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An Investigation of The Relationship Between Individual Energy Consumption and Economic Growth: The Future Perspective By Using The ANN Method

Kişi Başı Enerji Tüketimi ve Ekonomik Büyüme Arasındaki İlişkinin İncelenmesi: ANN Yöntemiyle Gelecek Perspektifi

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ÖZ

Bu çalışmada Türkiye için 2000-2019 dönemi için ekonomik büyüme, kişi başına enerji tüketimi, kişi başına doğrudan yabancı yatırım ve kişi başına ticaret hacmi arasındaki ilişki Granger nedensellik yöntemi kullanılarak incelenmiştir. Birinci dönem (2000-2019) nedensellik bulgularına göre, ekonomik büyümeden kişi başına doğrudan yabancı yatırıma ve kişi başına doğrudan yabancı yatırımdan kişi başına enerji tüketimine doğru tek yönlü bir nedensellik vardır. İkinci dönemin (2000-2025) nedensellik sonuçları, ekonomik büyümeden kişi başına doğrudan yabancı yatırımlara, kişi başına doğrudan yabancı yatırımlardan kişi başına enerji tüketimine doğru tek yönlü bir ilişki ortaya koymaktadır. Aynı zamanda hem ekonomik büyüme hem de kişi başına düşen enerji tüketiminden kişi başına ticaret hacmine doğru tek yönlü bir ilişki bulunmuştur.

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ABSTRACT

In this study, the relationship between economic growth, energy consumption per capita, foreign direct investment per capita and trade volume per capita was examined by utilizing the Granger causality method for the 2000-2019 period for Turkey. According to the causality findings of the first period, there is one-way causality from economic growth to foreign direct investment per capita and from foreign direct investment per capita to energy consumption per capita. The causality results of the second period present a unidirectional relationship from economic growth to foreign direct investments per capita, from foreign direct investments per capita to energy consumption per capita. Additionally, a one-way relationship is from both economic growth and energy consumption per capita to trade volume per capita.

1. Introduction

In the 21st century, energy stands out as the most fundamental parameter that determines the development levels of countries. The rapid population growth and the advancement of industrialization increase the energy need together with developing technologies day by day. In this context, it is very important to determine the energy requirements of countries and its impacts on their

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macroeconomic growth (Ren et al., 2021; Chiu and Lee, 2020; Doytch and Narayan, 2016). In the last two decades, because of the dramatic decrease of fossil reserves and the effect of environmental factors, the general trend of to correspond the energy needs of all countries has been towards new and renewable energy resources. The general energy policies of the countries have made it essential to use new energy sources such as wind, solar, hydro, geothermal and biomass more. In Turkey, one of the world's twenty largest economies the general situation is same as well as the other countries. In Turkey, in 2000 within the scope of new energy 39.998 GWh of electricity has produced (Enerji Atlası, 2021). This value has increased approximately three times to the 110.684 GWh in 2019. In the last twenty years, The GDP of Turkey has also raised from 272 billion USD to 754 billion in USD (TurkStat, 2021). Although the rapid increase in GDP and the new energy usage, the new energy resources should be utilized more efficient due to the problems related to climate change, environmental pollution and ecological balance as a result of traditional energy use. In this sense, increasing new energy resources and determining their relationship with economic growth play an important role to improve energy and economic policies of countries (Belke et al., 2011).

Today, the new energy and the renewable energy concepts are often confused with each other. While the new energy includes all types of energy obtained by new technologies (nuclear, hydro etc.), the renewable energy is considered as the energy types that are both inexhaustible and obtained from clean energy sources such as wind, solar, hydrogen and geothermal (Abusoglu et al., 2021). According to the data of Turkish Statistical Institute (TUIK) in 2000, the share of new energy sources in total electricity production was 25%, this value has increased to 32.4 % in 2019 (TurkStat, 2021). Within the scope of Turkey's new energy policies, it is aimed to increase the new energy generation share among the total electricity generation further years.

The impact of energy consumption (EC) on economic growth (GDP) is known as a vital parameter that is accepted by all authorities. However, there is a confusion regarding the direction of the relationship between GDP and EC (Belke, 2011). Considering the relevant studies in the open literature, there are various opinions about how both parameters affect each other. In this study, the causality relationship between GDP and EC is analyzed. Additionally, the new energy consumption per capita (NE), GDP, imports and exports per capita and foreign direct investment per capita in Turkey are revealed by utilizing the VAR model. VAR model is applied to contribute the previous studies in the open literature by using Granger causality test. Moreover, the NE and the GDP relationship are investigated via Artificial Neural Network (ANN) approach within the scope of the 2025 vision of Turkey. The study contains different propositions while examining the relationship between both parameters. These propositions are presented under two main headings which are whether the NE will affect macroeconomic growth and whether GDP will affect NE. Considering the studies in the open literature, although the causality relationship between GDP and NE has been discussed in some publications, the causality relationship with the forward estimation method has not been examined in detail. Thus, the relationship between GDP and NE is given for the recent portrait of Turkey and also the future projection is considered with the artificial neural network estimation method. In this respect, the study is expected to complete the gap in the literature.

