3. As can be seen factors 1 and 4 forms the most optimal combination for the GDP.

Table 2. Factors influence on GDP

| ANFIS model 1: in1 -->trn=792726.2989, chk=1117756.7874 |
|----------------------------------------------------------|
| ANFIS model 2: in2 -->trn=1429807.6034, chk=1468704.3377 |
| ANFIS model 3: in3 -->trn=1493654.3340, chk=1408339.6003 |
| ANFIS model 4: in4 -->trn=909715.9459, chk=2230315.8341 |
| ANFIS model 5: in5 -->trn=1822216.2325, chk=6067049.2763 |
| ANFIS model 6: in6 -->trn=2765247.9845, chk=5810924.3048 |
| ANFIS model 7: in7 -->trn=1855191.2124, chk=1967937.0754 |

**Source:** Authors’ calculations

Table 3. Two factors influence on GDP

| ANFIS model 1: in1 in2 -->trn=342960.7035, chk=2522862.7201 |
|-------------------------------------------------------------|
| ANFIS model 2: in1 in3 -->trn=479709.1662, chk=2423824.7198 |
| **ANFIS model 3: in1 in4 -->trn=84837.1519, chk=3387077.6216** |
| ANFIS model 4: in1 in5 -->trn=175552.4373, chk=9862009.8207 |
| ANFIS model 5: in1 in6 -->trn=346639.7586, chk=1946191.6651 |
| ANFIS model 6: in1 in7 -->trn=302732.4528, chk=2676305.7847 |
| ANFIS model 7: in2 in3 -->trn=646425.8995, chk=6962905.5315 |
| ANFIS model 8: in2 in4 -->trn=161513.4966, chk=652510.5949 |
| ANFIS model 9: in2 in5 -->trn=182402.3538, chk=15125120.6863 |
| ANFIS model 10: in2 in6 -->trn=218128.6032, chk=23763468.6240 |
| ANFIS model 11: in2 in7 -->trn=143255.5539, chk=1261341.8891 |
| ANFIS model 12: in3 in4 -->trn=164999.7892, chk=382264.7904 |
| ANFIS model 13: in3 in5 -->trn=167085.2171, chk=9023759.5316 |
| ANFIS model 14: in3 in6 -->trn=214559.7395, chk=25735917.0138 |
| ANFIS model 15: in3 in7 -->trn=137387.8742, chk=1906955.9818 |
| ANFIS model 16: in4 in5 -->trn=128090.9853, chk=4416677.0713 |
| ANFIS model 17: in4 in6 -->trn=166177.7496, chk=15333450.6547 |
| ANFIS model 18: in4 in7 -->trn=187333.9938, chk=3404479.0351 |
| ANFIS model 19: in5 in6 -->trn=5265733.0034, chk=13071558.7207 |
| ANFIS model 20: in5 in7 -->trn=1134210.1775, chk=289279828.8118 |
| ANFIS model 21: in6 in7 -->trn=497525.9212, chk=211961264.6433 |

**Source:** Authors’ calculations
Figure 3 shows scatter plots of GDP prediction by ANFIS based on input 1 while Figure 4 shows scatter plots of GDP prediction by ANFIS based on input 1 and input 4. As can be seen according to the coefficient of determination ANFIS results for two inputs outperforms results for one input. Table 4 shows GDP prediction based on three statistical indicators for ANFIS models. Based on the three indicators one can conclude that the ANFIS with two inputs outperforms ANFIS with one input for the GDP prediction.

**Figure 3.** ANFIS prediction of GDP based on input 1

![Graph showing ANFIS prediction of GDP based on input 1](http://ea.bg.ac.rs)

\[
y = 0.9316x + 615614
\]

\[
R^2 = 0.9316
\]

*Source: Authors’ calculations*

**Figure 4.** ANFIS prediction of GDP based on combination of input 1 and input 4

![Graph showing ANFIS prediction of GDP based on combination of input 1 and input 4](http://ea.bg.ac.rs)

\[
y = 0.9978x + 19610
\]

\[
R^2 = 0.9979
\]

*Source: Authors’ calculations*
Table 4. Statistical indicators for ANFIS prediction of GDP

|                | One input (1)      | Two inputs (1 and 4) |
|----------------|--------------------|----------------------|
| \( r \)        | 0.9652             | 0.9989               |
| \( R^2 \)      | 0.9316             | 0.9979               |
| RMSE           | 3728859.321        | 658353.2683          |

*Source:* Authors’ calculations

**Discussions**

The analysis was performed by artificial intelligence model namely adaptive neuro fuzzy inference system (ANFIS) since there are strong nonlinear relationships between input and output factors in the analyzing. Results shown that the whole sale price index has the highest relevance on the GDP growth rate. Moreover combination of whole sale price index and state per capita income forms the most optimal combination for the GDP. The GDP prediction based on the selected inputs has high accuracy based on three statistical indicators. The main feature of the ANFIS model is easy adaptation to any new inputs.

**Conclusions**

The main goal of the paper was to analyze and to make predictive models for gross domestic product (GDP) growth rate based on 7 factors. These factors are whole sale price index, consumer price index in urban areas, consumer price index in rural areas, state per capita income, exports, import and industry income. In conclusion ANFIS could be used effectively for GDP analyzing and prediction based on given factors or any other inputs.

ANFIS network has feature for training based on its performances. Based on this the network parameters are adjusted in order to make the performance optimal. Main goal of the learning type is based on optimization surfaces where there is need to find the optimal conditions for minimum and maximum of the surface.

There are different training laws in the category of learning performance. These learning laws is based on adjusting of network parameters during training process in order to optimize the network performances.

There are two steps during optimization process. The first step is based on definition of the performance criterion. In other words there is need to find a quantity measure for the network performance which is called performance index, which is small when the network produce good results and vice versa. The second step during the optimization process is based on the finding of parameters space in order to wind the performance index.

Optimization of neural networks represent a complex task since it is need to define the performance index of the artificial neural network for the further optimization process. There are several algorithms for optimization of the performance index of artificial neural networks. One of the most popular algorithm is steepest descent algorithm.
This algorithm requires only calculation of function gradient which represents index performance of the network. It is proved that the algorithm will converge up to optimal stationary point if the learning speed is slow. Drawback of the learning algorithm is learning time which is too large. Therefore ANFIS network uses combination of steepest descent algorithm with back propagation in order to increase the learning speed.

ANFIS network has adaptive adjusting feature of the learning parameters with any new additional training. In other words ANFIS network has advantage to save the learned knowledge based on the fuzzy logic system. Once trained ANFIS network has feature to keep the knowledge until new training with new dataset.

Conflict of interests

The authors declare no conflict of interest.

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