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ÖZGÜN ARAŞTIRMA

The Threshold Effect of Solar Energy Development from Change in Energy Prices: Evidence from Turkey and OECD

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Abstract

With the phenomenon of sustainable development gaining momentum, many economies around the world are substituting non-renewable energy production with the renewable sources of energy like biomass, hydro, solar energy, wind, or geothermal energy. Not only do contemporary sustainable power generation systems help preserve the environment., but they also provide macro-economic benefits such as increase in employment opportunities, reduction in trade deficit, and enhanced economic growth. Among various sources of renewable energy, solar energy is one of the most popular ones.This study aims to examine the threshold effect of solar energy development from change in energy prices in case of Turkey and OECD for the period 2000 to 2019. The analysis depicts that currently there is more energy generation in OECD countries compared to Turkey but with high variability, there is more scope of rise in solar energy development in case of Turkey. Further, as OECD countries are more economically developed thus, there is positive and significant influence of energy prices on the solar energy development while for Turkey solar energy development is unresponsive to energy prices.

Keywords: Solar Energy, Energy Prices, Economic Growth, Turkey, OECD Countries
Jel Codes: Q4

Güneş Enerjisi Kullanımının Enerji Fiyatları Değişimi Karşısında Eşik Etkisi Analizi. Türkiye Örneği

Özet

Sürdürülebilir kalkınma olgusunun ivme kazanmasıyla birlikte, dünyadaki birçok ekonomi, yenilenemeyen enerji kaynakları yerine biyokütle, hidro, güneş enerjisi, rüzgar ve jeotermal enerji gibi yenilenebilir enerji kaynaklarını tercih etmeye başlamıştır. Çağdaş sürdürülebilir enerji kaynaklarından yararlanmak sadece çevrenin korunmasına yardımcı olmakla kalmaz, aynı zamanda istihdam, dış ticaret açığı ve ekonomik büyüme gibi makro ekonomik değişkenler üzerinde olumlu etki yaratır. Çeşitli yenilenebilir enerji kaynakları arasında en popüler olanlardan biri güneş enerjisidir. Bu çalışma, 2000-2019 dönemi için Türkiye ve OECD özelinde enerji fiyatlarındaki değişimden güneş enerjisi gelişiminin eşik etkisini incelemeyi amaçlamaktadır. OECD ülkelerinde Türkiye'ye kıyasla daha fazla enerji üretimi olduğu, ancak değişkenliği yüksek olan Türkiye örneğinde güneş enerjisi kullanımında daha yüksek artış olduğu görülmektedir. Ayrıca, OECD ülkeleri ekonomik olarak daha gelişmiş olduklarından, enerji fiyatlarının güneş enerjisi kullanımı üzerinde olumlu ve önemli bir etkisi varken, Türkiye için güneş enerjisi kullanımındaki artış enerji fiyatlarına tepkisizdir.

Anahtar kelimeler: Güneş Enerjisi, Enerji Fiyatları, Ekonomik Büyüme, Türkiye, OECD Ülkeleri
Jel Kodu: *Q4*

1. INTRODUCTION

1.1. Renewable Energy Development in Turkey and OECD Countries

The usage of renewable source of energy is now inevitable not only for controlling the utilization of scarce fossil fuels but also for maintenance and sustenance of ecological

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balance. In 2014, renewable energy excluding hydro energy became the source of generating about 9.1% of total electricity generated, compared to 8.5% of world electricity generation in 2013.The OECD member countries contribution in global energy production is 30% while it constitute 44% share in global energy supply (Akan et al., 2015). Having dependence on the renewable source of energy, OECD countries in 2012 had12.8% share in the world energy related carbon emissions which would increase to 13% share in 2020 wherein 5.6% of emissions would be from liquid fuels, 3.3% from Natural gas, and 4.1% from coal based power generation (U.S. Energy Information Administration, 2016). Turkey is presently witnessing a rise in the consumption of energy due to population growth, economic development, and increasing industrialization and urbanization. Due to this the country imports over 70% of fossil fuels for power generation. Coal has been the largest source of energy for Turkey by contributing to 15.5% in total primary energy supply (TPES). In recent years Turkey has witnessed a rise in share of hydropower, solar energy, and geothermal in energy production(Akan et al., 2015). But by the end of 2008 the share was only 17.4% in energy generation. Due to the higher dependence on the fossil fuels in Turkey, the CO2 emissions increased to 263.5 mtons in 2010 compared to low level of 68.5 mtons in 1980 (Biresselioglu, 2012). Thus, it is essential to encourage the promotion of policies for improvement in energy production and usage efficiency, support the domestic supply of gas and oil in net energy importing countries, and boosting reliance on non-fossil fuels. These efforts would reduce the emissions of carbon dioxide (CO_2)(OECD, 2007).