The division of the study is as follows: Chapter 1 includes the purpose and importance of the study. In Chapter 2, other studies in the literature related to the subject are included. Chapter 3 contains information about data and methodology. Chapter 4 contains empirical results. In Chapter 5, conclusions and recommendations are given.

2. Literature

Considering the theoretical approaches to the relationship between energy consumption and economic growth, it is seen that the ecological growth model mainly focuses on three issues. These are: resource allocation, income distribution and especially the place of the economy in the ecosystem. A good allocation of resources should be Pareto optimally efficient. A good distribution of income and wealth must be equitable. The measure of well-being is that it is ecologically sustainable.

2.1. Beaudreau's Ecological Growth Model

In this model, the neoclassical growth model is criticized and a different production function is put forward. Contrary to the neoclassical growth model, which is accepted as the production function of only labor and capital, it is argued that raw materials and energy are also functions of production. Moreover, it is argued that only energy is productive. It is considered production as a function of energy consumption and organization (Yıldırım, 2019).

2.2. Kummel et al.'s Ecological Growth Model (1980-1982-1985-2002

Kummel claimed that the production flexibility of energy does not equal its ratio to the total cost. Capital, labor and energy are the physical factors of production. They realize industrial production through job performance and the use of knowledge. Labor and energy are measured by the work done by a man in an hour. It is expressed in energy units such as joules (Yıldırım, 2019).

2.3. Ayres and Warr's Ecological Growth Model

The innovation in this model is the inclusion of energy efficiency directly into the production function. For this purpose, they used a measurement that is often mentioned instead of energy. This concept consists of energy and raw material combinations. This measurement concept data can also be evaluated as a technological development measurement (Yıldırım, 2019).

When considering the studies in the open literature, it has been determined that there are many studies investigating the causality relationship between (EC) and (GDP). Herein, it can be stated that when the methods and findings applied in these studies are evaluated, the obtained results show that the relationship between EC and GDP is one directional or bi directional. The one directional studies can be emphasized as the directions both from the GDP to the EC or from the EC to the GDP. The conclusions are indicated that the directions of the causality relationship can be shown in four different ways.

- The direction from GDP to EC,
- The direction from EC to GDP,
- Bi directional causality,
- No causality.

Adhikari and Chen (2012) considered 80 developing countries based on causality relationship between the GDP and the EC via DOLS method. It was resulted that there is a causality from GDP to EC in low-income countries. Hwang and Yoo (2014) investigated the same relationship by using the Granger causality test for Indonesia and found that the causality is from GDP to EC. Cheng (1999) performed the Granger causality test for India and reached that there is one direction which is from GDP to EC. Farhani and Rejeb (2012) also carried out Granger causality test for 95 countries. It was resulted that there is one-way causality from GDP to EC. In the study of Aqeel and Butt (2001), the results for the causality relationship in Pakistan is obtained. It is found that the causality is from GDP to EC by using Hsiao's version of causality test. The studies mentioned above showed that the one directional causality from GDP to EC can be proposed that the policies of energy conservation may not affect significantly to the economic growth. Yıldırım (2019) examined the relationship between economic growth, energy consumption and carbon emissions for the 1964-2014 period. According to the empirical findings, there is a unidirectional causality running from GDP per capita to energy consumption per capita and a unidirectional causality from energy consumption per capita to carbon emissions.

Adhikari and Chen (2015) resulted also causality from EC to GDP in middle-income countries in their studies applying the DOLS method. Huang and Huang (2020) performed ARDL method in order to investigate the causality relationship between GDP and EC per capita in China. It was concluded that there is a direction from EC per capita to GDP. Lau et al. (2011) considered 17 Asian countries within the scope of causality relationship by using FMOLS. It was resulted that the direction of causality is seen from EC to GDP. The existence of one direction causality from EC to GDP refers to the economy is energy dependent. Therefore, energy saving policies may affect the economic growth negatively. Durğun and Durğun (2018) examined the relationship between GDP per capita and renewable energy consumption per capita for the 1980-2015 period. According to the findings, there is a unidirectional relationship from renewable energy consumption to economic growth.

Shakouri and Yazdi (2017) carried out an analysis of causality relationship by considering the model of ARDL for South Africa. The results show that there is two-way causality between the variables. Ahmed et al. (2013) examined the causality relationship in Pakistan via Granger causality test. As a result of the empirical evidences bi directional causality was obtained between the GDP and the EC. Belke et al. (2011) studied the causality relationship for 25 OECD countries to put forward the causality of GDP and the EC. The Granger causality test provides the evidence of bi-directional causality for both GDP and EC. As can be seen from the literature given above, it is also possible there is bidirectional causality between GDP and EC. Hayaloğlu et al. (2019) investigated the relationship between energy consumption and economic growth in OECD countries for the period 1990-2017 using panel data analysis. According to the results obtained, there is a two-way causality between energy consumption and economic growth. Yaniktepe et al. (2021) examined the relationship between energy consumption and economic growth for the period 1970-2015. The dependent variable is real Gross Domestic Product (GDP) and the independent variable is energy consumption. As a result of the causality analysis, it is found that there is a two-way causality between energy consumption and economic growth.

