JLECON

Volume / Cilt: 8, Issue / Sayı: 4, 2021, pp. 513-521
E - ISSN: 2148-4139
URL: https://www.journals.gen.tr/jlecon
DOI: https://doi.org/10.15637/jlecon.8.4.10

Received / Geliş: 18.09.2021
Acccepted / Kabul: 17.10.2021

RESEARCH ARTICLE / ARAŞTIRMA MAKALESİ

Analysis of the relationship between innovation, CO2 emission and renewable energy in Turkey*

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Abstract

Due to rapid technological development and increase in economic activities, environmental problems such as global warming and climate change, CO2 emission, environmental pollution are among significant global issues. In recent years, Eco-innovations, which are intended to benefit the environment and contribute to environmental sustainability, bring energy by saving technology, adding a new dimension to the concept of innovation as well as bringing its environmentalist face to the fore. In this study, the relationship between innovation, CO2 emissions and renewable energy for the 1990-2019 period for Turkey was examined and analyzed with Bayer-Hanck (2012) cointegration test together with Toda-Yamamoto (1995) and Hacker-Hatemi-J (2006) causality tests. According to Bayer-Hanck (2012) cointegration test, it was concluded that the variables are cointegrated in the long run. In line with the overlapping findings of the causality analyses of Toda Yamamoto (1995) and Hacker-Hatemi-J (2006), it was concluded that there is a one-way causality relationship from CO2 emissions to renewable energy consumption.

Keywords: Innovation, Co2 emissions, renewable energy, causality test.

JEL codes: Q20, O31, O44.

*This article was presented as a summary at the 3rd International Congress of Creative and Innovative Approaches, Pandemic Process and Innovation, 9-11 June 2021, https://ratingacademy.com/iccia/.

Citation/Atıf: İNANÇLI, S. & TORUSDAĞ, M., (2021). Analysis of the relationship between innovation, CO2 emission and renewable energy in Turkey. *Journal of Life Economics*. 8(4): 513-521, DOI: 10.15637/jlecon.8.4.10

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1. INTRODUCTION

Excessive energy consumption reduces the environmental quality and increases the CO2 emission rate (Apergis and Öztürk, 2015). Excessive use of energy supply increases the economic growth rate and CO2 emission of countries (Canbay, 2019: 141). Compared to other pollutants, CO2 emission is one of the indicators that causes more than 70% of the emission polluting environment (Khattak et al., 2020: 13869). Despite meeting increasing energy demand, achieving sustainable environment standards in the increase of CO2 emissions requires high environmental technology. This necessitates increasing alternative energy investment and production (Inançlı and Aki, 2020; 554-557).

In the 1990s, preference for renewable energy sources increased as a result of the increase in environmental awareness. Renewable energy sources that do not release greenhouse gases into the atmosphere are called clean energy (Caglar and Mert, 2017: 22). Increasing R&D activities such as carbon capture and storage and clean coal technologies are carried out to improve renewable clean energy investment and production in order to reduce the damage caused by fossil energy consumption to the environment due to carbon emissions (Coban and Sahbaz Kilinc, 2015: 196).

Today, the concept of commercial innovation and value-creating innovation takes green/ecological/environmental/sustainability dimensions into account the Chen et al. (2006) define green innovation as energy saving, reducing and preventing environmental pollution and recycling waste (Yigit, 2014: 254).

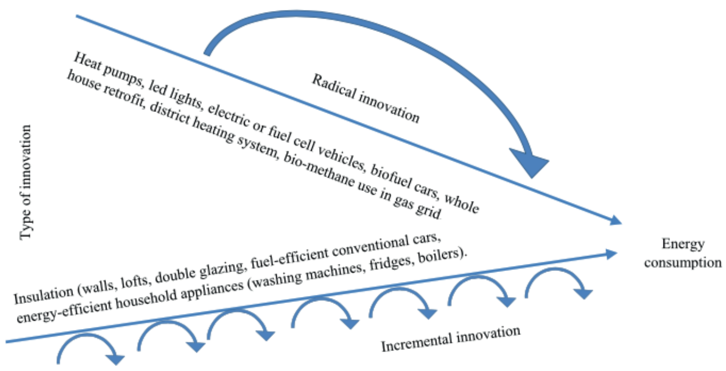
In recent years, renewable energy technologies related to energy and technology.have come to the fore. Renewable energy sources and supply depend on the economic, social and political developments and situations of the countries. Countries are developing their R&D activities in this direction. The perspectives of countries on technological development and energy security are determined by taking the share they allocate from GDP for energy-related R&D into account. In addition, it is prominent to reduce the increasing energy costs in R&D activities and in the use of new technologies. While renewable energy has a myriad of advantages such as minimizing environmental damage, reducing the greenhouse gas effect, preventing erosion, ensuring energy supply security and creating new employment opportunities, it also has certain disadvantages including low financing opportunities, high fixed investment costs and insufficient infrastructure for production (Bayramoglu, 2018). Renewable energy is affected by many internal and external factors. While external factor contain international economic structure, fossil fuel prices, low carbon use, and so fort internal factors include technological innovations, the development of renewable energy and its becoming a global energy model, and so on (Geng and Ji, 2016: 218). In this study, the relationship between innovation, environment (CO2 emissions) and renewable energy in Turkey is empirically analyzed for the period 1990-2019.