1.2. Usage of Solar energy in Turkey and OECD Countries

Global warming, exhaustion of fossil fuels, and inflation are three of the major factors playing a role in economicgrowth. The energy CPI witnessed rapid increase in 2004 from 137.4 to 159.7 whereas an increase in oil price by $10 would contribute to reducing the GDP growth by 0.5%. This requirement of stabilizing macroeconomic conditions created the need of promotion of renewable energy(Chang et al., 2009). In this regard, Turkey planned to raise the capacity of energy generation from renewable to 61000 MW by 2023 with 5000 MW contribution of solar energy. The Turkish SEPA (Solar Energy Potential Atlas) shows that receiving the annual sunlight of 2741 hours; the Turkey has capacity to generate 1527 kW/m^2 per year amount of solar energy. For this, the government focused on photovoltaic solar module production and investment in building the solar power plants(Kalehsar, 2019). In the OECD countries, Germany, Spain, and United states are the only countries with the highest generation of solar electricity i.e. 1% of total energy production. With the rapidly falling cost of installing power capacity, there has been shift in energy production towards solar photovoltaic. However, solar energy production is expensive, ranging about $350 – 680 per MWh, which is higher than any other renewable source of energy production. Some countries witness exploitation of solar energy due to low transmission capacity(OECD, 2010). Thus, it is essential to improve the available technologies. Considering the contribution of solar energy power plants in employment generation and sustainable development of energy generation, there is need for optimal development of solar energy(Comakli et al., 2008).

1.3. Aim & Objective

Renewable energy is an essential component in sustainable growth of a country. However, the variation in the energy prices influences the positive outcome of the development of renewable energy. Although Turkey and OECD countries are producers of solar energy, the costs associated with it tends to hamper the usage of solar energy based power generation. Thus, this study assesses the solar energy development from change in energy prices in case of Turkey and OECD countries.

2. LITERATURE REVIEW

2.1. Status of Renewable Energy

Energy is considered as the backbone and powerhouse of generation of wealth along with the development of society. Primarily the energy is harvested from the fossil fuels, however, the limited availability of these sources and generation of more greenhouse gases creates the need for renewable energy. International Energy Agency in 2013 defined renewable energy as the source of generating energy from the natural processes which can replenish at a rate faster than their consumption rate (SEforALL, 2013).

Turkey strongly depends on gas and oil imports for its energy production. About 77.5% of total primary energy supply (TPES) is being imported by Turkey in 2009(Erdil & Erbıyık, 2015). This dependence on foreign energy sources not only influences the economy negatively by raising deficit but also leads to more cost associated with the production of renewable energy. The energy consumption in Turkey has increased from 268kWh per capita to 1849kWh per capita from 1971 to 2001(Ã et al., 2007).Despite constant rise in demand of energy, the consumption is dependent on primary source with about 90.6% TPES by fossil fuel and remaining by renewable sources(Topkaya, 2012). Wind, hydro, solar, geo-thermal and biomass energy are the effective sources for generation of renewable energy, i.e. electricity. For supporting the rising demand of energy, the government of Turkey has adopted feed in tariff for promoting the locally produced equipment of renewable energy generation(UNDP, 2014). In 2015, $1.9 billion were invested for the development of renewable energy and by 2017 the generation capacity of Turkey increased to 85200 MW(Erdin & Ozkaya, 2019).In case of OECD countries, the supply of renewable energy has grown up by 2.7% annually from 1971 to 2014 compared to 1% per year growth of TPES. During 2010, only around 16% of the electricity output was generated from renewable energy sources(OECD, 2010).

