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The Relationship between CO2 Emission, Non-Renewable Energy Consumption and Economic Growth: A Case of Turkey

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Abstract
In this study, the relationships between carbon dioxide emission, non-renewable energy consumption and economic growth were examined. The analysis covers 25 years of period between 1990-2015 for Turkey. VAR Granger Causality Analysis was employed for the short-term causality analysis. The results indicated that there is a unidirectional relationship from non-renewable energy consumption to CO2 emission in the short-term. The only variable affecting CO2 in the short-term is non-renewable energy consumption. According to the variance decomposition test, in the second period, 13.8% of CO2 emissions were caused by non-renewable energy consumption, 2% was due to economic growth, while in the 8th period, 44% of CO2 emissions were caused by non-renewable energy consumption and 12% from economic growth. This result supports the "Neutrality Hypothesis", which asserts that there is no direct relationship between energy consumption and economic growth. Since it is revealed a unidirectional causality from NREC to CO2, measures regarding energy consumption will not have a negative impact on economic growth while reducing carbon dioxide emissions in Turkey.

Key words: Carbon dioxide emission, CO2 emission, Non-renewable energy consumption, economic growth.

CO2 Emisyonu, Yenilenmeyen Enerji Tüketimi ve Ekonomik Büyüme Arasındaki İlişki: Türkiye Örneği

Öz
Bu çalışmada karbondioksit salınımı, yenilenemeyen enerji tüketimi ve iktisadi büyüme arasındaki ilişkiler incelenmiştir. Analiz, Türkiye için 1990-2015 arasındaki 25 yılı kapsamaktadır. Kısa dönem nedensellik analiz için VAR Granger Nedensellik Analizi kullanılmıştır. Buna göre kısa dönemde yenilenemeyen enerji tüketiminden, CO2 salınımına doğru tek yönlü pozitif bir ilişki olduğu ortaya konmuştur. Kısa dönemde CO2 salınımını etkileyen tek değişken yenilenemeyen enerji tüketimidir. Varyans ayrıştırma testi sonucuna göre, ikinci dönemde, CO2 salınımının % 13,8'i yenilenemeyen enerji tüketiminden, % 2'si ekonomik büyümeden kaynaklanırken, 8. dönemde, CO2 salınımının % 44'ü yenilenmeyen enerji tüketiminden ve % 12'si iktisadi büyümeden kaynaklandığı görülmektedir. Bu sonuç, enerji tüketimi ile ekonomik büyüme arasında doğrudan bir ilişki olmadığını öne süren "Tarafsızlık Hipotezini" desteklemektedir. Buna göre enerji tüketimi ile iktisadi büyüme arasında bir ilişki olmadığından, enerji tüketimi ile ilgili alınacak tedbirler karbondioksit salınımını azaltırken iktisadi büyüme üzerinde olumsuz bir etki doğurmayacaktır.

Anahtar kelimler: Karbon dioksit salınımı, CO2 salınımı, Yenilenemeyen enerji tüketimi, İktisadi büyüme

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Introduction

Global warming is becoming one of the most important problems of the countries in the world. The increase in carbon dioxide emissions (CO2) is one of the major causes of global warming. The developments in the world economy, considerable increase in industrial production and hence economic growth (GDP) affects the environment significantly. However, increasing environmental problems stem from raising economic activity level have been ignored. Failure to take the necessary measures to prevent negative externalities, which emerge as a result of increasing economic activity, is the most important reason for increasing CO2 and so global warming. Furthermore, the rapid increase in the energy demand makes countries, which do not have sufficient fossil fuel resources, dependent on external resources. For this reason, it is important to use alternative energy sources other than non-renewables in order to prevent environmental pollution and to reduce foreign dependency.

In parallel with these developments in the world, Turkey's energy demand is increasingly rising. Moreover, the scarcity of non-renewable energy resources regarding fossil fuel production makes Turkey dependent on foreign sources and could cause to increasing CO2 which could create negative externalities. Turkey's energy consumption is very largely met by imports from external resources. This situation reveals the importance of the energy resources, in order to reduce the external dependency and minimizing the CO2 in Turkey.

The relationships between NREC and GDP are examined in four aspects in the literature. These are "the neutrality hypothesis", "the growth hypothesis", "the feedback hypothesis" and "the conservation hypothesis". In this context, the aim of this research is to reveal the causality between "Non-renewable energy consumption, economic growth and carbon dioxide emissions" from 1990 to 2015 in Turkey. This article consists of four headline. The general framework of the theoretical background is explained under the second headline. The empirical literature review, including the method used, selected countries, period investigated and the conclusions reached, is summarized under the third headline. The forth headline includes the econometric analysis that consists of methods, datasets, applications and conclusion.

Theoretical Background

The economic theories that investigate the relationships between innovation and economic growth begin with Joseph Schumpeter. Unlike the classics, Schumpeter did not associate the main reason of GDP with capital accumulation, but innovation, creativity and entrepreneurship. Accordingly, the relationship between GDP and NREC can be considered in the context of Schumpeter theory in terms of the need for new and different systems of renewable energy production or the production of energy with different techniques and resources (Śledzik, 2015, p. 92-94).

Kuznets propounded a hypothesis, known as the "Environmental Kuznets Curve", which examines the relationship between GDP and environmental changes. According to this hypothesis, as economic growth rates increase, first of all, negative environmental changes are experienced and then this process reverses after a certain level of income (Stern, 2004, p. 1419). The relationship between renewable energy and GDP can be considered in the context of the Environmental Kuznets hypothesis (Ranis, 2004, p. 4-6).

