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The Impact of Tax Revenues and Revaluation Rates on Poverty in Türkiye: Artificial Neural Network Approach

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ABSTRACT

The main objective of this study is to analyze the relationship between poverty, total tax revenues and revaluation rates, which indicate the increase rates of some fixed taxes each year and to test the effect of total tax revenues and revaluation rates on poverty between 1991 and 2021 in Türkiye. In this framework, income poverty data calculated by us based on per capita income data using the Hodrick-Presscot filter is used in this study. The relationship between the variables are tested with the artificial neural network method, which is used to obtain more realistic and resistant results, unlike the time series models used in the economic literature recently. Therefore, according to the weight values obtained from the output data in the 4-layer and 7-neuron artificial neural network model, it is concluded that a 1% increase in total tax revenues increases income poverty by 1.20% and a 1% increase in revaluation rates increases income poverty by 0.61%.

Keywords: Poverty, Tax Revenues, Revaluation Rate, Income Poverty, Artificial Neural Networks.

JEL Classification Codes: C45, F63, H20, H24

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INTRODUCTION

Tax revenues are the most important resources used by the state to finance public expenditures. Taxes can be used for many fiscal or non-fiscal purposes. First of all, taxes have the important function of financing public expenditures. In addition, taxes also have economic and social functions. Taxes can be used as a tool to achieve many objectives such as ensuring economic growth and economic stability, combating unemployment and inflation, ensuring fairness in income distribution (Yılmaz & Batı, 2023), and directing consumer behavior. In this respect, tax policies may directly or indirectly affect social, economic and demographic factors. The composition of taxes is also of great importance in this effect. The composition of direct and indirect taxes is still important today. Atkinson and Stiglitz (1976) were the first to address the interaction of direct and indirect taxes in achieving efficiency and equity objectives. According to Atkinson and Stiglitz, under certain assumptions, an optimal tax system for public sector financing or redistribution should be based solely on direct taxation and not on indirect taxes. From an economic growth perspective, the neoclassical framework suggests that tax composition does not have a permanent effect on the growth rate, while endogenous growth models suggest that stable tax structures can affect the growth rate. In this context, it is understood that tax composition and structure affect issues such as economic growth, economic stability and income inequality (Martinez-Vazquez et al., 2011).

In this framework, the relationship between taxes and poverty cannot be ignored in light of their effects on income distribution. In the most general definition, poverty is defined as the inability of individuals in a society to reach the level of income or consumption that can provide minimum living standards. In this framework, individuals who cannot have a decent and socially acceptable standard of living are considered to be in poverty. Individuals in poverty may experience unemployment, low income, housing problems, inadequate health care and many other social and cultural disadvantages (European Union, 2004). In this context, it can be said that poverty encompasses not only low income and consumption but also low achievement in education, health, nutrition and other areas of human development (World Bank, 2014). This broad meaning

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of poverty shows that poverty alleviation cannot be achieved only through economic policies and requires comprehensive and well-coordinated policy measures. In this context, taxes, one of the fiscal policy instruments, can be considered to have a significant impact on poverty (Ames et al., 2001).

There is a complex, multifaceted relationship between tax and poverty. The impact of tax policy on poverty in a country varies according to the economic, social and political conditions of the country. Firstly, tax policies implemented by governments may have effects on poverty. Low tax rates or tax rebate policies for low-income individuals and families may be effective in reducing poverty. In addition, direct taxes are subjective and taxation is made by taking into account the personal situation of taxpayers. Therefore, focusing tax policies on direct taxes may have positive effects on poverty. However, indirect taxes, which constitute a large portion of tax revenues in many countries, lead to an increase in poverty increasing the price of goods and services consumed by poor households (Anderson et al., 2018).