2.2. Energy Prices and the Development of Solar Energy

Solar energy being the natural source is one of the most popular sources of renewable energy. Due to the geographical location, Turkey has total radiation pressure on an average as 1.311kWh/m^2(Erdil & Erbıyık, 2015). With the low energy density of solar energy, the usage of photovoltaic (PV) modules needs coverage of larger areas for small energy generation. This leads to limited application of PV modules. Due to the high cost of technology associated with the solar energy production, the prevalence of solar energy based production is less (et al., 2007). IRENA (2019) report however stated that the global weighted average cost of electricity fell in 2018 due to renewable sources. With the usage of solar PV since 2010, the cost of energy production has declined by 77%. There also has been increase in savings for the industries and societies due to improvement in the air quality and reduction in carbon emission and other harmful greenhouse gases due to the control of usage for inefficient source of energy production(IRENA, 2012, 2019). Among these economic benefits, the economies also witnessed socio-economic benefits i.e. around 3.6 million people were able to get employment opportunity in 2018 and economies were able to improve the trade balance by more development of domestic industries. Thus, though there has been more cost involved in the production of the solar energy, the reduction in the energy prices due to cost saving and associated socio-economic benefits led to more focus of government on development of solar energy.

2.3. Empirical Review

Chang et al. (2009) assessed the influence of energy price variation on the development of renewable energy under different economic growth rate for the period 1997 to 2006. The analysis of the OECD member countries panel data suggests that one-threshold effect is present in relationship with 4.13% of 1-period

lag in annual GDP growth rate. Results of the analysis also shows that during the regime of higher economic growth there is positive relationship between CPI and renewable contribution in energy supply while in low economic growth countries this relationship is unresponsive. Dogan et al.(2015) examined the linkage between the renewable energy and economic growth for G20 countries for the period 1970-2013. The analysis of the ten different panel data using non-parametric technique shows that renewable energy is an important source for all countries. Expansion or contraction of the economy influence the absolute convergence of economy and thus, renewable energy policy should be specified as per regime. Ackah et al.(2016) further analyzed the efficiency of renewable energy consumption for oil producing African countries from 1971 to 2012. The analysis based on panel fixed effect, panel generalized method of moments and panel random effect models suggest that energy prices, economic growth, energy resource depletion, and carbon emission does have significant influence on the renewable energy demand.

Xie et al. (2018) assessed the new energy consumption influence on economic growth of seven countries i.e. Canada, Japan, China, France, Germany, South Korea, and US for period 1997 to 2016. The threshold model based analysis for the panel data showed that transformation of new energy consumption would raise the occasional economic cost leading to have negative economic growth whereas in absence of occasional economic cost positive influence could be seen. Thus, the impact would change from positive to negative as traditional energy dependence rises. Qi & Li (2018) also examined the influence of energy consumption on economic growth under transformation for China from 1990 to 2014. However, their analysis result shows that significant threshold effect could be seen on economic growth and renewable energy consumption has negative impact on economy growth. This result was supported by Chen et al.(2020) analysis wherein analysis of 103 countries from 1995 to 2015 was done. Analysis shows that positive influence of renewable energy consumption on economic growth could only be seen in developing countries if the countries surpass certain threshold level while for OECD countries there is presence of positive and significant impact.

Figure 1 shows that raising the share of solar energy in total energy production would not only decrease the associated cost with energy production via non-renewable sources but would also yield some socio-economic benefits like reduction in carbon emission, improvement in air quality and rise in employment opportunities. However due to low energy density and being expensive process of energy production, this method is less prevalent. Thus, for an economy the status of economic growth and the energy prices tends to have major influence on the development of solar energy.

3. METHODOLOGY

The study is exploratory in nature and makes use of secondary data in order to answer the aim of the study. Secondary data for the variables like solar energy generation (PV and Thermal), CPI for energy price, and the economic growth of countries (GDP growth rate) was collected from the reliable and official secondary sources like World Development Indicators from World Bank, OECD, and International Energy Agency (IEA) for the period 2000 – 2019. Initially for examining the nature of dataset and better examination of the solar energy development with change in energy prices and economic growth, trend analysis was performed. Herein, the natural log-based transformation was performed for dataset to derive more valuable information. This is followed by descriptive analysis, for which normality was tested using the Shapiro-Wild test. Further, for building in the linkage between the solar energy development and variation in energy prices, below stated hypothesis was tested:

Germany, US, and Japan hold the highest share in OECD countries. With the standard deviation