The economic growth theory developed by Walt Rostow is based on five stages of capital accumulation and development. These stages are "Traditional Society" based on agriculture. Capital accumulation is very limited and characterized by low labour productivity. Second is the so-called "Pre-conditions for take-off" characterized by the mechanization of agriculture. However, investments are limited due to low savings. Foreign aids and finance are required. The third stage is "Take-off" build on manufacturing. Savings and investment increase significantly. Infrastructure and institutions such as economic, social as well as political raise and create progress. However, external finance is still vital to pass the fourth stage called "drive to maturity". The most important problem for the poor countries in Rostow's model is the stage of take-off. He emphasizes that the poor countries have entered a vicious circle, which can be overcome by capital accumulation. External support may be required if internal accumulations cannot be increased. In addition, the transition from agriculture to industry will cause GDP to spread throughout the country. The fifth stage called "Age of mass consumption" In 1971 Rostow added "quality" as the sixth stage. He stated that economic growth could be achieved by continuously improving the quality of goods and services. Rostow has emphasized advanced technology and R & D. The establishment of energy production facilities, which are accepted as new and advanced technology,

and the impact of R & D activities on economic growth can be evaluated within the scope of this theory (Piętak, 2014, p. 49-51).

GDP theories are examined in two separated groups as endogenous growth theories and exogenous growth theories in the literature. The Harrod Domar Model, as exogenous growth theory, asserts that GDP is the function of the "national savings (S)" and the "productivity of capital investment". The productivity of capital investment can be measured with "capital-output ratio (COR)". With this regard, GDP can expressed as ΔGDP = S / COR. Therefore, GDP can be risen by increasing the "national savings (S)" and lowering the "capital-output ratio (COR)". If investments can be increased by shortening the consumption expenditures in the short-run, this will cause to increase GDP in the long run. Since energy is seen as a factor of production, it is assumed that there is a connection between GDP and energy consumption (Gökçe, 2007, p. 11).

Then the Solow and Swan model emerged within the framework of classical vision. In the Solow and Swan model, shortages in energy resources limit the GDP rates. If energy can be found in abundance and can be reached, then energy is a relatively less restrictive factor in terms of GDP (Korkmaz & Develi, 2012, p. 6).

The relationship between NREC and GDP is also explained by endogenous growth models. Romer and Lucas developed an endogenous growth model. In the model, the main factors enabling growth are population growth, technological development, human capital accumulation and the role of public (Özel, 2012, p. 64-68). Factors that explain the growth rates of countries such as knowledge accumulation, human capital, research and development activities affect the development level of countries. Nowadays, the inability to reach the latest information, the lack of sufficient human capital, and the incapability to use technology are the reasons explain the underdevelopment more accurately. It is not possible to explain the GDP of all economies with a single model or variable. In this context, internal growth models offer different classifications. From this perspective, low-cost energy supply and efficient utilisation in production will allow for an increase in GDP (Mucuk & Uysal, 2009, p. 106).

Hamilton and Burbridge's theories of GDP represent the Neoclassical view and include the energy factor. According to this theory, it is accepted that as the energy consumption increases in the industrial area, the total output will increase and therefore the GDP (Aytaç, 2010, p. 483).

The relationship between NREC and GDP is examined in four aspects in the literature. These are "the neutrality hypothesis", "the growth hypothesis", "the feedback hypothesis" and "the conservation hypothesis" (Öncel et al., 2017, p. 402, Shahateet, 2014, p. 349). Based on "the growth hypothesis", NREC is crucial in GDP-growth and there is a unidirectional causality from NREC to GDP (Shahateet, 2014, p. 349). Therefore, when energy consumption increases, economic growth increases. According to the growth hypothesis, energy consumption is crucial in GDP growth. There is a unidirectional causality from energy consumption to economic growth. Hence, when energy consumption increases, economic growth increases. The conservation hypothesis asserts that energy consumption is the function of GDP (Shahateet, 2014, p. 349). There is a unidirectional causality from economic growth to energy consumption that means an increase in economic activity level cause an increase in NREC. Therefore, energy saving policies have little or no impact on GDP. From different perspective, countries limiting their energy consumption imply that they will not significantly affect their level of GDP if they are not dependent on energy (Öncel et al., 2017, p. 402). The feedback hypothesis claims that there is a bi-directional causality between energy consumption and GDP-growth (Shahateet, 2014, p. 349). Within this context, both feed each other because of the bi-directional causality that exists between energy consumption and GDP. In contrast to that, the neutrality hypothesis argues that there is no relationship between energy consumption and GDP. These variables do not affect each other neither positively nor negatively.

Literature Review

The literature, which investigates the relationship between CO2 and GDP, is reviewed in the context of four main hypotheses, which are mentioned under the title of theoretical background, and is summarized in Table 1.