In addition, it is important to explain the revaluation rates used in this study which are different from the practices in other countries, for a better understanding of the analysis. The revaluation rate is a rate that shows how much the fixed amounts in the tax laws are increased in the next calendar year in Türkiye. With the revaluation rate, the fixed amounts in the tax laws are updated every year and the erosion of tax revenues is prevented against inflation. The decrease in the real value of money, especially in periods of high inflation, makes it necessary to update the amounts of taxes, fees and fines. The revaluation rate is the average price increase rate in the general index of domestic producer prices (PPI) in October of each year compared to the same period of the previous year (Tax Procesure Law (No. 213), repeated Article 298/B). The revaluation rate is published in October each year and applied for the following year. Fixed property tax, special communication tax, motor vehicles tax, stamp tax amounts are increased every year by the revaluation rate. In addition, fees paid for the use of various government services (such as passport and license fees) are also increased every year by the revaluation rate. The tax brackets in the tax laws and the amounts such as tax exemptions and tax penalties are also increased every year by the revaluation rate. In this respect, the revaluation rate directly affects how much revenue the state will receive from taxes, which is one of the most important sources of revenue for the state.

In this framework, this study aims to analyze the taxes that affect household poverty in Türkiye and the impact of revaluation rates, which cause an increase in certain taxes at certain rates each year, on poverty. The tax data used in the analysis refers to the total tax revenues collected by the public authority. In the analysis, the revaluation rate is included in the analysis as a separate data. Therefore, the effect of both total tax revenues and revaluation rates on poverty can be observed separately. The main point of the study is to emphasize the effect of revaluation rates on poverty. However, total tax revenues are included in the analysis as a variable that causes poverty and contributes to more consistent results.

LITERATURE

The relationship between tax and poverty is the subject of many studies in the literature. Friedman (1962) defended the negative income tax as a way to reduce poverty. Angyridis and Thompson (2016) analysed the effects of negative income tax on inequality and poverty using the neoclassical growth model with heterogeneous agents and found that increasing the demogrant-to-output ratio leads to a significant reduction in both absolute and relative poverty. Gallaway (1966), on the other hand, was sceptical that a negative income tax would contribute to improving the income situation of very low income earners and stated that it was not clear that it would contribute to increasing income (Gallaway, 1966).

Another area of research on tax and poverty is the effects of changes in tax systems and taxation preferences on poverty. Kamin (2013) found that changes in the tax system affect poverty more than inequality. Besley and Kanbur (1988) analysed commodity tax/subsidy rules for poverty reduction in the absence of income tax. Tanzi and Zee (2001) and Keen and Simone (2004) analysed the optimal tax structure that minimises poverty and generates high tax revenues in various developing countries. Schechtl (2022) analysed the relationship between consumption taxes and disposable income poverty and consumption tax-induced poverty across household types in 11 OECD countries and found that the increase in poverty due to indirect tax payment varies significantly across countries and household types, with higher increases in poverty rates for extended families and single parents in most countries. Pirttilä and Tuomala (2004) showed that relatively low commodity tax rates should be imposed on goods included in the poverty measure. Leventi *et al.* (2018) examined how income poverty is affected by changes in tax-benefit policies and which policies are cost-effective in reducing poverty or limiting its increase in 7 EU countries.

Adukonu and Ofori-Abebrese (2016) revealed that the increase in indirect tax policies increases poverty in Ghana (1984-2013), while the increase in direct tax policies has a mitigating effect on poverty in the long run and a reducing effect in the short run. Ramirez *et al.* (2017) found that taxes increased by local governments in Colombia increase poverty more and that policies implemented in different ways regionally are more effective in reducing poverty. Lustig *et al.* (2013) analyse the effect of social expenditures, subsidies and taxes on poverty reduction in Latin American countries. The study revealed that direct taxes reduce poverty less in Bolivia, Mexico and Peru than in Argentina, Brazil and Uruguay.