2. THE RELATIONSHIP BETWEEN INNOVATION, ENVIRONMENT (CO2 EMISSION) AND RENEWABLE ENERGY

Energy is a strategic input for the rapid development of an economy. Population growth, improvement in living conditions, developments in production and increase in economic competition affect energy demand. The increase in global energy consumption has increased the use of fossil fuels, which in turn has increased CO2 emissions, causing climate change and environmental degradation. These negative effects forced governments to take measures and caused countries to sign the Kyoto Protocol agreement in 2005 in order to reduce greenhouse gas emissions and put it into effect. In addition, the European Union (EU) commission has started to provide financing in order to reduce the use of fossil fuels, increase energy efficiency and provide new technological developments, especially renewable energy. In addition to environmental problems, energy dependence of economies that grow based on fossil fuel consumption causes uncertainty in energy supply (Inançlı and Aki, 2020; 553). In Addition, the the deterioration in the energy supply-demand balance also affects the economy negatively (Qayyum et al., 2021: 1, 2).

The inability to reduce the use of fossil energy resources such as Oil, Natural Gas, Coal, and the fluctuations in the direction of increase in oil prices caused energy crises and global environmental problems in some periods. CO2 emissions, one of the main sources of global warming (Stern, 2006), climate change et al. It also constitutes the main source of environmental problems (Wuebbles et al., 2002). Since the increase in the use of renewable energy sources such as wood, hydro, solar, marine, wind, geothermal, biomass and hydrogen energy reduces CO2 emissions (Chiu and Chang, 2009), it eliminates the negative effects on the environment. In addition, it allows to reduce foreign dependency in energy and to reduce foreign exchange expenses (Kumbur et al., 2015) and balance of payments deficits arising from energy imports.

Figure 1. Innovation and Energy Consumption Diagram

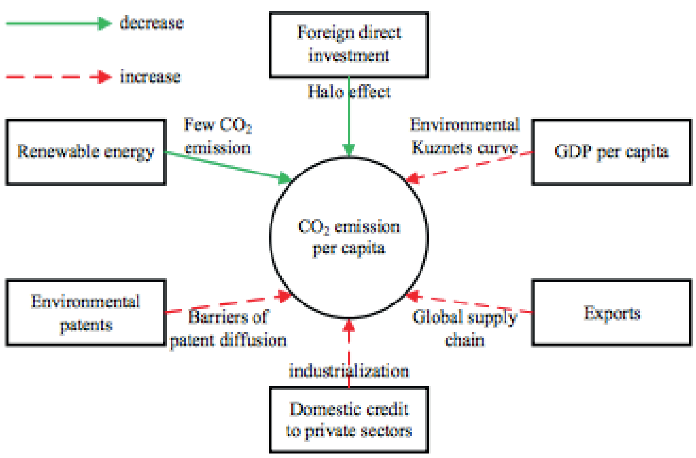


Source: Assi et al., 2021: 692.

On the other hand, in addition to economic growth, the increase in energy consumption affects the level of financial development and urbanization and CO2 emissions. Especially in developing countries, CO2 emissions are increasing due to industrialization and consumption of fossil fuels. This further increases the demand for fossil energy sources and forces countries to turn to alternative energy sources. Dependence on fossil energy sources and increase in consumption cause environmental degradation (Lau et al., 2012). It is thought that renewable and nuclear energy sources, which are used as alternative energy sources to fossil fuels due to global warming, also provide solutions to energy security and climate change problems (Menyah and Wolde-Rufael, 2010). Many countries are turning to renewable energy sources in order not to be affected by the increase in oil prices and to reduce energy dependence and environmental problems (Boluk and Mert, 2014). The production and consumption of renewable energy sources is accepted as one of the most outstanding methods of reducing CO2 emissions (Pata, 2018: 770, 771).