Table 1. *Literature Review*

Researcher	*Data Span and Method*	*Results*
Researches supporting The Neutrality Hypothesis		
Soytas & Sari (2007)	VAR, CUSUM and CUSUMSQ Granger Causality, Turkey, 1960-2000,	An increase in capital accumulation positively affects energy use, CO2 emission and economic growth. Energy consumption does not cause to CO2 emissions however, there is a unidirectional relation from CO2 to energy consumption in the short-term. On the other hand, there is no relationship between CO2 emission and economic growth in the long term. These results support the neutrality hypothesis.
Wahid et al. (2013)	Granger Causality and VEC Model Malaysia, Indonesia and Singapore 1975-2011	There is a unidirectional causality between CO2 and energy consumption and as well as between energy consumption and GDP in Malaysia. In Indonesia, there is a unidirectional causality between GDP and CO2 and as well as between energy consumption and GDP. In Singapore, there is not any causality between GDP and energy consumption and CO2, however, trade openness and industrialization cause to CO2. Although the study produces different results for the other countries, The results for Singapore support the neutrality hypothesis.
Obradović & Lojanica (2017)	VEC - Co-Integration Greece and Bulgaria 1980-2010	It is concluded that energy consumption supports GDP in long-run that means there is a causality between energy and CO2 in both countries in the long-run. However, in the short-run, there is not any causality between variables for neither Bulgaria nor Greece. Accordingly, it is concluded that the short-run CO2 can be reduced at the cost of the long-run growth or a higher growth can be achieved in the long-run at the cost of CO2". The short-term conclusions of the study support the neutrality hypothesis.
Researches supporting The Growth Hypothesis		
Lean & Smyth (2010)	Panel Co-integration and Granger Causality Test Five ASEAN countries, 1980 to 2006.	There is a significant and positive causality between electricity consumption and CO2. There is also a non-linear relationship between CO2 and real GDP in the context of the Environmental Kuznets Curve and an unidirectional causality from electricity consumption to GDP and from CO2 to GDP. In the short term, there is a unidirectional relationship from CO2 to electricity consumption and so growth. The results support the growth hypothesis.
Saibu and Jaiyeola (2013)	Granger Causality and Co-Integration Test Nigeria 1970-2011	As a result, the rate of GDP affects the crude oil production rate. Changes in the rate of crude oil production and consumption affect CO2. There is a causal relationship between oil production, CO2 and GDP.
Wahid et al. (2013)	Granger Causality and VEC Model Malaysia, Indonesia and Singapore 1975-2011	There is a unidirectional causality between CO2 and energy consumption and as well as between energy consumption and GDP in Malaysia. In Indonesia, there is a unidirectional causality between GDP and CO2 and as well as between energy consumption and GDP. In Singapore, there is not any causality between GDP and energy consumption and CO2, however, trade openness and industrialization cause to CO2. The results support the growth hypothesis for Malaysia and Indonesia.
Mahmood & Shahab (2014)	Co-integration –ARDL, Pakistan, 1973-2012	Energy consumption cause to GDP. Environmental pollution increases as a result of energy consumption. Considering rising of energy demand continuously, they underlined the importance of usage of new and clean energy sources
Deste & Okumuş (2019)	Panel cointegration test, FMOLS, and the panel VECM Granger. G-20 Countries, 1992-2013	A raising in biomass energy consumption cause to economic growth and reduces CO2. There is a bidirectional causality between biomass energy consumption and CO2. The results support the growth hypothesis.
Obradović & Lojanica (2017)	VEC - Co-Integration Greece and Bulgaria 1980-2010	It is concluded that energy consumption supports GDP in long-run that means there is a causality between energy and CO2 in both countries in the long-run. However, in the short-run, there is not any causality between variables for neither Bulgaria nor Greece. Accordingly, it is concluded that the short-run CO2 can be reduced at the cost of the long-run growth or a higher growth can be achieved in the long-run at the cost of CO2. The results support the growth hypothesis in the long-term.
Zhou et al. (2018)	Panel Data Analysis, China, India, Brazil, Mexico and South Africa, the United States, Canada and Japan 1981-2013	Energy consumption increases CO2. The effect of energy consumption on CO2 is higher in developed countries than in developing countries. Therefore, energy consumption increases economic growth and CO2 emissions. The study supports the growth hypothesis.

Table 1 - Continued

Researches supporting The Conservation Hypothesis		
Chebbi & Boujelbene (2008)	Johansen Co-integration, Tunısia	There is a positive relationship between production and energy consumption and between CO2 and energy consumption in the long-run. In the short-run, GDP increases energy consumption. The results support the conservation hypothesis
Jalil & Mahmud (2009)	ARDL Model, CUSUM and CUSUMSQ, Granger Causality, China, 1975-2005	There is a one-way causality relationship from economic growth to CO2 emissions. The study supports the conservation hypothesis.
Arouri et al. (2012)	Panel Co-integration Analysis MENA countries, 1981 - 2005	The relationship between economic growth and CO2 emissions varies between periods. There is an indirect relationship that is high in some periods and low in some periods. Therefore, not all countries need to reduce their economic growth rates in order to reduce their CO2 emissions." Results support the conservation hypothesis.
Hwang & Yoo (2014)	Grange Causality, 1965-2006	There is a unidirectional causality from economic growth to energy consumption and CO2 emissions. Energy saving and CO2 emission reduction policies can be performed without sacrificing economic growth. The results support the conservation hypothesis.
Palamalai et al. (2015)	VEC - Co-Integration India 1970 and 2012	There is a long-run relationship between energy consumption, CO2, GDP and trade. Increases in the level of economic activity cause more coal and electric energy consumption in the long-run. Higher growth rates result in more energy consumption. There is a similar relationship between CO2 and energy consumption in the long-run. The results support the conservation hypothesis.
Aye & Edoja (2017)	Panel Data Analysis, 31 developing countries 1971 and 2013	If the country has a low growth rate, the effect of GDP on CO2 is negative and if a country has a high growth rate, the effect of GDP on CO2 is positive. In addition, the energy consumption and the population have a significant and positive effect on CO2.
Mardani et al. (2018)	ANFIS Model G20 countries 1962-2016	GDP and energy consumption cause to CO2. Therefore when the GDP increases then energy consumption and so CO2 rise". The results support the conservation hypothesis.
Researches supporting The Feedback hypothesis		
Tiwari (2011)	Granger Causality and VAR Analysis India, 1971-2007	CO_2 had a positive effect on energy use and capital but had a negative effect on population and GDP. An increase in energy consumption affects GDP positively and vice versa. The results support The Feedback Hypothesis.
Farhani & Ben Rejeb (2012)	Granger Causality and Co-integration Test. Iran, 1975 – 2011.	It is concluded a strong bi-directional relationship between GDP and CO_2. In addition, it was determined both long-run and short-run causality between GDP and renewable energy consumption. The results support The Feedback hypothesis.
Nnaji et al. (2013)	ARDL, Granger Causality Nigeria, 1971-2009	There is a bidirectional causality between fossil fuel consumption and GDP, and a unidirectional relationship between electricity supply and CO_2. The results support The Feedback hypothesis.
Govindaraju & Tang (2013)	Granger Causality and Co-integration Test, China and India 1965-2009.	It is concluded for both short-run and long-run a bi-directional causality relationship between coal consumption and CO_2 and between coal consumption and GDP in China. In addition, unidirectional causality between GDP and CO_2 was also determined. In India, in the short-run, there is a bi-directional causality between GDP, CO_2 and between CO_2 and coal consumption. The results support The Feedback hypothesis
Linh & Lin (2014)	Granger Causality Vietnam	There is a dynamic relationship between CO_2, energy consumption, FDI and GDP. In the short-run, it is revealed a bidirectional causality between FDI, GDP and energy consumption. In addition, in the long-run, there is a bi-directional relationship between CO_2 and income and between energy consumption and income. The results support The Feedback hypothesis.
Bozkurt & Akan (2014)	VAR Analysis – Turkey, 1960-2010	Energy consumption has a positive impact on GDP, while CO_2 has a negative impact on GDP." The results support The Feedback hypothesis.
Antonakakis et al. (2015)	Panel data - Granger Causality and VAR 106 countries. 1971-2011	Although energy consumption varies in country groups, it has been underlined that coal consumption is becoming less important as an energy source. It was revealed a bidirectional relationship between GDP and energy consumption. The results support The Feedback hypothesis.
Lu (2017),	Panel Granger Causality and Cointegration 16 Asian countries 1990-2012.	An increase of 1% in energy consumption increases CO_2 by 0.82%. There is also a non-linear relationship between CO_2 and GDP. In the short-run, there is a bidirectional relationship between energy consumption and CO_2, between GDP and CO_2, and between GDP and energy consumption. The results support The Feedback hypothesis.