In addition to the relationship between taxation and poverty, many studies have also been conducted on the relationship between taxation and income distribution. As a matter of fact, the imbalance in income distribution significantly affects the level of poverty, and reducing the inequality in income distribution allows for a reduction in poverty. Therefore, studies examining the relationship between taxation and income distribution can be instructive in analyzing the relationship between taxation and poverty. In this context, Balseven and Tugcu (2017) analyzed the impact of fiscal policy on income distribution in 30 developed and 17 developing countries for the period 1990-2014 using panel data estimation techniques and concluded that tax revenues positively affect income inequality in developing countries. Martorano (2018) concluded that direct taxes reduce inequality in a panel data analysis of 18 Latin American countries for the period 1990-2015. Kanca and Bayrak (2019) analyzed the impact of direct and indirect taxes on income distribution using panel data analysis using 1990-2017 data of 36 OECD countries and concluded that direct and indirect taxes have a negative impact on income distribution. Contrary to the findings of Obaretin *et al.* (2017) that the effects of direct-indirect taxes on income distribution in Nigeria are insignificant with data for the period 1981-2014; Oboh and Eromonsele (2018) concluded that indirect taxes have a negative impact on income inequality in their analysis using time series data for the period 1980-2014 in Nigeria. Eydam and Qualo (2023) analyzed the relationship between income inequality and personal income tax for 61 selected countries for the period 1981-2005 using multivariate regression analysis and concluded that there is a negative relationship between progressivity of income tax and income inequality.

The studies on the relationship between taxation and poverty in Türkiye are mostly focused on analyzing the issue from a theoretical perspective. In these studies, theoretical evaluations are made on how tax policies are used to reduce poverty, how the indirect-direct tax structure affects poverty, and tax policy recommendations are made (Aydın & Türgay, 2011; Didinmez, 2021). Empirical studies are mostly on the relationship between income distribution and taxation. In their studies covering different periods, Albayrak (2010) and Akkoç *et al.* (2024) concluded that indirect taxes increase income inequality in Türkiye. Demirgil (2018) analyzed the relationship between indirect and direct taxes and the gini coefficient in Türkiye between 1980-2014 using the ARDL bounds test approach and concluded that increases in indirect taxes increase the gini coefficient and increases in direct taxes decrease the gini coefficient. Similarly, Günel (2019) analyzed the relationship between direct-indirect taxes and gini coefficient in Türkiye between 1987 and 2016 using Johansen cointegration test and concluded that increases in indirect taxes negatively affect income distribution, while increases in direct taxes improve income distribution. Hayrullahoğlu and Tüzün (2020) analyzed the relationship between tax revenues and income distribution between Türkiye and selected OECD countries between 2002-2019 using Panel ARDL model and concluded that an increase in total tax revenues reduces income inequality. Eser and Genç (2020) analyzed the relationship between income and wealth taxes and income distribution in OECD countries between 1997-2017 using panel regression method and concluded that income and wealth taxes have a corrective effect on income distribution. Kılınç Savrul and Taşkın (2020) analyzed the effect of tax structure on income distribution using the Kernel Regression Method using data for the period 2016-2018 and concluded that indirect taxes have a negative effect on income distribution fairness, while direct taxes have a positive effect. In addition to all these, Gemicioğlu *et al.* (2024), in their study based on data from 2003-2019, found that changes in indirect taxes worsen the distribution of real consumption in Türkiye. Thus, income inequality becomes more pronounced.

Studies on the revaluation rate consist of theoretical explanations on the definition, calculation and application of the revaluation rate and there are no empirical studies. We believe that this study will contribute to the literature since the relationship between taxation and poverty in Türkiye has mostly been addressed from a theoretical perspective, empirical studies have focused on taxation and income distribution, and the revaluation rate has not been used before in the relationship between taxation and poverty.

DATA SET AND MODEL

In this study, the effect of tax revenues and revaluation rates on income poverty in Türkiye between 1991-2021 is analysed using artificial neural networks regression method. The reason for using artificial neural network regression in the analyses is that this method can model complex relationships between variables, produce stable results in the presence of problems such as normal distribution, changing variance and autocorrelation in the series, and learn by taking into account the trend seasonality features in the series.