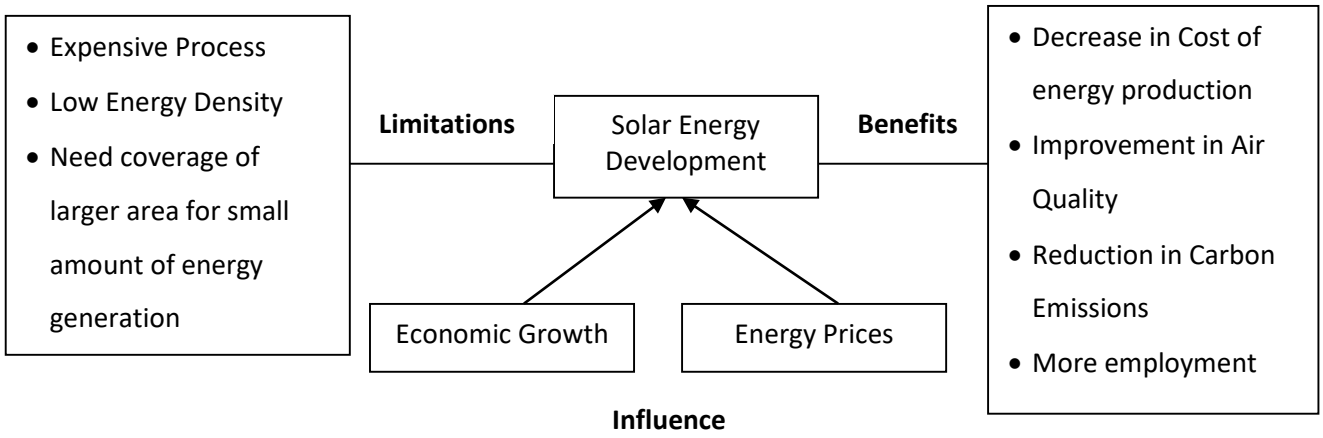

Figure 1: Conceptual Framework of Study

H_0: There is no significant threshold effect on solar energy development is present due to variation in energy prices.

H_A: There is a significant threshold effect on solar energy development is present due to variation in energy prices.

For verifying the hypothesis, the analysis was done at 10% level of significance using SPSS Software. For more adequate derivation of the linkage, bootstrap method with 10000 replications is used. Finally using the correlation and regression analysis, the aim of the study was fulfilled and the relevant conclusion was derived to study the contribution of energy price variation in solar energy development.

4. ANALYSIS

4.1. Descriptive Analysis

The descriptive analysis of the dataset for the OECD countries and Turkey states the basic information about the nature of solar energy generation, economic growth, and energy prices. Herein Table 1 shows that there is higher growth in the usage of solar energy compared to the status of solar energy usage in Turkey. Having the solar energy production of 364848 GWh in OECD countries compared to Turkey production of 9578 GWh in 2019, of 0.32023, the variability in solar energy development is less for the OECD countries in total compared to the Turkey investment in raising the use of solar energy. Thus, there is rapid increase in solar energy usage for Turkey. Further, the assessment of the energy prices shows that the prices for OECD countries tend to be less than the prices of energy in Turkey. Thus, the true cost of consuming electricity is more for the end-users of Turkey in comparison to the people of OECD countries. Further, with a low standard deviation value, it could be depicted that even the variation in the energy prices is more in Turkey compared to OECD countries. This depicts that Turkey has more incentive of reducing their energy prices by substitution of non-renewable energy from solar energy. Lastly, the assessment of the economic growth of OECD countries and Turkey shows that with higher value and low standard deviation, OECD countries are more prone to economic growth compared to Turkey.

Table 1: Descriptive Analysis

	Solar Energy (OECD)	Solar Energy (Turkey)	CPI (OECD)	CPI (Turkey)	GDP (OECD)	GDP (Turkey)
Mean	12.4033	6.86	4.6467	4.7567	31.5600	27.7767

Std. Dev.	.32023	2.439	.06408	.17929	.03742	.07967

These results are also shown in Figure 2 wherein the values show that the proportion of rise in solar energy development is more than the variation in the energy price. Initially from 2014 to 2016 with rise in solar energy development, the energy prices has reduced but later on as the proportion of rise in solar development decreased, there has been rise in energy prices for the OECD countries.