According to Sadorsky (2009), an indicator of economic development in the energy economy literature is energy consumption (Bulut, 2017: 15416). For this, it is essential to use methods that provide technological innovation, save energy and reduce CO2 emissions. Lee and Min (2015). With eco-technological innovations, low-carbon and efficient use of traditional fossil energy is ensured, and it is possible to use renewable energy at low cost with technological innovation. Technological innovation for conventional fossil energy can reduce energy consumption and CO2 emissions by increasing energy efficiency. This can result in energy savings and emission reductions. High renewable energy, technological innovation can enable countries to achieve renewable energy demand at lower cost (Chen and Lei, 2018). Renewable energy is considered as the energy of the future because it has clean energy characteristics (Sadorsky, 2014). Therefore, the use of renewable energies can increase energy security and provide environmental balance (Irandoust, 2016). In this respect, minimizing the energy cost is accepted as an effective method in order to be a country with low carbon emissions (Lin and Zhu, 2019: 1506).

Figure 2. Relationships Between CO2 Emission and Six Factors impacts CO2 Emission



Source: Cheng et al., 2019: 23.

3. LITERATURE REVIEW

Concerns are increasing day by day to minimize carbon dioxide emission, which has become a global threat with increasing environmental pollution (Godil et al., 2021: 4). In the literature, it is seen that the results of renewable energy consumption in reducing CO2 emissions in developed countries are similar. Yii and Geetha (2017), in their study for Malaysia for the 1971-2013 period, found that there is causality between technological innovations, growth, energy consumption and energy prices and CO2 emissions, and that technological innovation reduces CO2 emissions in the short term. Coban and Sahbaz Kilinc (2015) The causality relationship between renewable energy consumption and carbon emissions for the period 1990-2012 in Turkey was examined. As a result, it was concluded that there is a one-way causality relationship between renewable energy consumption per capita and carbon emissions per capita. Baek (2016), Cheng et al. (2018), in their study for developed countries, concluded that renewable energy significantly reduces CO2 emissions in the USA and 28 EU countries, respectively. Two notable factors seem to be effective in doing so. The first factor is that innovation is crucial to reduce CO2 emissions in 28 OECD countries (Mensah et al., 2018), while the second factor is related to environmental patents and GDP has negative impacts on CO2 emissions in 28 EU countries (Cheng et al., 2018). The result obtained is not consistent with the results obtained regarding GDP. Godil et al. (2020), it has been concluded that economic growth, technological innovation and renewable energy play an active role in reducing CO2 emissions in the transportation sector in China for the period 1990-2018, the increase in renewable energy and innovation reduces CO2 emissions in the Transportation sector, but the increase in GDP in the Transportation sector increases the CO2 emissions.

According to Hattak et al. (2020) examined the relationship between Kuznets curve and innovation, renewable energy consumption and CO2 emissions (CO2e) using the CCEMG method in a study covering the period 1980-2016 for BRICS countries. The analysis findings show that, apart from Brazil, innovation activities do not increase CO2 emissions in China, India, Russia and South Africa, and renewable energy consumption reduces CO2 emissions in the BRICS countries Russia, India and China (excluding South Africa). It has been concluded that the EKC hypothesis is valid for other BRICS country economies except India and South Africa. In addition, there is a bidirectional causality relationship between innovation and CO2 emissions, innovation and GDP per capita, innovation and renewable energy consumption, and CO2 emissions and income variables.

4. DATA AND METHODOLOGY

In this study, it is aimed to examine the relationship between innovation, CO2 and renewable energy for Turkey's 1990-2019 period. In the study, the logarithmic function of innovation (the share of R&D expenditures in GDP) and CO2 emissions (lnCO2) data were utilized. While these two variables were obtained from the TUIK (Turkish Statistical Institute) database, the renewable energy consumption (total energy consumption %) variable was obtained from the 'data.worldbank.com' database. In the study, ADF (1970) unit root test, Bayer-Hanck (2012) cointegration test and Toda-Yamamoto (1995) and Hacker-Hatemi-J. (2006) causality tests were used and analyzes of the study were tested using Eviews 10.0, Stata 12.0 and Gauss 10.0 programs.

4.1. Analysis Findings

In time series analysis, it is important whether the series has a unit root or not. Unit root tests are used to test for stationarity. Since the Extended Dickey Fuller ADF unit root test is sensitive to the number of lags, it is also crucial to determine the appropriate lag length. Moreover, it is vital to include error terms in the model to eliminate autocorrelation. Akaike Information Criteria (AIC), Schwart Information Criteria (SIC), Hannan Quin (HQ) and lag length criteria, which are the corrected forms of these three criteria, are among the lag criteria in the literature (Akyuz, 2018).