The total tax revenues used in the study are obtained from the World Development Indicator database and the revaluation rate data are obtained from the Ministry of Treasury and Finance database. The income gap ratio data, which expresses income poverty, is calculated by us based on per capita income data. Per capita income data is obtained from the World Development Indicator database. The equation used in the calculation of the income gap is as follows:

$$igap = \frac{pci_t - pci_t^*}{pci_t} \quad (1)$$

The potential per capita income data used in the calculation is obtained by utilising the Hodrick-Prescott filter. The course of the potential per capita income obtained from the Hodrick-Prescott filter is presented in the graph.

The $pci_t - pci_t^*$ in Equation 1 refers to the per capita income gap. The obtained income gap ratio represents the dependent variable in the study. The independent variables used in the study are tax revenues and revaluation rate. The linear model established in this framework is as follows:

$$igap = \beta_0 + \beta_1 tax + \beta_2 rr + \varepsilon_i \quad (2)$$

In the equations, *pci* is defined as per capita income, *igap* as income gap ratio, *tax* as total tax revenues and *rr* as revaluation rate. The artificial neural network model used in the analysis is explained below.

ARTIFICIAL NEURAL NETWORK

Artificial Neural Networks (ANN) are defined as a machine learning model, which is expressed as a mathematical model and computational structure inspired by human biological nerve cells (neurons). The main purpose of ANN is to learn the complex relationships in the data and to predict or classify the data obtained as a result of learning. ANN is frequently preferred in analysing economic data since it has a comprehensive function structure. Since ANN models are less sensitive to the assumptions made about the error term, they can produce better results in analyses with complex and higher data volume. In addition, since ANN models complete the weighting and learning processes based on the characteristics of the input data, there is