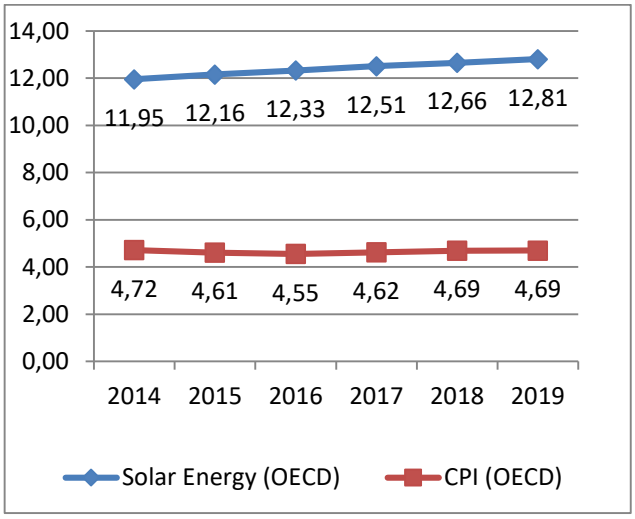

Figure 1: OECD Countries Trend Analysis

However for Turkey, Figure 3 depicts that with the lower level of solar energy, there has been high energy prices i.e. 4.62 in 2014. As there has been rise in proportion of increase in solar energy development, the energy prices have reduced but similar to OECD countries, the decline in proportion of rise in solar energy development resulted in increasing the energy prices for the end-users of Turkey.

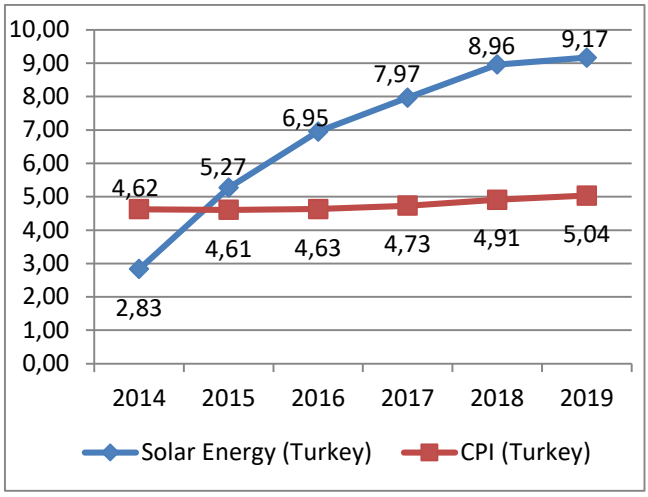

Figure 2: Turkey Trend Analysis

4.2. Normality Test

Normality test specifies the nature of distribution for the dataset. Herein, for the period 2000 to 2019, the nature is examined and the results are shown in below table.

Table 2: Shapiro-Wilk Test Results

Variables	P-value
Solar Energy (OECD)	.956
Solar Energy (Turkey)	.433
CPI (OECD)	.555
CPI (Turkey)	.122
GDP (OECD)	.961
GDP (Turkey)	.537

Table 2 shows that p-value for each of the variables in case of OECD Countries and Turkey is more than the required significance value of 0.10. Thus, the null hypothesis of normally distributed dataset is not rejected. As the dataset is normally distributed, thus analysis could be undertaken for deriving the influence of energy price on solar energy development

4.3. Model Building for Linking Energy Prices and Solar Energy Development

4.3.1. OECD Countries

The linkage between the energy price and solar energy development is examined using the correlation analysis. Herein, the results are shown in Table 3.

Table 3: Correlation Analysis for OECD Countries

	Pearson Correlation	Sig. (2-tailed)
Solar Energy (OECD)	1	
CPI (OECD)	0.912	0.000
GDP (OECD)	0.961	0.000

Above table shows that the p-value for all the variables is 0.000 is less than the required significant value of 0.10. Thus, there is possibility of a significant linkage between the energy prices and solar energy development. The Pearson correlation value further depicts that as the value is greater than 0.5 i.e. 0.912 for CPI and 0.961 for GDP, thus, there is existence of relationship between solar energy and energy prices.

In order to assess the threshold effect of the energy prices variation in the solar energy development, the regression analysis for the model was done. The results of the analysis with bootstrap of 10000 replications is shown in below table.

Table 4: Regression Results with Bootstrap of 10000 Replications

Solar Energy	Coefficient	P-value	R-square	Adjusted R-square	F-value
Constant	-462.83	0.00	0.94	0.93	127.78
CPI (OECD)	2.254	0.05			
GDP (OECD)	14.721	0.00			

Above table shows that the R^2 and Adjusted R^2 value is 0.94 and 0.93 wherein the adjusted R2 value depicts that about 93% of the variation in the solar energy development level is being represented by the energy prices and the economic growth of OECD Countries. With F-value of 127.78 which is greater than the required value of 1, the analysis shows that the model is efficient enough to predict the linkage between the solar energy development and energy prices. Further, the p-value of CPI is 0.05 which is less than 0.1 and for GDP it is 0.00 < 0.05 or 0.10, thus the null hypothesis of nosignificant threshold effect on solar energy development due to variation in energy prices is rejected. Coefficient value of the model states that, 1% rise in energy prices there has been increase in solar energy development by 2.254% and with rise in economic growth of OECD countries by 1% would lead to rise in solar energy development by 14.721%. Hence, in case of OECD countries, there is presence of positive threshold effect i.e. with presence of economic growth and rise in energy prices, the solar energy development takes place for countries.

