THE CAUSAL LINKAGES between RENEWABLE ENERGY CONSUMPTION, ECONOMIC GROWTH, OIL PRICES and CO_2 EMISSIONS in SELECTED OECD COUNTRIES

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ABSTRACT

Purpose: It is aimed to examine the relationship between Renewable Energy Consumption (REN), Economic Growth (GDP), Oil Prices (OP), and CO_2 emissions (CO_2) in selected OECD countries by using the data for the period 1980-2014.

Methodology: In the study, Kónya Panel Bootstrap causality method is utilized to determine the relationship between variables.

Findings: Firstly, there is a bidirectional causality relationship between REN and CO_2 for Canada and Italy; there is a one-way linkage from REN to CO_2 in Greece and Ireland, while there is unidirectional causality from CO_2 to REN in Austria, Switzerland, and United States. Secondly, there exists a bidirectional causality relationship between the REN and GDP in Italy. In contrast, there is a one-way causality linkage from GDP to REN in Switzerland and Belgium and from REN to GDP in the Netherlands. Thirdly, it is found that there is a bidirectional causality relationship between REN and OP in the United States; there is a one-way causality linkage from OP to REN in Austria, Greece, Italy, Portugal, Spain, and Switzerland, from REN to OP in Japan.

Originality: The study has originality in that it examines the relationship among the variables for the selected OECD countries and through Kónya causality method.

Keywords: Renewable Energy Consumption, CO_2 Emissions, Economic Growth, Oil Prices, Kónya Causality Method.

SEÇİLMİŞ OECD ÜLKELERİNDE YENİLENEBİLİR ENERJİ TÜKETİMİ, EKONOMİK BÜYÜME, PETROL FİYATLARI ve CO_2 EMİSYONU ARASINDAKİ NEDENSELLİK İLİŞKİSİ

ÖZET

Amaç: Seçilmiş OECD ülkelerinde Yenilenebilir Enerji Tüketimi (REN), Ekonomik Büyüme (GDP), Petrol Fiyatları (OP) ve CO_2 emisyonu (CO_2) arasındaki ilişkinin 1980-2014 dönemi periyoduna ait veriler kullanılarak incelenmesi amaçlanmıştır.

Yöntem: Çalışmada, değişkenler arasındaki ilişkinin tespit edilmesinde Kónya Panel Bootstrap nedensellik yönteminden yararlanılmıştır.

Bulgular: İlk olarak, Kanada ve İtalya için REN ve CO_2 arasında iki yönlü, Yunanistan ve İrlanda için REN'den CO_2'ye, Avusturya, İsviçre ve ABD için CO_2'den REN'e doğru tek yönlü nedensellik ilişkisi söz konusudur. İkinci olarak, İtalya için REN ve GDP arasında iki yönlü nedensellik ilişkisi mevcuttur. Buna karşılık İsviçre ve Belçika için GDP'den REN'e, Hollanda için REN'den GDP'ye doğru tek yönlü nedensellik söz konusudur. Üçüncü olarak, ABD'de REN ve OP arasında iki yönlü, Avusturya, Yunanistan, İtalya, Portekiz, İspanya ve İsviçre'de OP'den REN'e, Japonya'da REN'den OP'ye tek yönlü nedensellik ilişkisi tespit edilmiştir.

Özgünlük: Çalışma, değişkenler arasındaki ilişkiyi seçilmiş OECD ülkeleri için ve Kónya nedensellik yöntemiyle incelemesi açısından özgündür.

Anahtar Kelimeler: Yenilenebilir Enerji Tüketimi, CO_2 Emisyonu, Ekonomik Büyüme, Petrol Fiyatları, Kónya Nedensellik Yöntemi.