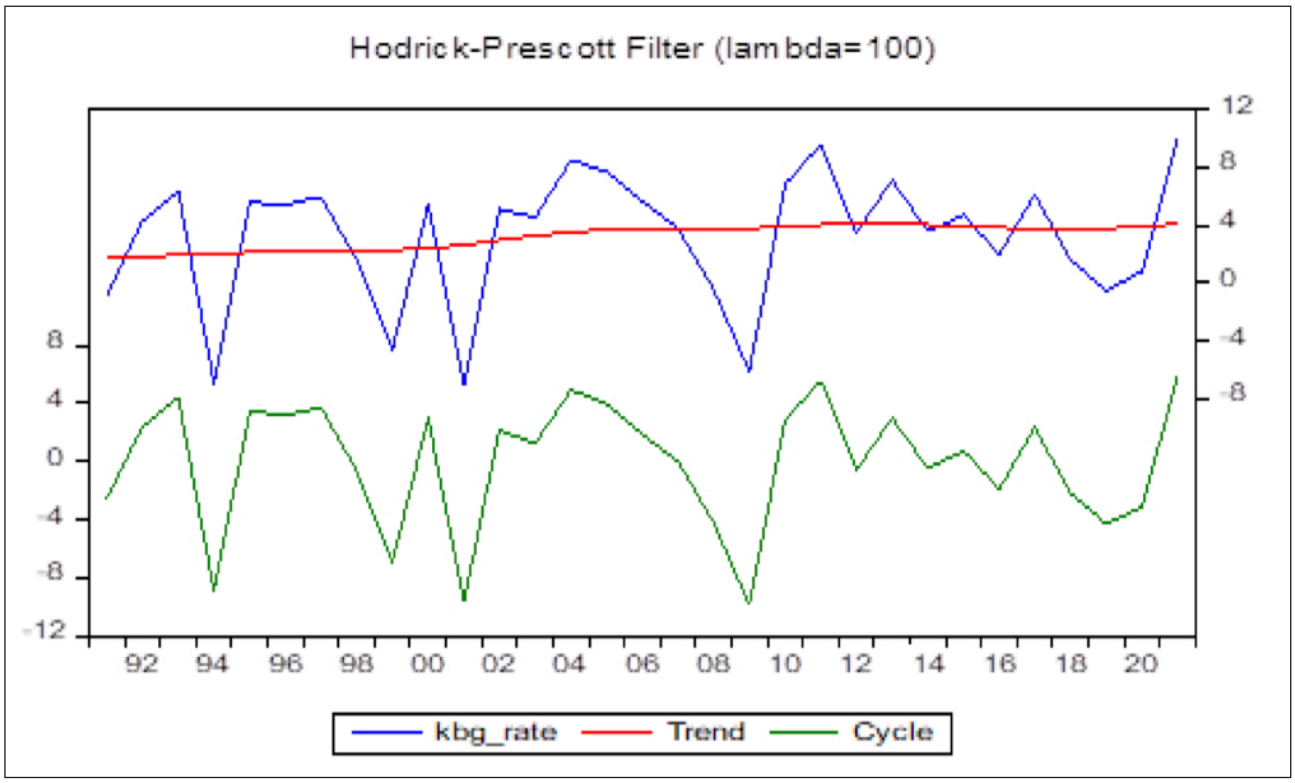

Figure 1: Hodrict-Presscott Filter Graphics

no need to define a specific model structure in these analyses. There is no need for a theoretical background in analysing economic data. Therefore, tests such as stationarity, seasonality and autocorrelation, which are used as a priori tests in macroeconomic time series, are naturally taken into account in ANN models (Chuku et al., 2019). It is suggested that a network structure designed in this way forms are the basis of deep learning models (deep neural networks) and enables great success in many application areas.

ANN structure is generally organised in layers. In ANN model, the first layer is the input layer and the last layer is the output layer. The layers in between are called hidden layers. The input layer consists of data provided from external sources loaded into the network structure. The first step of the artificial neural network model is realised by loading the data to the input layer. Data transfer from the input layer to the hidden layers is provided through artificial neurons by calculating certain weight coefficients. With the transfer of the data to the hidden layers, network training takes place. As the network is trained, data and weight values vary. This process is called the learning process in the artificial neural network model.

As a result of the completion of the learning process in the hidden layer, the data in the hidden layer are transferred to the output layer via neurons. ANN tries to improve the learning process by utilising the back propagation effect in each learning process. Thanks to this process, the data used in the input layer are learnt in the hidden layers with the back propagation effect and optimum results are obtained in the output layer (Chiang &Urban, 1995). In other words, this process continues until the data coming to the output layer generates its own activation function (Chuku et al., 2019). In this way, it is aimed to minimise the errors due to the back propagation effect between layers (Chiang & Urban, 1995).

ANN consists of simple computational units called artificial neurons or perceptrons. Each artificial neuron in the network structure multiplies the defined inputs by certain weights and transfers the multiplied input and weight values to an activation function. The weight values in the network structure represent the learning and adaptation of the model. Here, each input is multiplied by a weight value and the activation function is obtained by summing them in the neuron. From this activation function, the process of obtaining output is realised. In other words, the activation function shows the output level obtained from the neuron. The relationship between inputs *(*and output *()* in artificial neural networks is generally shown as follows:

$$y_t = w_0 + \sum_{j=1}^{q} w_{j.S}(w_{0J} \sum_{i=1}^{P} \Omega_{ij} x_{t-i}) + \varepsilon_t \quad (3)$$

The values $w_j, J = 0,1,\ldots,q; \Omega_{ij}, j = 0,1,\ldots,q;$ i=0, 1,…,p in the equation represent the weight parameters between the links in the model. The parameter w_j represents the weight values from the hidden layer to the output layer. Ω_{ij} parameter represents the weight values between the input layer and hidden layers. The p value in the equation indicates the number of input neurons. The *q* value in the equation is considered as the number of units in the hidden layer. In the equation, *S* represents the activation function and ε_t represents the error term. The activation function in the model is used to define the non-linear relationship between inputs and output in the network (Chuku et al., 2019). Based on this representation of artificial neural networks, the algebraic form of the artificial neural network regression used in the model established in the analyses is as follows:

$$f^{ANN}(w^0, w^1, x_i) = \sum_h w_h^1 (1 + exp(-\sum_j w_{jh}^0 X_{ij}))^{-1} = \sum_h w_h^1 \varphi(\sum_j w_{jh}^0 X_{ij}) \quad (4)$$