4.3.2. Turkey

In case of Turkey, the linkage between the solar energy development and the energy prices is drawn using the correlation analysis. Results of the correlation in shown in below table.

Table 5: Correlation Analysis for Turkey

	Pearson Correlation	Sig. (2-tailed)
Solar Energy (Turkey)	1	
CPI (Turkey)	0.79	0.06
GDP (Turkey)	0.98	0.00

The significance value for all the variables as 0.06 (CPI) and 0.00 (GDP) is less than the significance value of 0.1. Thus, there is possibility of a significant linkage between the solar energy development and energy prices. Further, assessment of the Pearson correlation value depicts that value greater than 0.5 i.e. 0.79 for CPI and 0.98 for GDP, there is possibility of influence of energy prices on the solar energy development.

To derive the threshold effect of solar energy development from the variation in the energy prices, a model is built using regression analysis. Herein, the results of the model using the bootstrap method with 10000 replications are shown in Table 6.

Below table shows that the value of R^2 and Adjusted R^2 is 0.97 and 0.95 which depicts that about 95% of the variation in the solar energy development in Turkey is being represented by the variation in the energy prices and the economic growth of the country. F-value of 53.08 is further greater than the required value of 1, thus showing that there is possibility of better assessment of the solar energy development by including energy prices and economic growth in the model as independent variables. Examination of p-value shows that as the p-value for CPI is 0.54 which is greater than the required significance value of 0.1 and even for GDP the value is 0.24 > 0.1. Thus, the null hypothesis of no significant threshold effect on solar energy development due to variation in energy prices is not rejected. Hence, the analysis shows that Turkey does not witness presence of any threshold effect which influences the solar energy development for the country.

Table 6: Regression Results with Bootstrap of 10000 Replications

Solar Energy	Coefficient	P-value	R-square	Adjusted R-square	F-value
Constant	-967.683	0.24	0.97	0.95	53.08
CPI (Turkey)	-2.878	0.54			
GDP (Turkey)	35.578	0.24			

5. CONCLUSION

Energy is an important component for the management of economic activities and the fulfillment of the needs of the people. However, the dependence on the non-renewable energy for energy generation leads to harvesting of scarce resources and emission of harmful greenhouse gases. This deterioration of environment promoted the usage of renewable energy and reducing the existing energy cost by replacing it with natural source of energy generation. Among these renewable energies, solar energy is one of that energy wherein though the process of energy generation is expensive and even due to low energy density, less energy is generated by coverage of larger area. But still the opportunity of rise in employment opportunity, reducing the cost involved in energy generation, and controlling the environment degradation is more. Considering these benefits of renewable energy, this study focused on examining the influence of variation in energy prices on the solar energy development for Turkey and OECD countries from 2000 to 2019.

Descriptive analysis for Turkey and OECD countries shows that with 364848 GWh of solar energy generation in OECD countries compared to 9578 GWh production in Turkey for 2019, the solar energy development is higher in OECD countries. Further, with low standard deviation, there is more opportunity of growth in solar energy development in turkey. Trend analysis for OECD countries and Turkey even depicts that energy prices variation is related to the development of solar energy as with decrease in proportion of increase in solar energy generation, there is rise in energy prices. For the OECD countries there is presence of significant threshold effect of solar energy development due to variation in energy prices and even herein, the rise in energy prices leads to shift in energy production towards solar energy development. With a focus towards raising the economic status of the countries, OECD countries have positive effect of economic growth on solar energy development. However, in Turkey the development of solar energy is unresponsive to energy prices.

As development of solar energy provides the opportunity to end-user for reduction in impact of energy prices, thus government of Turkey

and OECD countries should focus on such regulations wherein the installations of solar panels in houses is mandatory, interest free loans should be provided to the people and businesses for the purchase of equipment essential for having energy generation, and feed in tariff schemes should be promoted for solar panels. As in most of the regions of Turkey, solar energy is used for basic works like water heating, thus, there should be promotion of efforts to have solar energy usage for energy generation. Further as this study focused on examining the solar energy development for OECD countries and Turkey from 2000 to 2019 thus future studies could be directed towards a broader coverage and having examination of the solar energy development on the macro-economic aspects like economic growth or trade deficit.

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