Table 1 - Continued

Bazarcheh Shabestari (2018),	VEC Model, VAR, Granger Causality and Co-integration" Test, 1970 and 2016 Sweden	Energy is one of the determinants of GDP. Therefore, the implementation of policies to reduce CO_2 slows GDP. There is a bidirectional causality between CO_2 and energy consumption in the short-run. Energy consumption and GDP move in the same direction. In the long-term, there is a bi-directional relationship between energy consumption, CO_2 emissions and economic growth." The study supports the feedback hypothesis.

When the literature is examined, it is seen that the results show that growth and energy consumption affect CO2 emissions.

Econometric Analysis

Variables, Data Set, Model and Methodology

In the econometric analysis, "carbon dioxide emissions (kt)" was specified as the dependent variable while "economic growth (current USD)" and "Non-renewable energy consumption (TJ) were determined as the independent variables. The data set belongs to variables that covers 25 years between 1990-2015 was obtained from "the World Bank's Sustainable Energy database". NREC data was calculated by taking the difference between total final energy consumption data and renewable energy consumption data. Renewable energy consumption includes all renewable resources such as "hydro, solid biofuels, wind, solar, liquid biofuels, biogas, geothermal, marine and waste". Hereunder the functional expression of the model can be written as follows;

CO2 = f (NREC, Gross Domestic Product) (1)

CO2= f (NREC, GDP)

CO2 : CO2 (kt)

NREC : Nor-Renewable energy consumption (TJ)

GDP : GDP (current US$),

The relationship between CO2, GDP and NREC can be statistically stated as in Eq.(2)

$$CO_2 = a + \beta_1 NREC_t + \beta_2 GDP_t + u_{it} \quad (2)$$

where a the coefficient represents the fixed term. β coefficients indicate the relationship between the dependent variable and the independent variables. u_it is the error term.

Equation 2 is a static model. Considering the lag-length values of the series (i), the system is injected with dynamic elements. In this way, the dynamic equation can be written in the VAR system as follows.

$$dCO2_t = a_{11} + \sum_{i=0}^{n} \beta_{1i} dNREC_{t-i} + \sum_{i=0}^{k} \beta_{2i} d\,GDP_{t-i} + \sum_{i=0}^{l} \beta_{3i} dCO2_{t-i} + u_{1t}$$

$$dNREC_t = a_{21} + \sum_{i=0}^{n} \beta_{4i} dGDP_{t-i} + \sum_{i=0}^{k} \beta_{5i} dCO2_{t-i} + \sum_{i=0}^{l} \beta_{6i} dNREC_{t-i} + +u_{2t}$$

$$dGDP_t = a_{31} + \sum_{i=0}^{n} \beta_{7i} dGDP_{t-i} + \sum_{i=0}^{k} \beta_{8i} dNREC_{t-i} + \sum_{i=0}^{l} \beta_{9i} dCO2_{t-i} + u_{3t}$$

Where, d symbolize the first difference, u_1,u_2 and u_3 are the error correction terms. k, l and n are the number of lag-lengths.

In the study, primarily the regression equation will be established. The significance of the variables and the model will be tested. Since the series are not stationary, the analysis will lead to incorrect results. Therefore, the unit test will be employed to investigate the stationary of the series. After determining the integration level of the series, the short-run relationship between variables will be analyzed with the help of co-integration analysis. Johansen cointegration test will be performed to show the long-run relationship between variables. To reveal the short-run causality relationship, VAR Granger Causality Analysis will be conducted.

Variables, Data Set, Model and Methodology

Table 1 shows the statistics of the econometric model which was stated in Equation 2. Those statistics will be examined to reveal, whether the independent variables and model are meaningful.

CO2 the carbon dioxide emission is the dependent variable. "Economic growth" which is represented with GDP per capita and "Non-renewable energy consumption" presented by NREC are the independent variables of the model. The model was tested with the E-views 8.0 program using the LS Least Squares (NLS and ARMA) method and the results are summarized in Table 2. The model covers 26 observations between 1990-2015.

