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Article

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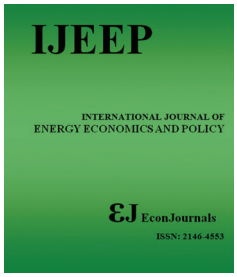
Provided in Cooperation with:
International Journal of Energy Economics and Policy (IJEEP)

Reference: Huseynli, Bahman (2023). Research and development expenditures and renewable energy : an empirical analysis in Türkiye. In: International Journal of Energy Economics and Policy 13 (6), S. 179 - 184. https://www.econjournals.com/index.php/ijeep/article/download/14601/7555/35006. doi:10.32479/ijeep.14601.



International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2023, 13(6), 179-184.

Research and Development Expenditures and Renewable Energy: An Empirical Analysis in Türkiye

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Received: 12 June 2023 **Accepted:** 25 September 2023 **DOI:** https://doi.org/10.32479/ijeep.14601

ABSTRACT

In recent years, the increase in imported energy demand in Turkey significantly increases the current account deficit. In developing countries such as Turkey, foreign dependence on energy resources such as oil and natural gas, which is necessary for the realization of production, causes the current account deficit to increase. In this context, turning to renewable energy sources and increasing the amount of energy obtained from these sources is one of the alternatives to get rid of Turkey`s dependence on foreign energy in terms of energy. The aim of this study is to examine the relationship between renewable energy consumption and research and development (R&D) expenditures in Turkey for the period 1998–2021 and to determine to what extent these variables affect each other. In the study, Granger causality analysis was applied using renewable energy consumption and R&D expenditure data. According to the findings obtained in the study, a unilateral causality relationship was determined from renewable energy consumption to R&D expenditures.

Keywords: Renewable Energy, Research and Development, Research and Development Expenditures, Causality Analysis, Türkiye
JEL Classifications: O30, Q42, Q43

1. INTRODUCTION

Considering the interdependence between production and energy today, we come across the situation that energy is an indispensable element for the continuation of economic activity. For this reason, energy has been one of the most important and indispensable needs throughout human history. Two areas of energy resources can be investigated. These can be considered as primary and secondary energy sources. Fossil fuels including coal, oil, and natural gas are the main energy sources. Renewable energy sources, such as geothermal, wind, and hydroelectric power, are secondary energy sources (Sarkhanov and Huseynli, 2022). Scarce energy resources also bring uncertainty about the future. Considering that these scarce resources can be exhausted and some of them are harmful to the environment, the importance of efficient use of energy resources becomes evident.

The question of how to use energy efficiently without losing the welfare of the economic decision units and without problems in terms of total supply is constantly up to date. In other words, the question of what should be done to use energy efficiently is one of the problems that must be solved for policy makers every period. In addition to the efficient use of energy, the importance of the type of energy used to leave a cleaner environment for future generations is also revealed. So much so that non-renewable energy (fossil fuels) sources are known to harm the environment more than renewable energy sources (Özbek and Naimoğlu, 2021). This situation constitutes both a cost factor and one of the factors that reduce the quality of life for the economies of many countries. This poses an important problem for policy makers.

Considering the 2018 data, the share of coal, oil, and natural gas, which is among the non-renewable energy sources in the world,

is around 81.20%. Within this ratio, oil has 32%, coal 27% and natural gas 23%. Renewable energy sources, on the other hand, were found to have a share of only 4.54% in the same year. In this ratio, hydro is 2.54%; wind, sun etc. It has a share of 2.01% (IEA, 2015). The fact that non-renewable energy sources have high usage rates is one of the problems that need to be solved in today's world where high technology is available. It is known that high CO2 emissions caused by non-renewable energy sources cause some deterioration in both human health and the environment. CO2 emission, which was around 2 billion tons in the 1900s, increased to 36.2 billion tons as of 2018 with the effect of industrialization (Gürler et al., 2020). This increase corresponds to an increase of approximately 1600%. This situation has caused many negative consequences in the deterioration of the natural order, especially in global warming. So much so that global warming, which was 0.636 oC in 1990, increased to 1.473 oC in 2019. It was determined that an increase of 131.6% occurred in the temperature change (Özbek and Naimoğlu, 2021).