In this study, ADF (1979, 1981) generalized unit root test will be applied. The regressions for the ADF unit root test are expressed in equations 1 and 2 (Yavuz, 2006: 164):

$$\Delta \mathrm{Y_t} = \alpha + \beta \mathrm{T} + \varphi y_{t-1} + \sum_{i=1}^{k} \delta_i \Delta y_{t-i} + u_t \quad (1)$$

$$\Delta \mathrm{Y_t} = \alpha + \varphi y_{t-1} + \sum_{i=1}^{k} \delta_i \Delta y_{t-i} + u_t \quad (2)$$

With Equations 1 and 2, the unit root existence is determined for the variable yt. Lagged difference terms are included in the model in order to free the error term from autocorrelation.

In Equation 1, the base model with the room root of yt is tested to see if the trend is stationary. In the equation 2, it is accepted that the yt preference is fundamental because of the basis and its avarage (Yavuz, 2006:164).

According to this;

H0: φ=0, The series is not stationary, the series has a unit root.

H1: φ<0, ADF test is applied with the hypotheses that the series is stationary and the series does not contain unit roots.

As seen in Table 1, while innovation (R&D), CO2 and

Table 1: ADF (1981) Unit Root Test

Variables	ADF Unit Root Test Results	
	Level I(0)	Differenced I(1)
Innovation	1.0908 (0.996)	-7.822** (0.000)
Co2	-0.661 (0.841)	-5.292** (0.000)
Renewable	-0.678 (0.836)	-5.024** (0.000)

Note: ***, **, * denote significance at 1%, 5% and 10% significance levels, respectively.

Table 2. Selection of Lag-Length

Lag	LogL	LR	FPE	AIC	SC	HQ
0	54.179	NA	5.19e-06	-3.655	-3.512	-3.612
1	**112.268**	**99.581***	**1.57e-07***	**-7.162***	**-6.591***	**-6.987***
2	120.268	11.999	1.73e-07	-7.090	-6.091	-6.785

* : Appropriate lag-length

renewable energy variables are not stationary at the level, when the first order differences of all three series are taken, it is seen that the series become stationary at the 5% significance level.

As seen in Table 2, LR, FPE, AIC, SC and HQ information criteria statistics were in the same direction and the appropriate lag length was determined as 1 according to the information criteria.

Bayer and Hanck (2012) Engle-Granger (1987), Johansen (1991), Boswijk (1994) and Banerjee et al. (1998), a new test statistic was obtained by combining Fisher type chi-square formula in equation 3, since it was a new and more significant cointegration test they applied.

If the calculated test statistic is greater than the critical values, it is decided that there is a cointegration relationship between the variables (Topal, 2018: 187):

$$EG-JOH-BO-BDM = -2\,[\ln(P_{EG}) + \ln(P_{JOH}) + \ln(P_{BO}) + \ln(P_{BDM})] \quad (3)$$

As the Fisher EG-J-Ba-Bo test statistic is greater than the critical value of Bayer and Hanck (2012), the Bayer-Hanck (2012) cointegration test result obtained from table 3 rejects the basic hypothesis stating that there is no cointegration relationship, and the alternative hypothesis stating that there is a cointegration relationship acceptable. In line with the cointegration test findings, it was concluded that the series are cointegrated in the long run for three different models where the renewable energy, CO2 emissions and innovation variables are taken as dependent variables, respectively.

In Toda Yamamoto (1995) causality analysis, it is possible to apply causality analyzes without the need for the existence of cointegration series of the same or different degrees. The modified Wald test (MWALD), developed by Toda-Yamamoto, can be applied wit-

Table 3: Bayer-Hanck (2012) Cointegration Tests Result

Model 1: Renewable = f(Co2, Innovation)				
Fisher Type Test Statistics, Bayer Hanck Test				
	Engle-Granger	**Johansen**	**Banerjee**	**Boswijk**
p-values	0.6401	0.002	0.038	0.0000
Test Statistics	-2.1895	30.283	-3.600	40.470
EG-J: 13.1308	10% critical value: 8.479			
EG-J-Ba-Bo: 74.8864	10% critical value: 16.444			