Table 2. *LS Estimation Results*

$CO_2 = a + \beta_1 NREC_{it} + \beta_2 GDP_{it} + u_{it}$	*Coefficient*	*Std. Error*	*t-Statistic*	*Prob.*
GDP	*5.166068*	*1.487379*	*3.473269*	*0.0021*
NREC	*0.073173*	*0.008806*	*8.309246*	*0.0000*
C	*51802.39*	*9150.933*	*5.660886*	*0.0000*
R-squared	0.987288	Mean dependent var		233501.9
Adjusted R-squared	0.986183	S.D. dependent var		64402.29
S.E. of regression	7570.179	Akaike info criterion		20.80999
Sum squared resid	1.32E+09	Schwarz criterion		20.95515
Log-likelihood	-267.5298	Hannan-Quinn criter		20.85179
F-statistic	893.1912	Durbin-Watson sta"		0.988221
Prob(F-statistic)	0.000000			

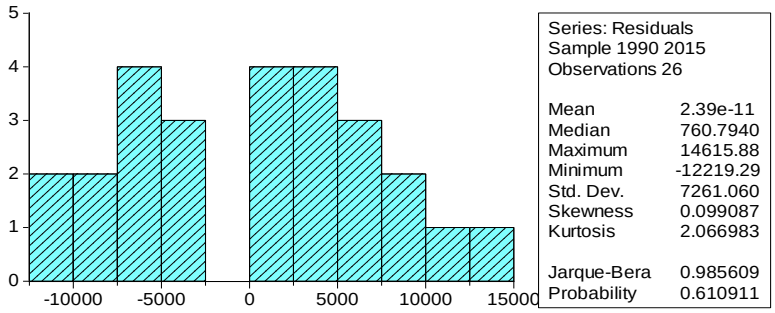
All variables of the model are significant due to the probability values of GDP, NREC, and constant (C) are lower than 0,05 the significance level. R2 values are significantly high at 0.98 level. The probability value of F-statistic is less than 5%. In this case, the hypothesis H0 is rejected, and the alternative hypothesis HA is accepted. In other words, there is no multiple linear correlations in the model, and so the model is significant.

However, once the "Variance Inflation Factors" (VIF) were examined, it is seen that all the centred VIF at the level are higher than 5. This is the indication of Multicollinearity that shows the multiple linear relationships between dependent variables. The results of the VIF test are summarized in Table 3.

Table 3. *Variance Inflation Factor*

	Level			*First Difference*		
Variables	*Coefficient Variance*	*Uncentered VIF*	*Centered VIF*	*Coefficient Variance*	*Uncentered VIF*	*Centered VIF*
GDP	2.212297	54.87778	13.07964	3.183982	1.310296	1.157760*
NREC	7.76E-05	157.7175	13.07964	0.000172	1.630269	1.157760*
C	83739574	37.99197	NA	3196771.	1.426841	NA

In order to solve the multicollinearity problem, the first differences of the series are taken, and the model is re-established again. The results of Centered VIF values, at first deference level, are equal to 1.157760. These values are between 1 and 5 and indicate that there is no multiple linear correlations in the model. In addition, Histogram Normality test results, which is seen in Graph 1, show that the Jarque-Bera Test probability value is greater than 0.05, so the distribution is normal at first difference level and therefore support the result of no multiple linear correlations. Both results indicate that the model is significant.



Graph 1. *Histogram Normality*

It is necessary to determine the existence of spurious regression even though R2 values high and the values of "f-statistics and t statistics" are below its confidence limit. To identify whether superious regression is present, the stationary of the error term is tested. If the error term is stationary at the level, this means residual doses not have unit root and therefore there is no "spurious regression".

Table 4. *Residual Series Test*

H0: Residual has a unit root	Intercept		H0: Residual has a unit root	Trend & Intercept	
ADF test statistic	t-Stat	Prob.(1)	ADF test statistic	t-Stat	Prob.(1)
	-4.853287	0.0011		-6.834018	0.0001
Test critical values	1%	-3.808546	"Test critical values"	1%	-4.498307
	5%	-3.020686		5%	-3.658446
	10%	-2.650413		10%	-3.268973

Not: *MacKinnon (1996) one-sided p-values. Exogenous: Constant, Linear Trend. Lag Length: 5 (Automatic - based on SIC, maxlag=5)

When we examine the Table 4, the ADF test statistics and probability values for both intercept and also intercept and trend are less than 0.05. Therefore the hypothesis of H0 is rejected and "residual has no unit root" the alternative hypothesis is accepted. Consequently, there is no spurious regression.

Unit Root Test

Unit root tests are performed to "assess the degree of the integration of the variables". In other words, unit root tests are employed to understand whether the time series are stationary or not. In this analysis, the stationary of the series will be tested by using the "Augmented Dickey-Fuller Unit Root Test (ADF-Test)".

The probability and the unit root t-statistic values at the level of the ADF test are given in Table 3. To assess the stationary of the series, the probability values are checked. If the probability value is less than 0,05, this indicates that the series does not have a unit root and so are stationary. The same result can be achieved by controlling the ADF t-statistic values as well.

Table 5. *ADF – Test*

	Level				*First Difference*			
	Intercept		*Trend&Intercept*		*Intercept*		*Trend&Intercept*	
GDP	ADF t-Stat.	Prob.(1)	ADF t-Stat	Prob.(1)	ADF t-Stat	Prob.(1)	ADF t-Stat	Prob.(1)
CO2	-0.386930	0.5071	-2.126525	0.5071	-4.678910	0.0011*	-4.531145	0.0074*
NRNWE	-0.350285	0.2806	-2.606258	0.2806	-5.260507	0.0003*	-5.075241	0.0023*
	0.234115	0.0679	-3.445911	0.0679	-5.275359	0.0003*	-5.295658	0.0015*

* shows that coefficients are statistically significant at the 1% significance level.
(1) MacKinnon (1996) one-sided p-values

When the ADF results in Table 5 are examined, it is seen that all series are significantly higher than 0,05 and therefore are not stationary at level. However, when the first differences of the series are taken,

they become stationary at 1% significance level. In other words, all the series belong to CO2, GDP, NREC are stationary at the first difference level. The fact that all series are I (1) indicates that they can be co-integrated. Therefore, it will be examined whether there is a co-integration between series under the headline of Cointegration Analysis.

Cointegration Analysis

Co-integration analysis help to determine whether there is a linear combination of series. In other words, the existence of the long-run relationship between variables is confirmed by employing the co-integration analysis.