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1. INTRODUCTION

There exists a growing interest in the importance of energy in the economy, particularly after the 2nd oil crisis. Later, new literature has emerged considering global warming to explain the dynamic relationship between environment, energy, and economy. The rising attention about greenhouse gas emissions that redoubled over the last three decades and continuous volatility of non-renewable energy prices such as crude oil, coal, and natural gas have caused countries to invest and consume more renewable energy (Al-mulali et al., 2013; Apergis and Payne, 2014a). Overall there is a remarkable consensus that renewable energy production and consumption have a significant impact on the economy and environment. Investigating the linkage between energy consumption, renewable energy, and economic growth is taken a consideration about energy policies of countries. In related studies, the causality linkages between renewable energy consumption and economic growth generally have been examined through different countries, modeling period, analysis variables, and methodology (Ocal and Aslan, 2013). These empirical approaches can be categorized into four different groups. Firstly, the neutrality hypothesis is that there does not exist any linkage between energy consumption and economic growth (Acaravci and Ozturk, 2010; Menegaki, 2011; Payne, 2009). In other words, changes in energy demand do not have any impact on economic growth. Secondly, *the growth hypothesis* indicates the presence of one-way causality running from energy consumption to economic growth. In this hypothesis, as energy consumption increases, GDP increases as well (Ho and Siu, 2007; Narayan and Smyth, 2008; Bowden and Payne, 2009; Acaravci and Ozturk, 2012; Fang, 2011). Thirdly, when there is a oneway causality from economic growth to energy consumption, that is referred *conservation hypothesis*. This hypothesis also means that decreasing in energy consumption does not affect economic growth negatively (Ocal and Aslan, 2013; Pao and Fu, 2013; Hwang and Yoo, 2014; Shahbaz et al., 2013). Finally, two-directional causality between energy consumption and economic growth is referred to as *the feedback hypothesis*. The linkage between these variables represents that energy conservation is negatively associated with economic growth, reduction in economic growth affects GDP negatively as well (Apergis and Payne, 2010a; Fuinhas and Marques, 2012; Shahbaz et al., 2015). In recent times, the renewable energy consumption issue examines in the context of oil prices fluctuation by scholars. (Henriques and Sadorsky, 2008; Sadorsky, 2009; Kyritsis and Serletis, 2019; Apergis and Payne, 2015; Shah et al., 2018). Since oil sharply continues to be one of the most remarkable economic factors globally, macroeconomic performance is closely affected by oil prices fluctuations. Especially in the 1970s and 1980s, the oil dependency level of developed countries distinctly raised (Rentschler, 2013: 2). Increasing energy demand makes something a current issue that economic growth and environmental structure must be balanced. So global community is more sensitive to consume renewable energy due to the energy security and global warming issue (Sadorsky, 2009). As Shah et al. (2018) asserted, rising oil prices promote increasing demand and supply for renewable energy. Fluctuation in oil prices causes investment in renewable energy as an important channel for escaping from oil prices shocks in not only oil importer country but also oil-exporting countries (Deniz, 2019).

Due to the concern of many countries on decreasing the level of CO_2 emissions, renewable energy has become the most cutest topic in related literature. Furthermore, scholars faced examining the relationship between economic growth, renewable energy, and CO_2 emissions within the emerging importance of sustainable development (Tugcu et al., 2012). According to International Energy Agency (IEA), thanks to cost reductions in renewables and improvements in digital technologies, a greater chance has occurred to adjourn for different energy policies. In the Stated Policies Scenario, the quantity of renewable energy (without the traditional use of biomass) in final energy consumption increases from more than 990 Mtoe today to nearly 2,260 Mtoe in 2040. In addition, the proportion of renewables in global heat rises by 60% and reaches almost 940 Mtoe in 2040. These results occur due to substantial growth in the modern use of bioenergy, renewable electricity, and also solar thermal (IEA, 2019a).

The high dependence of the global economy on fossil fuels such as oil, gas, and coal contrasts with sustainable development. Fossil fuels are one of the most critical factors that cause global warming. In addition, since energy is an essential factor for economic growth, the importance of sustainable energy resources that reduce environmental pollution is gradually increasing. (Halkos and Tzeremes, 2013). Renewable energy is important for economic growth and reduces dependence on foreign energy sources, fluctuations in oil prices in international markets, and natural gas prices (Apergis and Payne, 2010b). Moreover, renewable energy consumption reduces CO_2 emissions and leads to more efficient use of resources through increased efficiency (Chien and Hu, 2007). Economic growth is also critical in generating infrastructure resources that increase efficiency in developing renewable energy technologies (Yazdi and Shakouri, 2017). Domac et al. (2005) emphasize that renewable energy such as bioenergy contributes to the development of countries in macroeconomic terms, significantly raising efficiency. Therefore, a dimension of the relationship between renewable energy consumption, CO_2 emissions, economic growth, and oil prices is closely related to efficiency.