Farhani and Rejeb (2012) performed a study that relates to causality relationship between the GDP and EC by utilizing a method namely panel FMOLS for 15 ME-NA countries. However, it was not found any causality relation between the investigated variables. Chiou-Wei et al. (2008) considered 8 Asian countries and USA based on causality relationship between GDP and EC with Granger causality test and achieved that there is no causality relationship for USA, Thailand and South Korea. Lee and Chang (2008) studied the causality relationship between the GDP and EC for 16 Asian countries by using panel ECM method. It was concluded that there is no causality. According to the studies given above the absence of causality between EC and GDP signals that energy saving policies will not have remarkable effect on economic growth. Odhiambo (2021) examined the relationship between energy consumption and economic growth in Botswana for the period 1980-2016 using ARDL method. Empirical findings reveal that economic growth does not depend on energy consumption.

The recent studies on causality relationship summarized above gives the four different empirical results. In this study, the causality relationship between GDP and EC per capita is performed by investigating the Granger causality test. The empirical evidences showed that there is no causality between the variables for the case of Turkey.

3. Data and Methodology

3.1. Dataset

The data used in the study are annual and cover the period 2000-2019. Turkey is the sample country. According to the studies in the literature, there is a relationship between NE and GDP. Therefore, annual GDP data is chosen to represent economic growth in the model. In economic theory, Theoretically, it is known that investment and trade are factors that support economic growth. For this reason, per capita foreign direct investment (FDI) data is obtained by dividing total foreign direct investment by total population. In addition, import and export trade per capita volume (TR) is obtained by dividing the total import and export trade volume by the total population. New energy per capita (NE) data was obtained by collecting hydropower energy, geothermal energy, wind energy and solar energy data and dividing them by population. Then, the logarithm of all the data mentioned above was taken to better eliminate the different variance problem.

The Gross Domestic Product and Foreign Direct Investments data used in this study were drawn from the World Bank, New Energy data from the General Directorate of Energy Affairs (EIGM), and finally the Trade Volume data from the International Monetary Fund (IMF) databases. The logarithms of all variables used are taken. The definitions of the variables used in the analysis are given in the Table 1.

Table 1. Variable Definition

Dependent Variable	Definition
lnGDP	Gross Domestic Product
Explanatory variables	**Definition**
lnFDI	Foreign Direct Investment per capita
lnNE	New Energy Consumption per capita
lnTR	Trade Volume per capita

Table 2 shows the main statistical results of the variables.

Table 2. Descriptive Statistics

Variables	Mean	Standard deviation	Min.	Max.
lnGDP	27.10666	0.491709	26.02284	27.58034
lnFDI	4.727236	0.928275	2.743691	5.759655
lnNE	7.275256	0.326637	6.621782	7.886989
lnTR	8.133200	0.522069	7.034816	8.627738

As seen from Table-2, it is observed that the mean and standard deviation values are close to each other. The fact that the variances of the variables are approximately close to each other increases the possibility of suppressing the basic components of the variance of a variable and the significance level of the analysis to be made.

3.2. Methodology

The vector autoregression (VAR) model was used in the study. The model developed by Granger (1980) is based on the Granger causality test model. If there are two internal variables in the model, these variables are associated with the lagged values of both the internal variable and the other internal variable up to a certain period. Sims criticizes the state of internal and external variables in the structural model. He states that such a situation is unnatural. If Y_t and X_t series are considered, VAR model is defined as follows (Ertek, 2020):

$$Y_t = \alpha + \sum_{j=1}^{m} \beta_t Y_{t-j} + \sum_{j=1}^{m} \delta_j X_{t-j} + \varepsilon_{1t} \quad (1)$$

$$X_t = \alpha + \sum_{j=1}^{m} \theta_j Y_{t-j} + \sum_{j=1}^{m} \vartheta_j X_{t-j} + \varepsilon_{2t} \quad (2)$$

Here ε_{1t} and ε_{2t} are error terms. The lagged values of Y affect the X variable and the lagged values of X affect the Y variable. In this model, since there are only lagged variables on the right side of the equations, the values to be found by the least squares method will be consistent.

4. Empirical Findings

4.1. ADF Unit Root Test

Table 3 shows the ADF unit root test results of the series used in the study. In the table, GDP, FDI, NE and TR symbolize economic growth, foreign direct investment, new energy consumption and trade volume, respectively. Δ expressed variables represent the first differences of the variables mentioned above. According to the ADF unit root test results, when the level values of the variables are considered, the probability values are insignificant. Therefore, for the GDP, FDI, NE and TR series, the null hypothesis stating that the series has unit root cannot be rejected. Considering the first difference values of the series, it is seen that the probability values are significant. For this reason, the null hypothesis stating that the series has unit root for the first difference values is rejected. According to the ADF unit root test results, GDP, FDI, NE and TR series become stationary when the first difference is taken by containing unit root. The stationarity levels of these series are I (1).

4.2. Johansen Cointegration Test

After performing the stationarity test of the series, it was tested with the Johansen Cointegration Test whether there is a long-term cointegration relationship among the variables in the study. The cointegration test results are summarized in Table 4. The results in the table indicate that the variables have cointegration in the long run. In other words, it seems that in the long run, the series are cointegrated, that is, they act together.