Model 2: Co2 = f(Renewable, Innovation)				
	Engle-Granger	**Johansen**	**Banerjee**	**Boswijk**
p-values	0.7019	0.0022	0.4059	0.0083
Test Statistics	-2.0597	30.283	-2.2796	19.103
Fisher Type Test Statistics, Bayer Hanck Test				
EG-J: 12.9465	10% ciritical value: 8.479			
EG-J-Ba-Bo: 24.3328	10% ciritical value: 16.444			

Model 3: Innovation = f(Co2, Renewable)				
Fisher Type Test Statistics, Bayer Hanck Test				
	Engle-Granger	**Johansen**	**Banerjee**	**Boswijk**
p-values	0.9345	0.0022	1.0000	0.0022
Test Statistics	-1.269	30.283	3.649	22.543
EG-J: 12.372	10% ciritical value: 8.479			
EG-J-Ba-Bo: 24.610	10% ciritical value: 16.444			

***, **, * indicate that the variables are stationary at 1%, 5% and 10% significance levels, respectively.

hout any pre-test as it is based on the standard asymptotic distribution. In the Toda-Yamamoto causality test (maximum degree of integration of the d series), the VAR (p+d) model is estimated. It is not necessary to test the existence of a cointegration relationship between non-stationary series and to estimate the VEC model (Caliskan, Karabacak, and Mecik, 2017: 50):

$$y_t = v + A_1 y_{t-1} + \cdots + A_p y_{t-p} + \cdots + A_{p+1} y_{t-p-d} + \mu \quad (4)$$

In Equation 4, y_t, k is the vector consisting of the variable k, v is a vector of constants, μ is the vector of error terms, and A is the parameters matrix. The obtained MWALD statistic has an asymptotic chi-square distribution with p degrees of freedom. The MWALD statistics based on the Hacker-Hatemi-J (2006) bootstrap distribution are taken into account in the analysis of small samples of the MWALD statistic with a standard chi-square distribution (Caliskan, Karabacak and Mecik, 2017: 50).

In order to apply the Toda-Yamamoto (1995) analysis expressed in Table 4, the appropriate lag length must first be determined. The appropriate lag length was determined as 1 according to the AIC, SBC, HQ information criteria. In line with the causality findings created by the estimated VAR (2) model, it has been estimated that CO2 emissions at the 5% significance level are the cause of renewable energy consumption.

In the Hacker-Hatemi (2006) causality test, which was developed based on the Toda-Yamamoto (1995) causality test, the bootstrap distribution is taken into account. The use of bootstrap simulation techniques developed by Efron (1979) in obtaining critical values allows to obtain more reliable critical values. It is an advantageous causality test in that it is not sensitive to the assumption of normality and time-varying volatility (Hacker-Hatemi-J, 2006: 1490-1492; Arı, 2016: 61, 62). Hatemi-J (HJC) information criterion was obtained from the average of Hatemi-J (2003), SIC and Hannan-Quinn (HQ) information criteria (Pata, 2018: 104):

$$\text{HJC} = \ln(|\widehat{\Omega}|+j\,(\frac{n^2 lnT + 2n^2 \ln(lnT)}{2T}), \qquad j=0.......,k \quad (5)$$

In Equation 5, $|\widehat{\Omega}|$ While j gives the variance-covariance matrix of the error terms of the estimated VAR model depending on the lag length, n represents the number of equations in the VAR model. T gives the number of observations. In the Hacker-Hatemi-J test, HJC is important for determining the appropriate lag length (Pata, 2018: 104). Hacker-Hatemi-J (2006) causality test analysis findings are given in Table 5.

According to the results of the Hacker-Hatemi-J (2006) bootstrap causality analysis expressed in Table 5, it was found that CO2 emission at the 1% significance level was the cause of renewable energy consumption. This result is supported by the results of the Toda-Yamamoto (1995) test. By applying both causality tests, it was concluded that there is a one-way causality relationship from Co2 emissions to renewable energy

Tablo 4. Toda Yamamoto Causality Results

Causality Direction	x^2 test statistic	df	Prob	**Decision**
Innovation → Co2	2.836	2	0.242	No causal relationship from innovation to CO2 emissions
Renewable Energy → Co2	8.178	2	0.610	There is no causal relationship from renewable energy consumption to CO2 emissions.
Co2 → Innovation	0.468	2	0.791	There is no causality from CO2 emissions to innovation
Co2 → Renewable Energy	5.742	2	0.056**	There is a causal relationship from CO2 emission to renewable energy consumption at the 5% significance level.
Innovation → Renewable Energy	2.828	2	0.243	There is no causal relationship from innovation to renewable energy
Renewable Energy → Innovation	0.249	2	0.882	There is no causal relationship from renewable energy to innovation

Note: ***, **, * indicate that the variables are stationary at 1%, 5% and 10% significance levels, respectively.