The co-integration is to establish an equilibrium relationship between the non-stationary variables in the long run. Therefore, cointegration analysis is an approach used in estimating parameters and indicating long-run or equilibrium relationship between non-stationary variables. If there is no long-run relationship between variables, the predicted regression model will be a "spurious regression". In the case of spurious regression, the parameters of the predicted model are generally statistically significant and therefore could give good results with a high R2 value. In order to avoid spurious regression, the series is transformed into stationary by taking the difference of series. (Sevüktekin and Çınar, 2014: 592)

Before passing to Johansen (1995) analysis, the VAR model should be estimated and the appropriate time lags number should be determined. Table 6 the VAR Lag Order Selection Criteria shows the time lags results according to five different criteria.

Table 6. *VAR Lag Order Selection Criteria*

Endogenous variables: dCO2, dGDP, dNREC						
Lag	*LogL*	*LR*	*FPE*	*AIC*	*SC*	*HQ*
0	-636.2020	NA*	1.16e+24	63.92020	64.06956*	63.94936
1	-631.8148	7.019656	1.86e+24	64.38148	64.97892	64.49810
2	-627.5010	5.607947	3.21e+24	64.85010	65.89561	65.05419
3	-617.7727	9.728236	3.66e+24	64.77727	66.27087	65.06884
4	-606.0786	8.185847	4.41e+24	64.50786	66.44954	64.88690
5	**-572.0053**	**13.62932**	**1.02e+24***	**62.00053***	**64.39029**	**62.46704***

Note: * indicates lag order selected by the criterion. LR: sequentially modified LR test statistic (each test at 5% level); FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion.

According to the VAR Lag Order Selection Criteria Analysis seen in Table 5, four of five criteria (FPE, AIC, SC, HQ) shows that five is the appropriate time lags for the VAR model established.

Table 7. *Johansen Co-integration Test*

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	*Eigenvalue*	*Trace Statistic*	*(0.05) Critical Value*	*Prob.***
None *	0.684727	42.44073	29.79707	0.0011
At most 1 *	0.346483	15.89142	15.49471	0.0436
At most 2 *	0.233212	6.107546	3.841466	0.0135
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	*Eigenvalue*	**Max-Eigen Statistic**	*(0.05) Critical Value*	*Prob.***
None *	0.684727	26.54930	21.13162	0.0078
At most 1 *	0.346483	9.783878	14.26460	0.2265
At most 2 *	0.233212	6.107546	3.841466	0.0135

Note: * denotes rejection of the hypothesis at the 0.05 level and **MacKinnon-Haug-Michelis (1999) p-values.

"Johansen co-integration test" was employed to determine the existence of a long-run relationship between the variables. Based on test results seen on Table 7, all of the values of trace test statistics are higher than their critical values at 5% significance level. Similarly, Maximum Eigenvalue test statistic values of "None" and "At most 2" are higher than their critical values at 5% significance level. Accordingly Max-eigenvalue test indicates one cointegrating equation at the 0.05 level, and Max-eigenvalue test indicates one cointegrating equation at the 0.05 level. There is a co-integrated vector between the variables. As a result, there is a relationship between CO2 and GDP and NREC in the long run.

Short-run Causality Analysis

VAR Model is a system of equations in which each endogenous variable in an equation system includes both its own and the lagged values of other variables in the system. The field of use of VAR models is to establish interactions between variables and to pre-report for the future, rather than policy-making. In other words, the purpose of the VAR model is not to determine the parameter estimates, but to reveal the mutual effect between the variables (Sevüktekin and Çınar, 2014: 496).

With this regard, to determine the presence and direction of the short-run relationship between the variables Granger Causality Test was implemented below.

Table 8. *VAR Granger Causality Test Results*

Dependent variable: dCO2			
Excluded	Chi-sq	df	Prob.
*d*NREC	11.98230*	5	**0.0350**
*d*GDP	6.311703	5	0.2771
All	15.40566	10	0.1180
Dependent variable: dNREC			
Excluded	Chi-sq	df	Prob.
dCO$_2$	2.449511	5	0.7841
*d*GDP	2.601753	5	0.7611
All	5.154548	10	0.8806
Dependent variable: dGDP			
Excluded	Chi-sq	df	Prob.
dCO$_2$	6.727406	5	0.2417
*d*NREC	5.510561	5	0.3568
All	7.639294	10	0.6640

Note: * it is statistically significant at the 5% significance level.

Table 8 shows the VAR Granger causality test results. Based on the results of the model that CO2 is dependent variable and NREC and GDP are independent variables, the probability value of NREC is less than 5%, and Chi-sq (F statistics) value is high. Except for NREC variable, none of the variable is significant in any of VAR model. Therefore NREC is the only variable causes an increase in CO2. There is a unidirectional relationship from NREC to CO2. In the short run, there is not a causality between GDP and CO2.

Variance Decomposition

Table 9 shows the variance decomposition results for eight periods. In the second period, 13.8% of the CO2 is originated from 13,8% NREC, 2% GDP and 84% itself. However, in the 8th period, it was observed that 44% of CO2 were caused by NREC and 12% by GDP.

Table 9. *Variance Decomposition of CO2*

Period	*S.E.*	*dCO2*	*GDP*	*NREC*
1	12702.91	100.0000	0.000000	0.000000
2	18972.40	84.05742	2.109947	13.83264
3	26909.64	91.38088	1.324461	7.294659
4	30404.24	71.61637	11.25361	17.13002
5	40185.60	82.43790	6.742826	10.81928
6	48786.95	55.96376	24.16449	19.87175
7	62670.87	55.28772	14.78850	29.92377
8	92249.79	43.06368	12.61782	44.31850

Cholesky Ordering: dCO2, dGDP, dNREC

Conclusion

In this study, the relationship between CO2, GDP and NREC in Turkey was investigated by using the yearly data between 1990-2015. The study was initiated with the establishment of a regression equation in which CO2 was determined as dependent variables and GDP and NREC as independent variables

"Johansen Co-integration" and " VAR Granger Causality tests were employed to reveal the relationship betwee GDP, NREC and CO2. Test results indicated that NREC is the only variable that causes an increase in CO2. There is a unidirectional relationship from NREC to CO2 in the short-run. This result supports the "neutrality hypothesis" argues that there is not a direct relationship between energy consumption and GDP. Since it is revealed a unidirectional causality from NREC to CO2, measures regarding energy consumption will not have a negative impact on economic growth while reducing carbon dioxide emissions.