Table 3. ADF Unit Root Test Results

	ADF				Phillips-Perron			
	Constant		**Constant and Trend**		**Constant**		**Constant and Trend**	
VARIABLES	t-stat.	p-value	t-stat.	p-value	t-stat.	p-value	t-stat.	p-value
LNGDP	-1,583	0,4714	-0,503	0,9734	-1,5715	0,4470	-0,5418	0,9709
ΔLNGDP	-4,0333	0,0070*	-6,8496	0,0002*	-3,9841	0,0077*	19,3646	0,0001*
LNFDI	-1,5663	0,4784	-1,2220	0,8741	-2,4899	0,1332	-1,8978	0,6162
ΔLNFDI	-4,6490	0,0020*	-4,6822	0,0081*	-4,6490	0,0020*	-4,6310	0,0089*
LNNE	0,9986	0,7317	-3,5295	0,0647	-0,4676	0,8776	-3,5621	0,0611
ΔLNNE	-5,8470	0,0002*	-5,6605	0,0013*	-7,5530	0,0000*	-7,2768	0,0001*
LNTR	-1,9697	0,2963	-0,8696	0,9390	-2,2939	0,1836	-0,2731	0,9850
ΔLNTR	-3,5342	0,0192*	-4,3943	0,0149*	-3,5342	0,0192*	-10,1025	0,0000*

Note: The lagged length selection for ADF is based on Schwarz Information Criteria (SIC), Phillips-Perron is based on Newey-West optimal adaptation lags.

Table 4. Johansen Cointegration Test Result

Trace Statistic Values				
H_0 Hypothesis:				
No cointegration	**Eigenvalue**	**Trace stat.**	**Critical value (%5)**	**p-value****
None	0,815932	69,18048	55,24578	0,0019
At Most 1	0,775827	38,71634	35,01090	0,0192
At Most 2	0,392381	11,80029	18,39771	0,3241
At Most 3	0,145607	2,832546	3,841466	0,0924

Note: The Trace Test shows that there is a cointegration equation at the 0.05 level, * H_0 shows that the Hypothesis is rejected at the 0.05 level, ** MacKinnon-Haug-Michelis (1999) shows the probability values.

Maximum Eigen Statistic Values				
H_0 hypothesis:				
No cointegration	**Eigenvalue**	**Max. Eigen Stat.**	**Critical value (%5)**	**p-value****
None	0,815932	30,46414	30,81507	0,0552
At Most 1	0,775827	26,91605	24,25202	0,0217
At Most 2	0,392381	8,967745	17,14769	0,4990
At Most 3	0,145607	2,832546	3,841466	0,0924

Note: The Maximum Eigenvalue Test shows that there is a cointegration equation at the 0.05 level, * H_0 hypothesis shows that it is rejected at the 0.05 level, ** MacKinnon-Haug-Michelis (1999) shows the probability values

4.3. Error Correction Model (short term analysis)

Whether a deviation that will occur in cointegrated series is corrected or not is tested by error correction model. In this model, it is investigated how the series that move away from equilibrium, approach the mean (Tari, 2010). In the error correction model, the lagged value of the error terms obtained after OLS estimation (ECT_{t-1}) and the differences of the series are explained. In this direction, it is possible to show the relevant model as follows:

$$\Delta lnGDP_t = \alpha_0 + \alpha_1 \Delta lnFDI + \alpha_2 \Delta lnNE + \alpha_3 \Delta lnTR + \alpha_3\, ECT_{t-1} + \varepsilon_t \quad (3)$$

Table 5 shows error correction model test results. According to the test results, the coefficient of the error correction term is between 0 and -1 and it is statistically significant. Deviation from balance comes to equilibrium after about 1.5 periods.

Table 5. Error Correction Model Test Results

Dependent Variable	**Independent Variable**	**Coefficient**	**T-Stat.**
ΔlnGDP	ΔlnFDI	-0.023976	-0.949737
	ΔlnNE	-0.044176	-0.657086
	ΔlnTR	0.816770	9.344430
	ECT_{t-1}	-0.717142	-3.208654
	C	0.000808	0.053047
R^2 = 0.88	F(p) = 26.73 (0.00)		DW = 1.36

Note: C refers constant term and ECT_{t-1} refers lagged error correction term.

4.4. Reverse Roots of the AR Characteristic Polynomial

Whether the variables to be used in the VAR Model are stationary or not is still a matter of debate. The reason for this situation is that taking the differences of the variable series in the model to stabilize may cause information loss. However, according to Sims (1980) and Doan (1984), the purpose of VAR analysis is not parameter estimation. The main purpose is to reveal the relationships between variables and they are opposed to taking the differences even if these series contain unit roots. Similarly, Cooley and Roy (1985) argue that the purpose of VAR analysis is to predict the relationships between variables rather than parameter estimation (Zengin and Çaycuma, 2001). For this reason, in line with the information provided, the level states of the series of the variables to be used in the VAR model established in this study were used. It was tested whether the established VAR model has a balanced structure and the Reverse Roots of the AR Characteristic Polynomial are shown in Fig.1. The Fig.1 indicates that the Reverse Roots of the AR Characteristic Polynomial of the estimated VAR model are not outside the reference values (-1 to +1). For this reason, it can be said that the established VAR model does not contain any problems in terms of stability.