Table 5: Hacker- Hatemi-J (2006) Causality Analysis for Turkey

Causality Direction	**w-stat (MWald).**	**Critical Value**		
		%1 (***)	**%5 (**)**	**%10 (*)**
Renewable Energy → Innovation	0.870	9.427	5.109	3.424
Innovation → Renewable Energy	0.376	8.161	4.292	2.962
Co2 → Innovation	0.098	9.242	4.896	3.338
Innovation → Co2	0.000	8.380	4.551	3.020
Renewable Energy → Co2	0.016	8.463	4.518	3.023
Co2 → Renewable Energy	10.218***	7.987	4.129	2.877

Note: Bootstrap critical values are achieved in 10,000 cycles. The appropriate lag length was determined according to the AIC (Akaike Information Criterion). ***, **, * indicate that the variables are stationary at 1%, 5% and 10% significance levels, respectively. In the HH causality test, the bootstrap critical values were obtained with 1000 iterations, the lag length was determined by the Hatemi-J information criterion.

consumption in Turkey for the period examined according to the common result. This finding also coincides with the analysis findings of Coban and Sahbaz Kilinc (2017)'s studies on Turkey.

5. CONCLUSION

With the effect of factors such as globalization, increasing industrialization, urbanization and population growth, energy consumption increases due to the increase in the level of welfare. The increase in demand and dependence on the primary energy source increases the level of CO2 emissions and environmental pollution. In addition, issues of global warming and climate change have emerged due to the increase in carbon emissions. Countries are turning to renewable energy sources in order to minimize carbon dioxide emissions. Besides, energy-related R&D expenditures also play an important role within the scope of innovation activities.

In this study, the relationship between innovation, environment (CO2) and renewable energy for the period of 1990-2019 in Turkey, Bayer-Hanck (2012) cointegration test and Toda-Yamamoto (1995) and Hacker-Hatami-J. (2006) is estimated by causality tests. According to Bayer-Hanck (2012) cointegration test findings, renewable energy, CO2 emission and innovation variables were taken as dependent variables, respectively, and three different models were established. According to the analysis findings, it was concluded that the series are cointegrated in the long run. Also, Toda-Yamamoto (1995) and Hacker-Hatemi-J. (2006) determined that there is a one-way causality relationship from CO2 emission to renewable energy consumption in Turkey in line with the causality test findings. According to the results of this analysis, the necessity of turning to renewable energy sources arises due to the increase in fossil fuel consumption and carbon dioxide emissions in Turkey.

While countries use carbon storage-capture techniques to reduce carbon emissions, economic instruments such as carbon tax and carbon trade, and renewable energy investments and production are increasing with R&D and innovation activities carried out in the field of energy. In addition, there is an international consensus on carbon tax rates, which expresses the internalization of economic externalities through the price mechanism, within the scope of combating environmental pollution and global warming. The 'polluter pays' principle and the Pigouvian tax practice are effective.

According to the results of the analysis, it is seen that the development of low-carbon emission renewable energy sources and prioritizing innovative activities in the field of energy R&D, supporting them economically and allocating resources in this regard are necessary. Thus, environmental factors should also be taken into consideration in energy production and distribution. Fossil fuel consumption, which causes an increase in carbon emissions, should be reduced and it is inevitable to turn to renewable energy sources that cause the least damage to the environment.

REFERENCES

AKYUZ, H. (2018). Statistical Analysis of Climatic Variables with Vector Autoregression (VAR) Model. *International Journal of Engineering Research and Development*, 10(2), 183-192.

APERGIS, N. & OZTURK I. (2015). Testing Environmental Kuznets Curve Hypothesis in Asian Countries. *Ecological Indicators*, 52: 16–22.

ARI, A. (2016). Analysis of the Relationship between Economic Growth and Unemployment in Turkey: A New Cointegration Test. *Journal of Politics, Economics and Management Studies*, 4(2): 57-67.

ASSI A.F., ISIKSAL A.Z. & TURSOY, T. (2021). Renewable Energy Consumption, Financial Development, Environmental Pollution, and Innovations in the ASEAN + 3 Group: Evidence from (P-ARDL) Model. *Renewable Energy*, 165, 689-700.

BAYER, C. & HANCK, C. (2012). Combining Non-Cointegration Tests. *Journal of Time Series Analysis*, 34 (1), 83-95.