Increases in CO2 emissions lead to negative developments such as global warming and water scarcity. It is thought that with the increasing global temperature in the world, the tendency to renewable energy sources, which is expressed as environmentally friendly, will increase. However, the hydro resource, which has a share of approximately 56% in renewable energy resources, is under threat with increasing global warming (Özbek and Naimoğlu, 2021). In addition to this threat, developments such as the increasing population in the world and the 11% efficiency experienced in oil, coal, gas, biomass, nuclear and renewable energy inputs clearly demonstrate the importance of energy efficiency (Gürler et al., 2020).

Renewable energy, which is expressed as environmentally friendly energy, offers many opportunities in terms of ensuring energy efficiency. Renewable energy is of great importance all over the world and especially in developing countries that are dependent on foreign energy. The economies of countries that increase their share of renewable energy both get the opportunity to reduce foreign dependency and can ensure the protection or increase of energy efficiency. Reducing the current account deficit is of great importance in terms of ensuring the basic macroeconomic balance in the economies of countries with foreign dependency in terms of energy. Increasing the share of renewable energy supports this situation. Reducing greenhouse gas and greenhouse gas emissions is also among the important features of renewable energy use. Compared with traditional energy sources, geothermal energy (Fridleifsson, 2001), biomaterials energy (Dias et al. 2009), solar energy (Kabalci, 2013), hydroelectric energy (Sipahutar et al. 2013) and wind energy (Cheng and Zhu, 2013) are among the renewable energy sources. Because the mentioned energies are both green, clean, environmentally friendly and have low installation costs. Therefore, investments to be made in the field of renewable energy and technological innovations in this field are of great importance for the future of the world.

In this study, the relationship between renewable energy consumption and research and development (R&D) expenditures is examined. It is important to know which type of energy is more effective in R&D studies in terms of energy consumption in Turkey. For this purpose, it is aimed to contribute to the literature by using the data of R&D expenditures and energy consumption of the Turkish economy. The effectiveness of R&D expenditures in Turkey, which can set an important example for countries that are dependent on energy imports, is of great importance. In the following section, previous studies on the subject are given. In the analysis part of the study, the data set and the empirical method are introduced and the analysis findings are given. As a result, the study is concluded by making evaluations in the light of empirical findings.

2. THEORETICAL BACKGROUND

2.1. Literature Review of R&D Expenditures and Renewable Energy

In this section, selected literature research on energy efficiency and R&D expenditures is given. There are many studies in the literature in terms of ensuring energy efficiency and effectiveness. In general, it is seen that technological developments and R&D expenditures in the field of energy increase energy efficiency or reduce the costs of using environmentally friendly renewable energy. On the other hand, it has been determined that there is a decrease in CO2 emissions because of the increased use of renewable energy and the creation of a clean environment. While examining the relationship between technology and energy consumption (renewable and non-renewable energy), it was concluded that different variables were used to represent technology. Some studies using patent and patent data as an indicator of technological development are Griliches (1998), Acs et al. (2002) and Sohag et al. (2015); the study in which foreign direct investments are used as a technology variable is Dai and Bie (2006).

Lantz and Feng (2006) examined the relationship between technological development and CO2 emissions in the Canadian economy. In the study examining the period 1970–2000, the results revealed that the investments and developments in the field of energy in Canada have a decreasing effect on the overall energy consumption without causing a decrease in the quality and quantity of production. In addition, it was concluded that this situation has a reducing effect on CO2 emissions. In his study, Dinda (2011) investigated the relationship between environmental pollution and production technology in the USA during the 1963–2007 period. Empirical findings have revealed that an increase in the share of innovation and R&D expenditures in the production process will reduce CO2 emissions. In addition, it has been found that this situation helps to increase energy efficiency and environmental quality. Cho et al. (2013), investigating the relationship between oil prices, renewable energy consumption, income, and renewable energy R&D expenditures in EU countries, benefited from the 1995-2006 period data. Empirical results show that increased income will increase R&D expenditures; It has been revealed that the increase in energy prices will increase the use of renewable energy. It was emphasized that policy makers should attach importance to the use of renewable energy to provide cleaner, more efficient, and sustainable energy to EU countries.