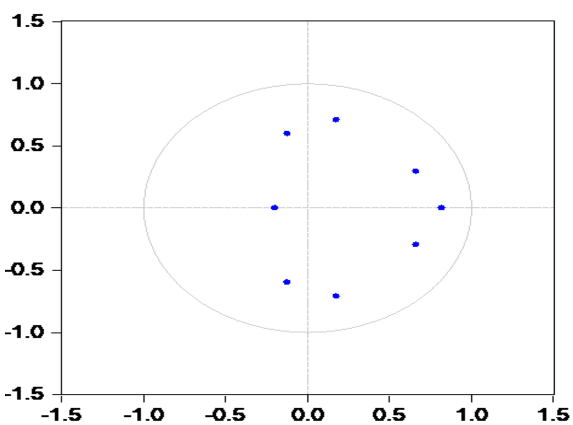

Figure 1. Reverse Roots of the AR Characteristic Polynomial

4.5. Granger Causality Test

After the stability test of the variables used in the VAR model, the Granger Causality Test was conducted to determine the causality relationship between the variables. Test results are shown in Table 6.

In the Granger Causality Test, according to the H0 hypothesis, it states that there is no causality among the variables, while the H1 hypothesis states that there is causality between the variables. Looking at Table 6, when FDI is the dependent variable, the probability value of GDP is less than 5% and the null hypothesis is rejected. In other words, Gross Domestic Product is the Granger cause of Foreign Direct Investment. This situation shows that there is a unidirectional causality relationship between GDP and FDI. In the case where NE is the dependent variable, the probability value of the FDI is less than 5% and the null hypothesis is rejected. In other words, Foreign Direct Investment is the Granger cause of New Energy Consumption. This shows that there is a one-way causality relationship between FDI and NE.

Table 6. Granger Causality Test Results

Causality Direction	Chi-Square Test Statistics	p-value
Dependent Variable: GDP		
FDI > GDP	0.436022	0.8041
NE > GDP	1.649644	0.4383
TR > GDP	1.869257	0.3927
Dependent Variable: FDI		
GDP > FDI	7.501540	0.0235*
NE > FDI	0.007964	0.9960
TR > FDI	1.596810	0.4500
Dependent Variable: NE		
GDP > NE	0.974735	0.6142
FDI > NE	6.483284	0.0391*
TR > NE	0.641173	0.7257
Dependent Variable: TR		
GDP > TR	3.256315	0.1963
FDI > TR	0.394909	0.8208
NE > TR	1.353939	0.5082

Note: Variables are significant at the 5% significance level.

The relationship between the variables in line with the results is shown in Fig. 2. According to the figure, there is one-way causality from gross domestic product to foreign direct investment. At the same time, there is a unidirectional causality from foreign direct investments to new energy consumption.

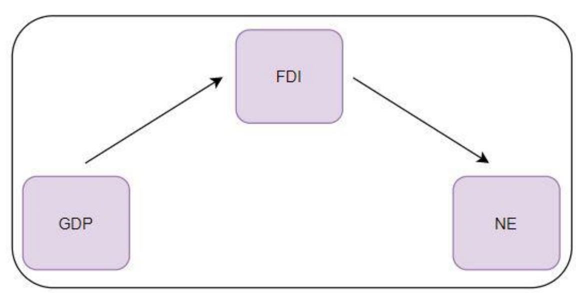

Figure 2. Granger Causality Flow Between Variables

In the Granger Causality Test, according to the H_0 hypothesis, it states that there is no causality among the variables, while the H_1 hypothesis states that there is causality between the variables. Looking at Table 7, when FDI is the dependent variable, the probability value of GDP is less than 5% and the null hypothesis is rejected. In other words, Gross Domestic Product is the Granger cause of Foreign Direct Investment. This situation shows that there is a unidirectional causality relationship between GDP and FDI. In the case where NE is the dependent variable, the probability value of the FDI is less than 5% and the null hypothesis is rejected. In other words, Foreign Direct Investment is the Granger cause of New Energy Consumption. This shows that there is a one-way causality relationship between FDI and NE. When TR is dependent variable, the probability value of GDP and NE is less than 5% and the null hypothesis is rejected. In other words, Gross Domestic Product and Energy Consumption is the Granger cause of Trade.

Table 7. Granger Causality Test Results with Forecasting

Causality Direction	Chi-Square Test Statistics	p-value
Dependent Variable: GDP		
FDI > GDP	0.445017	0.8005
NE > GDP	3.346951	0.1876
TR > GDP	2.660001	0.2645
Dependent Variable: FDI		
GDP > FDI	11.09727	0.0039*
NE > FDI	0.086232	0.9578
TR > FDI	1.961099	0.3751
Dependent Variable: NE		
GDP > NE	2.114333	0.3474
FDI > NE	10.12778	0.0063*
TR > NE	3.747937	0.1535
Dependent Variable: TR		
GDP > TR	6.541590	0.0380*
FDI > TR	0.564548	0.7541
NE > TR	6.256616	0.0438*

Note: Variables are significant at the 5% significance level.