φ in the equation denotes the sigmoid function. The parameters w_h^1 *and* w_{jh}^0 are called weight coefficients. Weight coefficients express how much weight one neuron imposes on the next neuron. The full regression function obtained from the artificial neural network is as follows:

$$y_i = \sum_h w_h^1 \varphi\left(\sum_j w_{jh}^0 X_{ij}\right) + y_i \quad (5)$$

Here, the value of the output neuron is obtained from a certain combination of hidden neurons. At the same time, lagged values of the dependent variable are also included in the input layer. Therefore, including the lagged value of the dependent variable in the input layer allows the linear relationship to be obtained directly (Jahn, 2020).

ARTIFICIAL NEURAL NETWORK APPLICATION RESULTS

In this study analyzing the impact of tax revaluation rates and total tax revenues on income poverty, artificial neural network regression based on the linear artificial neural network model has been used. In the artificial neural network model, the regression algorithm works in a different structure than the classification algorithm. ANN regression is basically considered as a function of the explanatory variables in linear regression. ANN regression and traditional regression approaches are considered to be similar and there are no specific and different structures between them (Jahn, 2020). In this

framework, the linear model code in which artificial neural network regression is analyzed is as follows:

```
{ANN <- neuralnet(ann_formul, data = training,
hidden = c(7,7,2), err.fct = "sse", threshold = 0.05, linear.output = TRUE)}  (6)
{plot(ANN)}
```

The coding of the neural network regression in the equation shows that the variables are tested according to the 5% threshold value and the model is tested in linear form different from the classification algorithm. The artificial neural network model with 4 layers and 7 neurons and the network structure are shown in the Figure 2.

value is 3.70 and the mean absolute error (MAE) value is 3.02. In the forecasting stage, RMSE is 1.17 and MAE is 0.88. Therefore, the decrease in the error squares shows that the model produces stable and accurate results. At the same time, it is seen that the R-Square value obtained from the model has also increased. This shows that the explanatory variables in the model are increased the explanatory power of the dependent variable. In addition, the evaluation criteria of Lewis regarding test and prediction errors are important. Accordingly, if the RMSE is <10%, these models are called very good models, models between 10% and 20% are called good models, and models between 20% and 50% are called acceptable models. According to Lewis' evaluation criteria, it is