In the light of the growing interest in renewable energy as an alternative source, the goal of this paper is to reveal the dynamic relationship between renewable energy consumption, CO_2 emissions, economic growth, and oil prices in the case of selected OECD countries (Australia, Austria, Belgium, Canada, Denmark, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States) over the period 1980-2014 using Kónya (2006)'s panel bootstrap causality method. This study extends the existing literature specifically on the causal relationship between those variables by considering country-specific results.

The first reason for choosing OECD countries as the sample is that OECD economies are the ones who consumes 38% of total final consumption in 2017 (IEA, 2019b). It has glittered as Figures' below that share of renewable energy consumption increases sharply over the period 1990-2015 while the world average moves slowly. Another result is that according to the Renewable Energy Country Attractiveness Index (RECAI) report, in renewable energy investments, 25 of the largest 40 countries are OECD members.

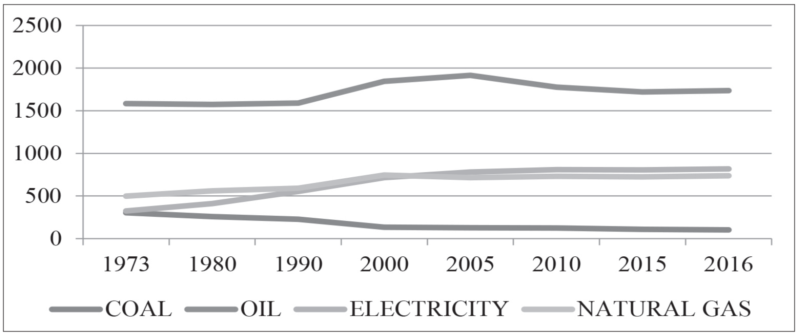

Figure 1. Final consumption of energy types (Mtoe)

Source: *IEA (2018)*

In Figure 1, it can be seen that the final consumption of coal falls and the electricity, natural gas rises whereas oil is the highest value of final energy consumption. Due to the oil prices fluctuation, oil consumption still preserves its highest amounts. Because the transportation sector is the largest energy-consuming sector in OECD and transportation almost heavily depends on oil consumption (primarily gasoline and diesel). As reported in IEA (2018), the share of total final consumption for the industry was 41% and transportation 24% in 1971, but this proportion has changed in recent years. The new share is 31% and 34% for industry and transportation, respectively, in 2016 (IEA, 2018). On the other hand, raising the share of electricity gives us an essential clue to estimate the future of global climate change. Electricity[3]has a vital role in both energy use and CO_2 emissions. For example, increasing share of electricity causes to expansion demand for more electric intensity products. Besides electricity-based economy may help to reduce CO_2 emissions; thus, this supports the critical role of renewable energy to play in providing access to electricity for all countries (IEA, 2019b).

[3] Here, we should underline that electricity is generated from which sources. In a given period, the electricity has been generated from renewable sources and has been generated from non-renewables. As IEA (2018) reported that 27,81% of electricity has generated from coal, 2,22% from oil, 27,45% from natural gas, 17,96% from nuclear energy, 12,91% from hydro energy 11,65% from non-hydro renewables and waste for the OECD in 2016. Also, electricity generation from total renewables varies year by year. For instance share of renewables in electricity generation was 19,67% in 1980, 17,30% in 1990, 22,80% in 2015 and it has raised to 23,74% in 2016.

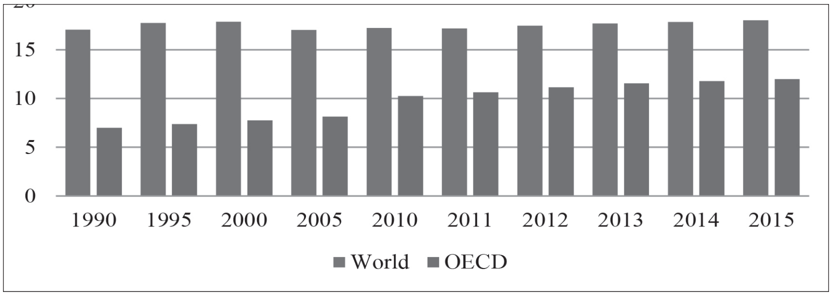

Figure 2. Renewable energy consumption (% of) (Total Final Consumption)