BAYRAMOGLU, T. (2018). Energy and Innovation, *Imaj Publishing House*, Ankara.

BANERJEE, A., DOLADO J. & MESTRE, R. (1998). Error-Correction Mechanism Tests for Cointegration in a Single-Equation Framework. *Journal of Time Series Analysis*, 19 (3), 267-283.

BAEK, J. (2016). Do Nuclear and Renewable Energy Improve the Environment? Empirical Evidence from the United States. *Ecol. Indic*. 66, 352-356.

BOLUK, G. & Mert, M. (2014). Fossil & Renewable Energy Consumption, GHGs (Greenhouse Gases) and Economic Growth: Evidence from A Panel of EU (European Union) Countries. *Energy*, 74, 439-446.

BOSWIJK, P., H. (1994). Testing for an Unstable Root in Conditional and Unconditional Error Correction Models. *Journal of Econometrics*, 63, 37–60.

BULUT, U., (2017). The Impacts of Non-renewable and renewable energy on CO2 Emissions in Turkey. *Environmental Science and Pollution Research*, 24, 15416-15426.

CAGLAR, A., E. & Mert M. (2017). The Environmental Kuznets Hypothesis and the Effect of Renewable Energy Consumption on Carbon Emissions in Turkey: Co-integration with Structural Breaks. Management and Economics: *Journal of Celal Bayar University Faculty of Economics and Administrative Sciences*, 24(1), 21-38.

CANBAY, S. (2019). Effects of Economic Growth and Renewable Energy Consumption on Environmental Pollution in Turkey. *Journal of Finance*, 176, 140-151.

CALISKAN, S, KARABACAK M & MECIK, O. (2017). Relation between Education Expenditure and Economic Growth in Turkish Economy: Bootstrap Toda-Yamamoto Causality Test Approach. *Kocaeli University Journal of Social Sciences*, (33), 45-56.

CHEN, YU-SHAN, SHYH-BAO L. & CHAO-TUNG, W. (2006). The Influence of Green Innovation Performance on Corporate Advantage in Taiwan. *Journal of Business Ethics*, 67 (4), 3313.

CHEN, W. & LEI, Y. (2018). The Impacts of Renewable Energy and Technological Innovation on Environment-Energy-Growth Nexus: New Evidence from a Panel Quantile Regression. *Renewable Energy*, 123, 1–14.

CHENG, C., REN, X., WANG, Z. & SHI, Y. (2018). The impacts of non-fossil energy, economic growth, energy consumption, and oil price on carbon intensity: Evidence from a panel quantile regression analysis of EU 28. *Sustainability*, 10, 4067.

CHENG C, REN X., WANG Z. & YAN C. (2019a). Heterogeneous impacts of renewable energy and environmental patents on CO2 emission evidence from the BRIICS. *Science Total Environment*, 668 (10), 1328-1338.

COBAN, O. & KILINC, N., S. (2016). Investigation of Energy Use of Environmental Impact. *Marmara Cografya Journal*, (33), 589-606.

DICKEY, D.A. & FULLER, W.A. (1979). Distrubition of the estimators for autogressive time series with unit root. *Journal of the American Statistical Association*, 74, 427-431.

DICKEY, D.A. & FULLER, W.A. (1981). Likilihood ratio statistics for autoregressive time series with a unit root. *Econometrica*, 49(4), 1057-1072.

ETKB, (2018). http://www.eie.gov.tr/yenilenebilir/turkiye de_jeo.aspx. Date of Access: 12.04.2021.

EFRON, B. (1979). Bootstrap Methods: Another Look at the Jackknife. *The Annals of Statistics*, 7(1), 1-26.

ENGLE, R.F. & GRANGER, C.W.J. (1987). Co-integration and Error Correction: Representation, Estimation, and Testing. *Econometrica*, 55 (2), 251-276.

GODIL, D.I., YU, Z., SHARIF A., USMAN R. & KHAN, S.A.R. (2021). Investigate the Role of Technology Innovation and Renewable Energy in Reducing Transport Sector CO2 Emission in China: a path toward Sustainable Development. *Sustainable Development*, 1-14.

HACKER, R.S. & HATEMI-J, A. (2006). Tests for Causality between Integrated Variables Using Asymptotic and Bootstrap Distributions: Theory and Application. *Applied Economics*, 38, 1489- 1500.

IRANDOUST, M. (2016). The Renewable Energy-Growth Nexus with Carbon Emissions and Technological Innovation: Evidence from the Nordic Countries. *Ecological Indicators*, 69, 118–125.