The variance decomposition test result, in the second period, shows that 13.8% of the CO2 is originated from NREC, from 2% GDP and from 84% itself. However, in the 8th period, it was observed that 44% of CO2 stem from NREC. Moreover the results did not support "Environmental Kuznet's Curve Hypotheses". However, the reason for this may be that Turkey's income levels have not yet reached that mentioned in the Kuznet's Hypothesis. To reduce the CO2 emission it is needed to be use renewable energy sources instead of non-renewable.

Ethical Declaration

During the writing process of this study titled "The Relationship between CO2 Emission, Non-Renewable Energy Consumption and Economic Growth: A Case of Turkey", scientific, ethical and citation rules were followed; no falsification was made on the collected data and this study was not sent to any other academic publisher for evaluation.

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TÜRKÇE GENİŞ ÖZET

Günümüzde küresel ısınma, tüm ülkelerin en önemli sorunlarından biri haline gelmiştir. Dünya ekonomisindeki gelişmeler ve iktisadi büyüme (GSYH) çevreyi önemli ölçüde etkilemektedir. Artan ekonomik faaliyetlerin bir sonucu olarak ortaya çıkan negatif dışsallıkları önleme için gerekli önlemlerin alınmaması, CO2 salınımının artması küresel ısınmanın en önemli nedenidir. Sanayileşme sonucunda, fosil yakıt kullanımındaki artışa paralel olarak CO2 hızla arttığı görülmektedir. Dünyadaki bu gelişmelere paralel olarak, Türkiye'de de enerji talebi artmaktadır. Bu bağlamda bu çalışmada, 1990-2015 yılları arasında Türkiye'nin "yenilenemeyen enerji tüketimi (NREC)", "iktisadi büyüme (GSYH)" ve "karbondioksit salınımı (CO2)" arasındaki nedensellik analiz edilmiştir.

İnovasyon ile ekonomik büyüme arasındaki ilişkileri araştıran teoriler Joseph Schumpeter ile başlar. Klasiklerin aksine, Schumpeter iktisadi büyümenin ana nedenini sermaye birikimi ile değil, inovasyon, yaratıcılık ve girişimcilik ile ilişkilendirmiş inovatör-girişimci kavramına önem vermiştir. GSYH ve yenilenebilir enerji arasındaki ilişki, enerji ihtiyacının, yeni teknik ve farklı kaynaklarla karşılanabileceği düşünülerek, Schumpeter'in yaklaşımı bağlamında incelenebilir (Śledzik, 2015).

Kuznets, GSYH ile çevresel değişimler arasındaki ilişkiyi inceleyen ve "Çevresel Kuznets Eğrisi" olarak isimlendirilen hipotezinde; gelişmişlik düzeyine bağlı olarak, iktisadi büyüme başlangıçta çevresel olumsuzluklara neden olsa da, belirli bir gelir seviyesinden sonra bu süreç tersine döneceğini öne sürmektedir (Stern, 2004). NREC, CO2 ve GSYH arasındaki ilişki, Çevresel Kuznets hipotezi bağlamında düşünülebilir (Ranis, 2004).

Walt Rostow tarafından geliştirilen büyüme teorisinde, iktisadi büyüme, sermaye birikimime ve kalkınmanın beş aşamasına dayanmaktadır. Bu aşamalardan ilki tarımsal üretime dayalı geleneksel toplumdur. Bu safha sınırlı sermaye birikimi ve düşük işgücü verimliliği ile karakterize edilir. İkinci safha, tarımda mekanizasyonu ile karakterize edilir. Ancak bu safhada da tasarrufların düşük olması nedeniyle yatırımlar sınırlıdır. Bu nedenle finansmanda dış yardımlar önemli bir yere sahiptir. Üçüncü aşama, tasarrufların ve yatırımların dolaysı ile üretimin arttığı kalkış safhasıdır. Altyapı yatırımlarının arttığı, iktisadi, sosyal ve politik kurumların geliştiği bir süreçtir. Ancak, dış finansman dördüncü aşamayı geçiş için hayati önem taşımaktadır. Rostow'un modelinde fakir ülkeler için en önemli sorun kalkış aşamasıdır. Zira yoksul ülkeler yeterli sermaye birikimini sağlayamadıklarında fasit bir döngüye girebilmektedir. Bu durumda ülke içi tasarrufların artmaması nedeniyle dış destek ihtiyacı ortadan kalkmayacaktır. Diğer yandan tarımdan sanayiye geçiş, GSYH'nın ülke geneline yayılmasına neden olacaktır. Beşinci aşama "toplu tüketim çağı" olarak adlandırılan safhadır. 1971'de Rostow, altıncı aşama olarak, mal ve hizmetlerin kalitesinin sürekli iyileştirerek iktisadi büyümenin sağlanabileceğini ileri sürdüğü "kalite safhasını" ilave etmiştir. Bu safhada Rostow ileri teknoloji ve Ar-Ge'yi vurgu yapmıştır. Yeni ve ileri teknoloji olarak kabul edilen yenilenebilir enerji üretim tesislerinin kurulması ve Ar - Ge faaliyetlerinin iktisadi büyümeye etkisi bu teori kapsamında değerlendirilebilmektedir (Piętak, 2014, s. 49-51).