The relationship between the variables in line with the results is shown in Fig. 3. According to the figure, there is one-way causality from gross domestic product to foreign direct investment. At the same time, there is a unidirectional causality from foreign direct investments to new energy consumption. Besides, there is one-way causality from gross domestic product and Energy Consumption to Trade.

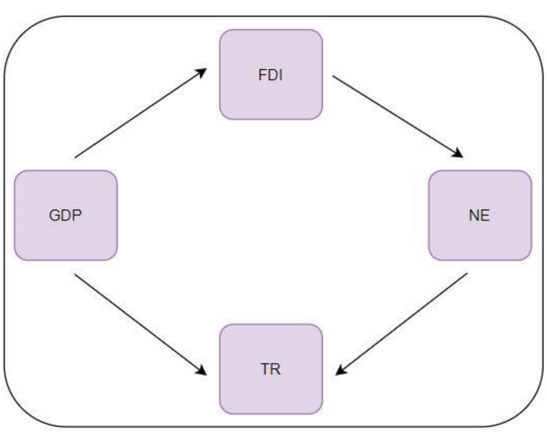

Figure 3. Granger Causality (forecasting) Flow Between Variables

4.6. Artificial Neural Network (ANN)

Artificial neural network (ANN) is an information processing model that is inspired capabilities of biological neural networks (Rojas, 2013). Also, one of the most well-known application areas is forecasting. ANN is a method used in complex structured data and relations, making sense of the relationship between input and output. For this purpose, in this study, energy data between the years 2020-2025 were forecasted using input data (GDP, FDI, TR) between 2000-2019. First of all, GDP, FDI and TR data were used as input and Energy data as output, an estimation model was created with ANN. In this model, additional ANN models were used to predict each GDP, FDI and TR data for 2020-2025. Using the forecasting model created in the first step, 2020-2025 energy data were estimated based on GDP, FDI and TR data. In this study, ANN toolbox (nntool) of MATLAB R2019b is used to forecast Energy demand with Levenberg-Marquardt Feed forward Back Propagation Algorithm.

4.7. Prediction of GDP, FDI, TR

Defined inputs and targets are put into the network after the network has been created. Then, the results are obtained by training the network. The network structure using trainlm as a training function consists of 2 layers and 8 neurons (2L-8N1). ANN network structure is shown as in Fig. 4.

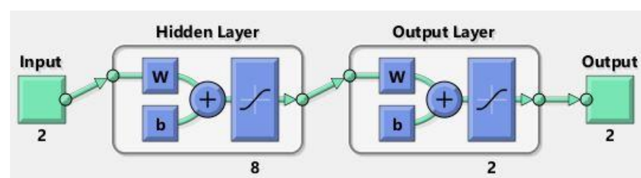

Figure 4. Neural network diagram for 2L-8N1 model (Trainlm Function)

In this study, Tansig and Logsis functions are used for training with 8 and 10 neurons. A linear regression between the network outputs and the corresponding targets are shown from the Fig.5 to Fig. 7 for GDP, FDI and TR respectively.