In a study conducted by Huseynli (2022b), the relationship between traditional energy and renewable energy in the economic

growth of Turkey and Azerbaijan was examined. As a result of multiple linear regression analysis, no relationship was found between renewable energy or conventional energy production and economic growth in Turkey. Economic growth, which is one of the most important indicators showing that a country's share in the economy is increasing, is an important variable for every country (Huseynli, 2022a). Kumar and Narayanan (2013), who investigated the relationship between non-renewable energy sources and CO2 use in the manufacturing industry in India in the 2000–2011 period, revealed that the increasing use of non-renewable energy increases CO2 emissions. On the other hand, it has been found that increasing R&D activities will increase the consumption of renewable energy, which is an environmentally friendly energy source, and it has been found that this will be effective in reducing CO2 emissions. Lee and Min (2015) investigated the relationship between renewable energy R&D expenditures and the environment and financial performance of companies in the Japanese economy in the period 2001-2010. The empirical results revealed that the increase in renewable energy R&D expenditures increased the use of renewable energy. Thus, the result was obtained that the CO2 emission decreased. Investigating the relationship between R&D expenditures, energy efficiency and greenhouse gas emissions using data from the 1994-2000 period in 28 OECD countries, Balsalobre et al. (2015) revealed that increased R&D expenditures reduce both energy intensity and greenhouse gas emissions.

Álvarez-Herránz et al., (2017) who conducted a similar study for 28 OECD countries in the period 1990–2014, investigated the relationship between energy innovation and greenhouse gas emissions. The findings revealed that all kinds of innovations in energy have a reducing effect on greenhouse gas emissions compared to fossil fuels. Álvarez-Herranz et al. (2017), the relationship between energy innovation and air pollution in the period 1990–2012 for 17 OECD countries was examined. The results show that investments in energy innovation reduce air pollution and increase environmental quality. Li et al. (2017) examined the impact of technological developments on CO2 emissions in the 1997–2014 period for 30 cities in China. The results showed that the technological developments in the energy field in China have a reducing effect on CO2 emissions by achieving the same output with less energy. Kahouli (2018), investigating the relationship between R&D investments and CO2 emissions for Mediterranean countries, benefited from the 1990–2016 period data. The findings showed that there is a negative relationship between CO2 emissions and total R&D investments.

On the other hand, it has been stated that R&D expenditures on energy are important for a cleaner environment. Mensah et al. (2018) investigated the relationship between technological development and CO2 emissions with data from 28 OECD countries for the period 1990–2014. The findings revealed that technology innovations in most OECD countries play an important role in reducing CO2 emissions. Investigating the impact of total R&D expenditures on CO2 emissions, Fernández et al. (2018); It has benefited from the 1994-2013 period data of the EU, USA and China. The results showed that increased R&D spending has a reducing effect on CO2 emissions in the EU and the USA. But in China, the situation was reversed.

Renewable energy has become an energy form followed and supported by policy makers not only to prevent climate change, but also to improve energy security, reduce carbon emissions and local air pollution, increase energy independence, and provide employment (Stadelmann and Castro, 2014; Marques and Fuinhas, 2012). In the 2030 Sustainable Development Guide published by the United Nations, targets related to sustainable development have been determined. One of these goals is "increasing the share of renewable energy in the global energy mix and doubling the global energy efficiency" (Hille et al., 2020). To achieve these goals, the share of renewable energy production in total energy resources production and renewable energy consumption in final energy consumption has been increasing in recent years. Thus, While the share of renewable energy sources in primary energy worldwide was 6.04% in 1965, it increased to 11.41% in 2019. In Turkey, this rate increased from 6.96% to 18.47% in the same period (Kilinç and Şahbaz, 2021). According to the IEA, the share of modern renewable energy sources in the final energy consumption in the world was 6.6% in 1990, while it increased to 10.5% in 2017 (Özbek and Naimoğlu, 2021). In the EU-27 group, the share of renewable energy resources consumption in total energy consumption was 19.7% in 2019 (EUROSTAT, 2021). As of 2018, the share of renewable energy in global electricity generation is 26% (Özbek and Naimoğlu, 2021).