INANÇLI S., AKI A. (2020). The Empirical Analysis of the Relationship Between Energy Imports and Renewable Energy in Turkey. *Econder*, 4(2), 551-565.

ISIK, N. & KILIC, E.C. (2014). The Relationship Between CO2 Emissions and Energy R&D Expenditures in the Transportation Sector. *Journal of Sosyoekonomi*, 22 (22), 321-346.

J., B. GENG, Q., JI & Y., FAN (2016). How Regional Natural Gas Markets Have Reacted to Oil Price Shocks Before and Since the Shale Gas Revolution: A Multi-Scale Perspective**.** *Journal of Natural Gas Science and Engineering*, 36, 734-746.

JOHANSEN, S. (1988). Statistical Analysis of Cointegration Vectors. *Journal of Economic Dynamics and Control*, 12, 231-254.

KHATTAK, S.I., AHMAD, M., KHAN, Z.U. & KHAN, A. (2020). Exploring the Impact of Innovation, Renewable Energy Consumption, and Income on CO2 Emissions: New Evidence from the BRICS Economies. *Environmental Science and Pollution Research*, 27, 13866–13881.

LAU L.C, LEE K.T. & MOHAMED A.R. (2012). Global Warming Mitigation and Renewable Energy Policy Development from the Kyoto Protocol to the Copenhagen Accord—a comment. *Renewable Sustainable Energy Review*, 16: 5280–5284.

LEE, K.H. & MIN, B. (2015). Green R&D for Eco-Innovation and Its Impact on Carbon Emissions and Firm Performance. *Journal of Cleanar Production*, 108, 534–542.

LIN, B. & ZHU, J., (2019b). The Role of Renewable Energy Technological Innovation on Climate Change: Empirical Evidence from China. *Science and Total Environment*, 659, 1505–1512.

MENSAH, C.N., LONG, X., BOAMAH, K.B., BEDIAKO, I., A., DAUDA, L. & SALMAN, M. (2018). The effect of innovation on CO2 emissions of OCED countries from 1990 to 2014. *Environ. Sci. Pollut. Res*. 25, 29678-29698.

MENYAH, K. & WOLDE-RUFAEL, Y. (2010). CO2 Emissions, Nuclear Energy, Renewable Energy and Economic Growth in the US. *Energy Policy*, 38, 2911-2915.

ORGAN, I. & CIFTCI, T. (2013). Carbon Tax. *Journal of Nigde University Faculty of Economics and Administrative Sciences*, 6 (1), 81-95.

PATA, U.K. (2018). Renewable Energy Consumption, Urbanization, Financial Development, Income and CO2 Emissions in Turkey: Testing EKC Hypothesis with Structural Breaks. *Journal of Cleaner Production*, 187, 770–779.

PATA, U.K. (2018). Analysis of the Relationships Between Inflation, Savings and Economic Growth in Turkey with Symmetric and Asymmetric Causality Tests. *Journal of Finance,* 174, 92-111.

QAYYUM, M., ALI, M., NIZAMANI, M.M., LI, S., YU, Y. & JAHANGER, A. (2021). Nexus between Financial Development, Renewable Energy Consumption, Technological Innovations and CO 2 Emissions: The Case of India. *Energies*, 14, 4505.

SADORSKY, P. (2009). Renewable Energy Consumption and Income in Emerging Economies. *Energy Policy*, 37: 4021–4028.

SADORSKY, P. (2014). The Effect of Urbanization on CO2 Emissions in Emerging Economies. *Energy Economics*, 41 (1), 147–153.

TODA, H., Y. & YAMAMOTO, T. (1995). Statistical Inference in Vector Autoregressions with Possibly Integrated Processes. *Journal of Economics*, 66 (1-2), 225-250.

TOPAL, M., H. (2018). An Analysis of the Relationship Between Military Expenditures and Economic Growth in Turkey (1960-2016). *Journal of Finance*, 174, 175-202.

YAVUZ, N. (2011). Test of the Effect of Tourism Revenues on Economic Growth in Turkey: Structural Break and Causality Analysis. *Dogus University Journal*, 7 (2), 162-171.

YII K & GEETHA C. (2017). The Nexus Between Technology Innovation and CO2 Emissions in Malaysia : Evidence from Granger Causality Test. *Energy Procedia*, 105, 3118–3124.

YIGIT, S. (2014). The Environmental Face of Innovation and Turkey. Management and Economics: *Journal of Celal Bayar University Faculty of Economics and Administrative Sciences*, 21, 251-265.