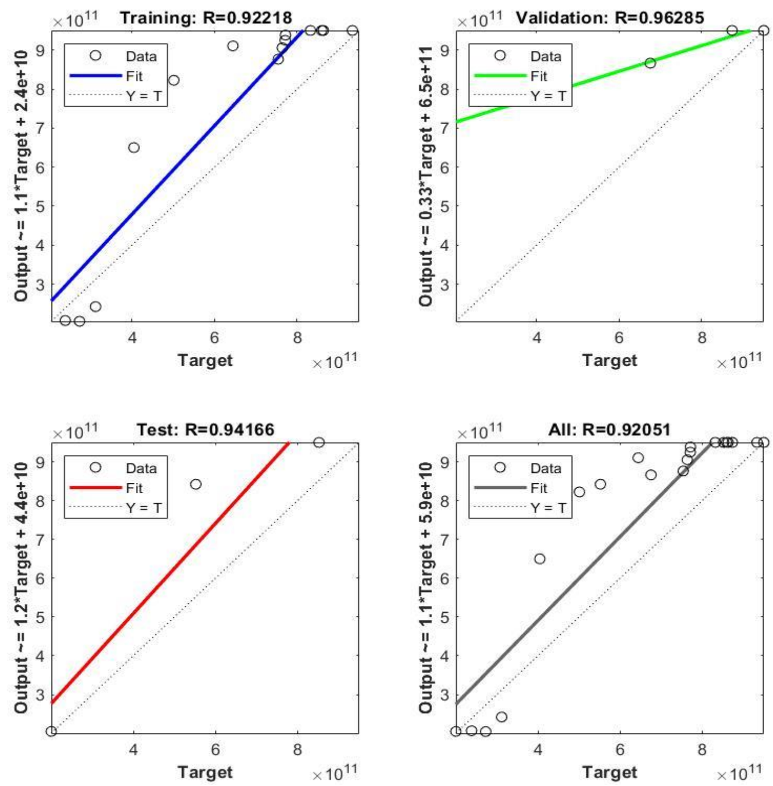

Figure 5. Network regression for GDP

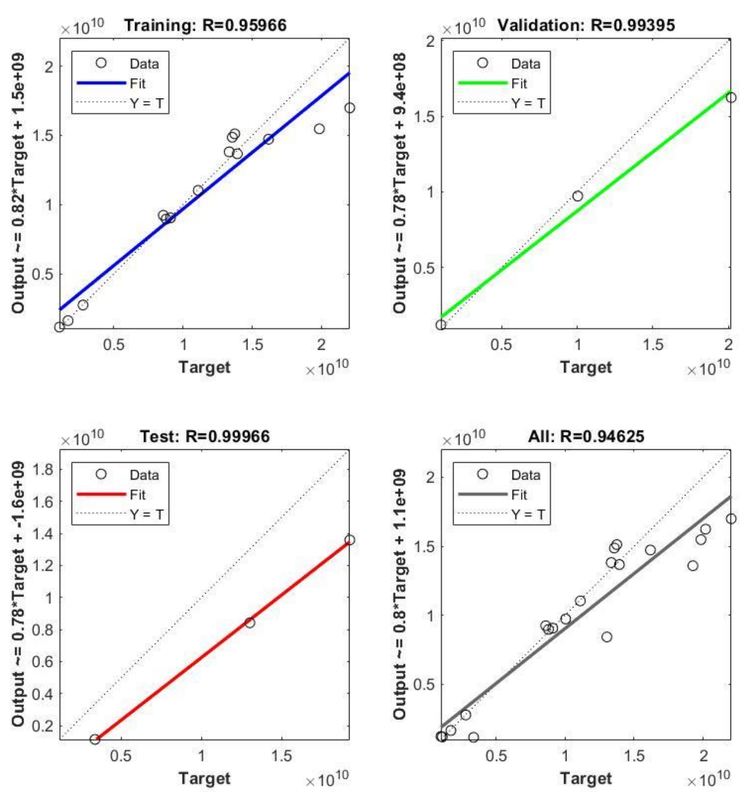

Figure 6. Network regression for FDI

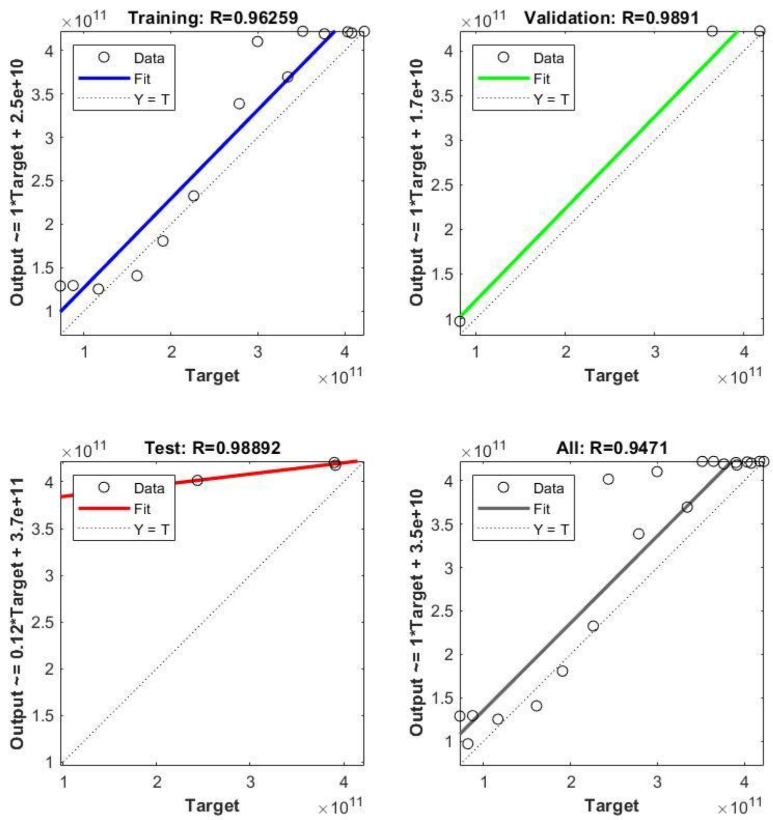

Figure 7. Network regression for TR

The output appears to follow the goals for training, validation, and testing very well. These values can be equivalent to a total response of R-values 0.92051, 0.94625, 0.9471 for GDP, FDI and TR respectively. In this case, the network response is satisfactory, and simulation can be used for entering new inputs. In the circumstances, the network response is quite enough and can be used to enter new inputs for prediction. Thus, 2020-2025 forecast data of the created models are presented in Table 8.

Table 8. Predicted data for GDP, FDI and TR between 2020-2025

Year	GDP	FDI	TR
2020	818860819027,22	9608562858	4,14055E+11
2021	787346868567,48	9669257187	4,13517E+11
2022	782626771979,23	9672531872	4,13487E+11
2023	782124183527,52	9672701880	4,13485E+11
2024	782072855270,51	9672710688	4,13485E+11
2025	782067635854,47	9672711144	4,13485E+11

Then, Trainlm function is used for training with 8 neurons. A linear regression between the network outputs and the corresponding targets are shown in Fig. 8. The Network properties are as follows:

- ❖ Network inputs: GDP, FDI, TR.
- ❖ Network outputs: EN.
- ❖ Network type: Feed-Forward Back-Propagation.
- ❖ Training function: TRAINLM.
- ❖ Adaption learning function: LEARNGDM.
- ❖ Performance function: MAPE.