Accelerating technological innovations in renewable energy technologies can reduce the production cost of renewable energy, making it possible to compete with traditional fossil fuel sources such as oil, coal and natural gas. Innovation activities that will increase energy efficiency lay the groundwork for the realization of the energy transition. Technological innovations in the field of renewable energy play an important role in reducing overall energy intensity and in transitioning to efficient, low-carbon energy systems at the lowest cost. Some of the factors affecting the rate of technological innovation in renewable energy technology; electricity demand, population size, CO2 emissions, per capita income (Emodi et al., 2015; Rexhäuser and Löschel, 2015). Reducing environmental pollution in the energy sector requires the use of renewable energy technologies, while renewable energy technologies require innovations that reduce the cost and increase the performance of energy forms such as solar and wind (Bayer, et al., 2013).

R&D activities increase the competitiveness of renewable energy technologies, both by reducing the need for energy and raw materials and reducing capital costs, and by increasing the efficiency of renewable energy production. R&D, which represents an increase in knowledge capital, promotes renewable energy production by enabling the development and diffusion of technological knowledge (Paramati et al., 2021). R&D activities enable the discovery of alternative energy sources to reduce the non-renewable energy composition in the energy composition and thus contribute to the economic growth of countries (Adedoyin et al., 2020).

3. RESEARCH METHODOLOGY AND DATA

3.1. Data Set

The purpose of this study is to investigate the link between renewable energy usage and R&D spending in Turkey from 1998

to 2021 and to determine how these two factors interact. The data used in this study were obtained from the World Bank on an annual basis. Since the data covering the years 1998–2021 were taken as a percentage, no logarithmic operations were used.

3.2. Research Method

Although both VAR analysis and causality analysis are used in time series analysis, they are independent and different analyzes. Within the scope of the study, it is thought that the causality analysis will be applied and the cause-effect relationship between the variables used in the study will be revealed. For this purpose, Granger causality analysis was applied. In the Granger causality analysis developed by Granger (1969), there is no prerequisite in the form of dependent and independent variable distinction as in the regression analysis, but the direction of the relations between the variables is investigated. For example, if an X value can be better predicted from the past values than the present value of the Y variable, it can be said that there is Granger causality from the Y variable to the X variable. The causality relationship between the variables can be unidirectional or bidirectional (Yilmaz and Akinci, 2011).

The causality model for two stationary time series is expressed as follows (Granger, 1969):

$$X_t = \sum_{j=1}^{m} c_j X_{t-j} + \sum_{j=1}^{m} b_j Y_{t-j} + \varepsilon_t \quad (1)$$

Table 1: Level values of series

ADF test resault	Renewable energy use		R&D expenditures	
	t-statistics	Possibility	t-statistics	Possibility
ADF testing statistics	−2.927458	0.0576	−1.135885	0.6813
Test critical values				
1%	−3.752946		−3.788030	
5%	−2.998064		−3.012363	
10%	−2.638752		−2.646119	

Table 2: Stationarity level of first order series

ADF test resault	Renewable energy use		R&D expenditures	
	t-statistics	Possibility	t-statistics	Possibility
ADF testing statistics	−5.694099	0.0001	−6.136253	0.0000
Test critical values				
1%	−3.769597		−3.769597	
5%	−3.004861		−3.004861	
10%	−2.642242		−2.642242	

$$Y_t = \sum_{j=1}^{m} c_j X_{t-j} + \sum_{j=1}^{m} d_j Y_{t-j} + n_t \quad (2)$$

Before performing the Granger causality tests, it is necessary to know the degree of integration of the time series used in the analysis and whether there are common trends (Gül and Ekinci, 2006).