Source: *World Development Indicator (2020)*

In Figure 2, we compare the proportion of renewable energy consumption of OECD countries with the world. As we saw clearly from Figure 2, the share of renewable energy consumption in the total final consumption grew slowly in a given period worldwide and during the recent years in OECD countries. Many reasons cause this situation. For example, in developed countries, energy demand slowly increases because it takes up time to change the existing traditional energy infrastructure and energy consumption habits. In developing countries, energy demand overgrows, and fossil fuels play an important role in satisfying energy demand. Moreover, it seems unlikely that the energy generated from renewable energy sources can compete with fossil fuels in pricing in the short run. In this regard, it is predicted that it will take up time to raise the share of renewable energy consumption in the total energy consumption (Karagol and Kavaz, 2017: 10).

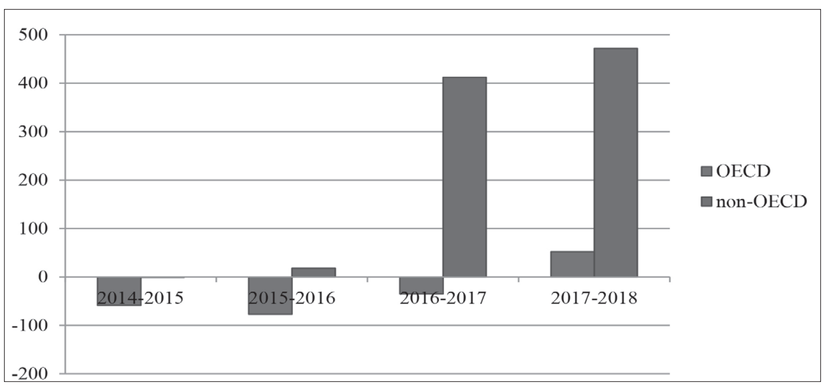

Figure 3. Annual change in CO_2 emissions, 2014-2018

Source: *World Development Indicator (2020)*

In Figure 3, it is clearly shown that CO_2 emissions goes to rise increasingly in non-OECD countries while it decreases except between 2017 and 2018 for OECD members. Due to the improvements in energy efficiency and increased penetration of renewables, annual CO_2 emissions fall distinctly in OECD. But in 2018, it starts to rise again through United States, Canada, and Korea. Although the overall increase in CO_2 emissions in this period, some developed countries in the OECD had net falls in CO_2 emissions, such as Japan, Germany, and France.

Based on these approaches, this paper aims to examine the relationship between Renewable Energy Consumption (REN), Economic Growth (GDP), Oil Prices (OP), and CO_2 emissions (CO_2) in selected OECD countries by using the data for the period 1980-2014.

The remaining parts of the study are organized as follows: Section 2 briefly reviews the literature regarding the causality between renewable energy consumption, economic growth, CO_2 emissions, and oil prices. Section 3 describes the data and empirical estimation methodology. Section 4 reports the empirical findings. Section 5 provides conclusions and discussion.

2. LITERATURE REVIEW

In the field of energy economics, primary drivers of renewable energy consumption and its causal linkages with other factors have been primarily examined chiefly as part of economic growth (Pao and Fu, 2013; Lin and Moubarak, 2014; Kahia et al., 2017; Maji et al., 2019; Bayar and Gavriletea, 2019; Rahman and Velayutham, 2020). In addition to this, some studies investigate the linkages between oil prices and renewable energy consumption (Henriques and Sadorsky, 2008; Sadorsky, 2009; Payne, 2012; Apergis and Payne, 2014a, Brini et al., 2017). This approach can require different methodology of different modeling and other determinants of renewable energy consumption. The related studies are summarized in Table 1.

It can be seen from Table 1, results of the studies are changing in terms of cross-section features (country group, firms), covering the period of analysis, econometric model specification, and variables type.