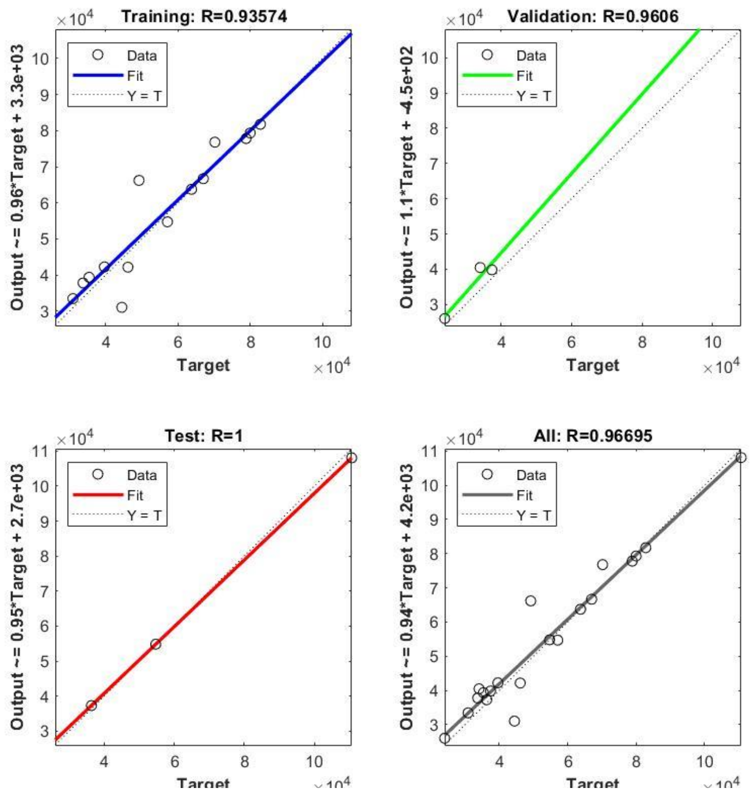

Figure 8. Network regression between GDP, FDI, TR and EN.

The output seems to follow the targets very well for training with R-value = 0.93574, validation with R-value = 0.86323, and testing with R-value = 0.86289. However, the total value of R is observed 0.96695. Thus, it has been shown that prediction between 2020-2025 Energy demand using the input data of the network is sufficiently convenient and presented in Table 9.

Table 9. Predicted data for Energy Demand between 2020-2025.

Year	Energy Demand Predictions
2020	105469.275467042
2021	108353.626516268
2022	108640.682758580
2023	108669.626488762
2024	108672.588127654
2025	108672.890576135

5. Conclusion and Policy Recommendations

Energy is among the priority issues of today in terms of economic and social development. This situation can be explained by the unbalanced distribution of energy resources by regions and the fact that reserves are limited, but continue to be used as a basic input in the production process. As a matter of fact, energy will continue to remain on the agenda, with the consumption level of which will be raised in the future depending on population and industrialization. The energy consumption in Turkey has shown a tendency to increase over time, for the reasons stated. However, it is more important here to question whether energy consumption is realized in a way that helps economic growth by using efficiency and productivity principles rather than the increase in energy consumption.

This study evaluates the causality relationships between economic growth, energy consumption per capita, foreign direct investment per capita and trade volume per capita. In this study, Granger causality method was applied in Turkey for the period 2000-2019. Granger causality method has been applied for two periods. The first period covers the 2000-2019 period. The second period covers the 2000-2025 period, which is obtained by estimating with the Artificial Neural Network (ANN) method. ADF and Phillips-Perron unit root tests were applied in the study. According to unit root tests, data contain unit root in series. The first differences of the variables are taken and made stationary. As a result of the Johansen cointegration test, it was revealed that there is a cointegration between variables and a long-term relationship between these variables. Granger causality analysis was performed with the first differences of the series. According to the causality findings for the first period (2000-2019), there is a one-way causality from economic growth to foreign direct investments per capita and foreign direct investments per capita to energy consumption per capita. In the causality results for the second period (2000-2025), a one-way relationship was found from economic growth to foreign direct investments per capita, foreign direct investments per capita to energy consumption per capita. At the same time, there is a one-way relationship from both economic growth and energy consumption per capita to trade volume per capita. In light of these results, it can be said that Turkey is less dependent on energy factor to gain economic growth.

It is natural for developing countries to increase energy use while achieving economic growth. In Turkey, which is one of the developing countries, while economic growth is achieved, energy use is increasing. Considering the results, the solution for Turkey can be explained as follows; The energy needed for sustainable economic growth is to be provided by existing domestic and renewable energy resources, not by imports. The share of solar and wind energy, which is one of the renewable energy sources, can be increased. Due to Turkey's geographical location, these opportunities can be turned into profits by taking advantage of both the average sunshine hours throughout the year and the prevailing wind diversity and power. As a result of the active use of domestic energy resources, dependence on foreign energy can be reduced. Also, it can be said that energy saving policies can be implemented in a way that does not affect the economy much. However, energy saving, control of energy consumption and increase of investments in equities in Turkey's dependence on energy toward reducing the risks posed in the long term will provide a positive contribution.

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