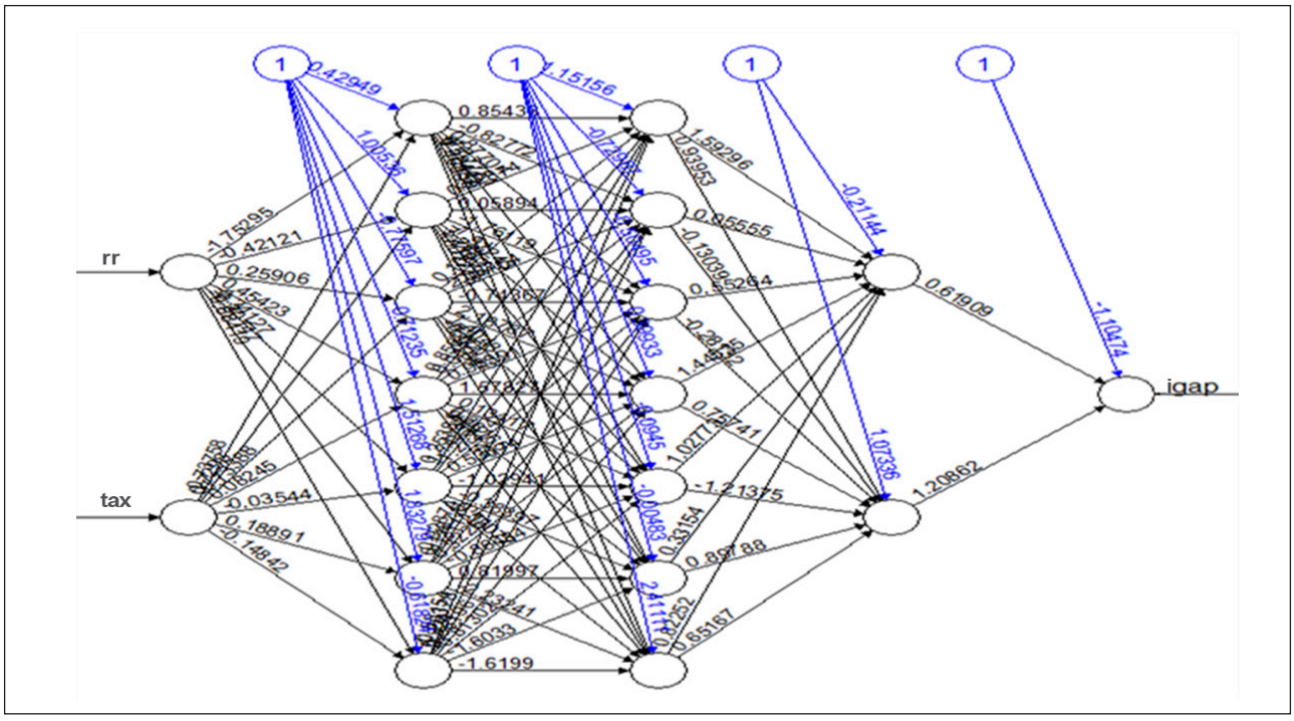

Figure 2: Artificial neural network structure obtained from analyses

According to the weight values obtained from the output data in the artificial neural network model with 4 layers and 7 neurons, 1% increase in total tax revenues increases income poverty by 1.20% and 1% increase in revaluation rates increases income poverty by 0.61%. These results obtained from the artificial neural network model were calculated based on the test and prediction error values. Accordingly, by comparing these results with the results obtained from the error squares, inferences can be made about the reliability of the model. Test and prediction error values is given below in Table 1.

It is observed that the test and prediction error values decreased in the ANN model. Accordingly, in the test error model, the root mean square error squared (RMSE) observed that the established model is a "very good" model, that is, a stable model.

It is clear from the test and prediction error data in Table 1 that the ANN model, which is a learning algorithm, minimizes the error squares. Accordingly, the minimization of errors suggested in basic statistical models is also obtained concretely from the ANN model. Therefore, the ANN model differs from the classical basic econometric and statistical models in terms of producing more stable and consistent coefficients by further minimizing errors and is considered as a better model.

Table 1. Test and Prediction Error Values Obtained from ANN Model

Model	RMSE	Rsquared	MAE
Test Error	3.706728	0.182419	3.027292
Prediction Error	1.1712651	0.9521816	0.8857793

CONCLUSION

According to the weight values obtained from the output data in the 4 layers and 7 neurons ANN model established in this study, which analyses the effect of revaluation rates and total tax revenues on income poverty in Türkiye, 1% increase in total tax revenues increases income poverty by 1.20% and 1% increase in revaluation rates increases income poverty by 0.61%. According to the artificial neural network results obtained from the study, tax revaluation rates and total tax revenues affect income poverty. In particular, the fact that the increase in total tax revenues increases income poverty and supports tax revaluation rates is important in terms of revealing the reliability of the study results. From this point of view, reassessment of tax policies may be important in terms of policy success in order to prevent income poverty in Türkiye and to ensure more effective results of anti-poverty policies. In this framework, an analysis of the structure of total tax revenues in Türkiye reveals that the share of indirect taxes in tax revenues is high. Therefore, collecting a single type of tax by ignoring the income of individuals may cause the tax burden to be felt more severely on the poor. This may result in further impoverishment of individuals or households with low incomes. Likewise, the application of revaluation rates in the form of indirect taxes regardless of income status is important as a reason that increases income poverty as in total tax revenues.

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