In the related empirical literature, however, in the single country analysis, it is possible to discuss and determine the findings in the context of country-specific, in the multi-country panel approaches, most of the studies mainly focus on forecasting coefficient or parameter using different methods and revealing the causality relationship between variables without taking into a consideration country-specific. Hence, in this paper, we concentrate on fill this gap in the empirical literature by determining the type of causality direction among the variables for the country by country in the OECD members.

Table 1. Literature review on environment-renewable energy consumption-growth; renewable energy consumption and oil prices; renewable energy-growth relationship

Study	Variables	Period and Country	Methodology	Findings
Henriques and Sadorsky (2008)	Clean Energy Index (ECO), Technology Index (PSE), Crude Oil Futures Prices (OIL), Interest Rate (RATE)	Between January 3, 2001 and May 30, 2007-40 firms in USA (335 Weekly observations)	Vector Autoregression Model (VAR)	Causality runs from PSE, OIL, and RATE to ECO. Additionally A shock in PSE further effect than OIL on ECO
Sadorsky (2009)	Renewable Energy Consumption Per Capita (RE), Real GDP Per Capita (Y), CO_2 Emissions Per Capita (CO_2), Real Oil Prices (ROP)	1980-2005, G7 Countries	Panel Unit Root, Panel Cointegration, FMOLS, DOLS	In the LR, Y, and CO_2 lead to increase RE while ROP has a minor but negative effect on RE
Menyah and Wolde-Rufael (2010)	CO_2 Emissions (CO_2), Renewable Energy Consumption (REC), Nuclear Energy Consumption (NEC) and Real GDP (GDP)	1960-2007, US	Granger Causality Test	There is a unidirectional causality running from NEC to CO_2 and two-way causality exists between REC and CO_2
Marques et al. (2010)	Renewable Energy Supply (LCRES), Oil Prices (OILP), Natural Gas Prices (GASP), Coal Prices (COALP), Energy Security (IMPTDP), Carbon Dioxide Emissions (CO_2PC), Energy Consumption (ENERGPC), Geographic Area (AREA), Income (GDP), Continuous Commitment on RE (DCONT) and Some Control Variables	1990-2006, 24 European Countries	Fixed Effects Vector Decomposition	OILP has a positive impact on LCRES
Apergis and Payne (2010b)	Renewable Energy Consumption (REC), GDP Per Capita (GDPPC), Real Gross Fixed Capital Formation (K), Labor Force (L)	1985-2005, 20 OECD Countries	Panel Unit Root, Panel FMOLS, Panel Causality	REC, K, and L are positively associated with GDP. Therefore, there exist a causality linkage between GDP and other variables in the LR
Apergis and Payne (2011)	Real GDP (GDP), Renewable Energy Consumption (REC), Real Gross Fixed Capital Formation (K), Labor Force (L)	1980-2006, Central America	Panel Unit Root and Panel FMOLS, Panel Causality	REC, K, and L have a positive effect on GDP. Additionally, there is a two-way relationship between GDP and REC both in the SR and LR
Menegaki (2011)	Real GDP Per Capita (GDPPC), Renewable Energy Consumption (REC), Final Energy Consumption (CON), Greenhouse Emissions (GRE) and Employment Rate (EMP)	1997-2007, European Countries	Panel Random Effect Model	There is no causality linkage between GDP and REC
Payne (2012)	Renewable Energy Consumption (LREC), Carbon Emissions (LCDE), Real GDP (LRGDP), Real Oil Prices (LROP) and Dummy Variable for Renewable Energy Legislation (D78)	1949-2009, US	Toda-Yamamoto Long Run-Causality	D78 is positively associated with LREC, while LRGDP, LCDE, and LROP do not have any causal effect on LREC
Salim and Rafiq (2012)	Renewable Energy (RE), Income (Y), Carbon Emissions (CO_2), Oil Prices (ROP)	1980-2006, Brazil, China, India, Indonesia, Philippines and Turkey	Ordinary Least Square (FMOLS), Dynamic Ordinary Least Square (DOLS), and Granger Causality	ROP has a smaller negative effect on RE. Y and CO_2 are positively associated with RE in Brazil, China, India, and Indonesia. Y only determines the RE for Turkey and Philippines
Managi and Okimoto (2013)	Stock Index of Clean Energy Firms (CE), Index of the Prices of Technology Stocks (TECH), Interest Rate (RATE), Oil Price (OIL)	January 3, 2001-February 24, 2010-478 observations (weekly)	Markov-Switching Vector Autoregressive (MSVAR) model	There exists positive linkage among OIL and CE
Shafiei and Salim (2014)	CO_2 Emissions (CO_2), Renewable Energy Consumption (REC), Non-Renewable Energy Consumption (NREC), GDP Per Capita (GDPPC), $GDPPC^2$, Urbanization (UR), UR^2, Total Population (POP), Industrialization, Service Sector (SER), Population Density (POPDEN)	1980-2011, 29 OECD Countries	STIRPAT Econometric Model	NREC increases CO_2 whereas REC decreases CO_2
Apergis and Payne (2014a)	Real GDP Per Capita (Y), Renewable Electricity Consumption (RE), (CO_2), Real Coal Prices (RCOALP), Real Oil Prices (ROILP)	1980-2010, 7 Central American Countries	Panel Unit Root, Panel Cointegration, FMOLS, Panel causality	LR cointegration exists between RE, Y, CO_2, ROILP, and RCOALP
Apergis and Payne (2014b)	Renewable Energy Consumption Per Capita (RE), Real GDP Per Capita (Y), CO_2 Per Capita (CDE) and Real Oil Prices (ROP)	1980-2011, 25 OECD Countries	Panel cointegration and Error Correction Model	In the LR linkage exists among RE, Y, CDE. Feedback causality exists in the SR and LR between ROP, RE, and Y
Omri and Nguyen (2014)	Renewable Energy Consumption (RE), CO_2 Emissions (CO_2), Real Oil Prices (ROP), Per Capita GDP (Y), Trade Openness (TO)	1990-2011, 64 Countries	Dynamic System-GMM Panel	ROP is negatively associated with RE
Boluk and Mert (2014)	CO_2 Emissions (CO_2), GDP Per Capita (GDPPC), GDPPC2, Renewable Energy Consumption (REC), Fossil Fuel Energy Consumption Per Capita (FOSS)	1990-2008, 16 European Countries	Panel Coefficient Estimators	REC and FOSS have positive impacts on CO_2