However, it is not correct to proceed directly to the solution of a model in time series. First of all, it is necessary to test whether the time series used in the model are stationary. A time series is stationary if its mean and variance do not change over time and the common variance between two periods depends only on the distance between the two periods, not on the period in which this common variance is calculated (Gujarati and Porter, 2009).

In econometric models, there is a dependency of a variable with other variables, but this dependency does not mean that there is an absolute causality relationship between the variables (Akkaya and Pazarlıoğlu, 1998). In applied econometric studies, the most used method for determining causality relationships between time series is the causality analysis developed by Granger (1969).

In addition, the causality test, which was included in the literature by Granger, was used to determine the causality relationship between the variables.

$$Y_t = a + \beta X_t + \varepsilon_t \quad (3)$$

If we arrange this model for Azerbaijan, is

$$RE_t = \alpha_0 + \alpha_1 R\&D_t + \varepsilon_t \quad (4)$$

4. ANALYSES AND RESULTS

When working with time series, the first thing to do is to analyze the stationarity of these series. In this study, the stationarity analysis was performed with the ADF unit root test. In Table 1 and Table 2, the level values of the renewable energy consumption and R&D expenditures series and the results of the ADF unit root tests according to the first difference are given.

While the series were not stationary with their level values, when the first differences of the series were taken, they were found to be stationary at 1% and 5% significance levels.

Table 3: Appropriate delay length

Lag	LogL	LR	FPE	AIC	SC	HQ
0	−12.54604	NA	0.018984	1.711299	1.809324	1.721043
1	9.826319	36.84859	0.002202	−0.450155	−0.156080	−0.420924
2	16.70193	9.706741*	0.001615	−0.788462	−0.298337	−0.739743
3	18.07100	1.610676	0.002356	−0.478941	0.207234	−0.410734
4	21.47775	3.206347	0.002894	−0.409147	0.473079	−0.321452
5	23.13369	1.168899	0.004910	−0.133375	0.944901	−0.026192
6	26.32397	1.501308	0.008713	−0.038114	1.236213	0.088557
7	56.57378	7.117604	0.001129*	−3.126327*	−1.655951*	−2.980169*

*Indicates the appropriate lag length for the relevant test

Table 4: Granger causality test

Hypotheses	F-value	Probability value (P)	Decision at 1% significance level
Renewable energy consumption is the reason for R&D expenditures	6.737630	0.0468	Accepted
R&D expenditures are the reason for renewable energy consumption	0.313034	0.8551	Rejected

After the stationarity levels of the series were determined, the transition to the determination of the appropriate lag length was made. As can be seen from Table 3, the optimal appropriate lag length for this data set is 7.

To understand the direction of the relationship between renewable energy consumption and R&D expenditures, the standard Granger causality test was applied after the cointegration test, and the results are shown in Table 4. While these findings indicate that there is a causality from renewable energy consumption to R&D expenditures at the 1% significance level, no causality from R&D expenditures to renewable energy consumption was found. This situation shows that there is a one-way causality relationship from renewable energy consumption to R&D expenditures in Turkey in the period under review.

5. CONCLUSION

Turning to renewable energy sources and increasing the amount of energy obtained from these sources is one of the alternative methods to get rid of Turkey`s dependence on foreign energy in terms of energy. For this, there should be an increase in the investments and expenditures of the country in this area. As a matter of fact, if the investment is made with the right analysis and the right strategies, it will give positive results in terms of getting a return in the future.

The aim of this study is to examine the relationship between renewable energy consumption and R&D expenditures in Turkey between the years 1998–2021 and to reveal to what extent these variables affect each other. In the study, Granger causality method was used by using renewable energy consumption and R&D expenditure data.

Findings obtained because of the analysis; while pointing out that there is a causality from renewable energy consumption to R&D expenditures at the 1% significance level, it has been revealed that there is no causality from R&D expenditures to renewable energy consumption. This situation shows that there is a one-way causality relationship from renewable energy consumption to R&D expenditures in Turkey in the period under review.

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