GSYİH teorileri, içsel büyüme teorileri ve dışsal büyüme teorileri iki ayrı grupta incelendiği görülmektedir. Dışsal büyüme teorisi olarak Harman Domar Modeli, GSYH'nın "ulusal tasarruf (S)" ve "sermaye üretkenliğinin" bir fonksiyonu olduğunu iddia eder. Sermaye yatırımlarının üretkenliği "sermaye-çıktı oranı (COR)" ile ölçülebilir. Bu bağlamda, GSYH, ΔGSYH = S / COR olarak ifade edilebilir. Dolayısıyla, "ulusal tasarrufları (S)" artırarak ve "sermaye-çıktı oranını (COR)" düşürerek GSYH yükseltilebilir. Kısa dönemde tüketim harcamalarını azaltılması ve yatırımların arttırılması uzun dönemde GSYH'nın artmasına neden olacaktır. Harrod Domar modelinde, enerji üretim faktörü olarak görüldüğü için GSYİH ile enerji tüketimi arasında bir bağlantı olduğu varsayılmaktadır (Gökçe, 2007, s. 11). Klasik yaklaşım çerçevesinde ortaya çıkan Solow ve Swan modelinde, enerji kaynaklarındaki yetersizlikler büyüme oranı artışını olumsuz etkilemektedir. Başka bir ifade ile enerji kaynaklarının bol ve ulaşılabilir olması durumda enerji, ekonomik büyüme açısından görece daha az sınırlayıcı bir etken konumundadır (Korkmaz ve Develi, 2012, s. 6).

NREC ve GSYH arasındaki ilişki içsel büyüme modelleri ile de açıklanmaktadır. Romer ve Lucas tarafından geliştirilen modelde büyümeyi sağlayan temel faktörler nüfus artışı, teknolojik gelişme, beşeri sermaye birikimi ve kamunun ekonomik aktivite düzeyini etkilemedeki rolüdür (Özel, 2012, s. 64-68). Bilgi birikimi, beşeri sermaye, AR-GE faaliyetleri gibi ülkelerin büyüme oranlarını açıklayan faktörler, ülkelerin gelişmişlik düzeylerini etkilemektedir. Bu bağlamada düşük maliyetle enerji temin edilmesi ve üretimde verimli şekilde kullanılması ekonomik büyümenin artışına olanak sağlayacaktır (Mucuk ve Uysal, 2009, s.106). Neoklasik görüşe tabi olan Hamilton ve Burbridge'ın iktisadi büyümeye ilişkin çalışmalarında enerji

faktörüne yer vermiştir. Bu teoriye göre endüstriyel anlamda kullanılan enerji miktarı arttıkça toplam hasılanın artacağı, beraberinde de ekonomik büyümenin artacağı kabul edilmektedir (Aytaç, 2010, s. 483).

Enerji ile ekonomik büyüme arasındaki ilişki büyüme, korumacılık, geri besleme ve yansızlık hipotezleri olmak üzere dört açıdan incelenmektedir. Büyüme hipotezine göre; enerji kullanımında olumlu gelişmeler iktisadi büyümeyi buna paralel olarak olumlu yönde etkilerken, tersi durumun ise büyümeyi olumsuz etkiler. Korumacılık hipotezi; enerji tüketimini sınırlandıran ülkeler enerjiye bağımlı değilse, iktisadi büyümenin bundan önemli ölçüde etkilenmeyeceğini iler sürer. Geri besleme hipotezi; enerji tüketimi ile ekonomik büyüme arasında var olan çift yönlü nedensellik nedeni ile bunların birbirini beslediğini savunmaktadır. Yansızlık hipotezi ise; enerji tüketimi ile ekonomik büyüme arasında doğrudan bir bağlantı olmadığını ifade etmektedir (Öncel vd., 2017).

Bu çalışmanın uygulama kısmında karbondioksit salınımı (CO2), yenilenemeyen enerji tüketimi (NREC) ve iktisadi büyüme (GDP) arasındaki uzun ve kısa dönemdeki ilişkileri incelenmiştir. Analiz, Türkiye için 1990-2015 arasındaki 25 yılı kapsamaktadır. Çalışmaya, CO2'nin bağımlı değişken, GSYH ve NREC ise bağımsız değişkenler olduğu regresyon denkleminin kurulması ile başlanmıştır. Serilerin durağan olmaları nedensellik analizlerinde doğru sonuçlara ulaşmak için önem arz etmektedir. Bu amaçla ADF birim kök testi ile serilerin durağanlıkları sınanmış ve seriler seviyede durağan değilken birinci sıra farkları alındığında durağan hale geldiği görülmüştür. Modelin anlamlı olup olmadığını test etmek için VIF (varyans büyütme faktörü) Testi, Histogramı Normallik Testi, ve kalıntıların durağan olup olmadıkları sınanmış ve sonuç olarak sahte regresyon ve çoklu doğrusal bağıntı sorunun olmadığı soncuna ulaşılmıştır.

Serilerin entegrasyon seviyelerinin I(1) olması nedeniyle aralarındaki uzun dönemli eşbütünleşme ilişkisinin varlığı "Johansen Eşbütünleşme Testi" ile sınanmış ve seriler arasında uzun dönemli bir ilişki olduğu sonucuna varılmıştır. Değişkenler arasındaki kısa dönemli nedensellik analizi "Granger Nedensellik Testi" ile sınanmıştır. Buna göre kısa dönemde yenilenemeyen enerji tüketiminden, CO2 salınıma doğru tek yönlü pozitif bir ilişki olduğu ortaya konmuştur. Kısa dönemde CO2 salınımını etkileyen tek değişken yenilenemeyen enerji tüketimidir. Bu sonuç, enerji tüketimi ile ekonomik büyüme arasında doğrudan bir ilişki olmadığını öne süren "Tarafsızlık Hipotezini" desteklemektedir. Ancak yenilenemeyen enerji tüketiminden karbondioksit salınıma doğru tek yönlü ilişki tespit edildiğinden, bu çalışmanın sonuçlarına göre enerji tüketimi ile ilgili alınacak tedbirler karbondioksit salınımını azaltırken, iktisadi büyüme üzerinde olumsuz bir etki doğurmayacaktır. Ayrıca, sonuçlar "Çevresel Kuznets Eğrisi Hipotezlerini" desteklememektedir. Ancak bu durum, Türkiye'nin Kuznets'in hipotezinde belirtilen eşik gelir seviyesine henüz ulaşmamış olmasından kaynaklandığı düşünülmektedir.