Table 1. (Continued)

Study	Variables	Period and Country	Methodology	Findings
Sebri and Ben-Salha (2014)	Real GDP Per Capita (GDPPC), Renewable Energy Consumption (REC), CO_2 Emissions (CO_2) and Trade Openness (TRADE)	1971-2010, BRICS Countries	ADF-MAX and Zivot-Andrews unit root tests. ARDL Bounds Testing VECM Granger Test	There is a bidirectional causality between REC and GDP. It means that feedback hypothesis is valid
Shahbaz et al. (2015)	Real GDP Per Capita (GDPPC), Renewable Energy Consumption Per Capita (REC) and Labor Per Capita (EMP)	1972Q1-2011Q4, Pakistan	ARDL, VECM Granger Test, Rolling Window Approach	There is a feedback effect between GDP and REC
Sinha (2015)	Renewable Energy Production (RE), GDP Per Capita (GDPC), Oil Imports (OILIMP), Oil Prices Volatility (VOL)	1970-2014, 132 Countries	Generalized Method of Moments (GMM) Methods	As increases VOL, RE rises as well
Inglesi-Lot (2016)	Renewable Energy Consumption (REC), GDP Per Capita (GDPPC), Real Gross Fixed Capital Formation (K), Labor Force (L), R and D Expenditure (R&D)	1990-2010, 34 OECD Countries	Panel Cointegration and Panel Coefficient Estimators	REC, K, L and R&D have a positive impact on GDPPC
Bhattacharya et al. (2016)	Real GDP (GDP), Real Gross Fixed Capital Formation (K), Total Labour Force (L) Renewable Energy Consumption (REC), and Non-Renewable Energy Consumption (NREC)	1991-2012, Selected 38 Countries	Panel Unit Root, Panel Cointegration and Panel FMOLS	REC, NREC, K, and L are positively associated with GDP, and also NREC is the cause of GDP
Al-mulali and Ozturk (2016)	Real GDP, GDP2, Electricity Consumption from Renewable Sources (REC), Electricity Consumption from Non-Renewable Sources (NREC), Total Trade (LTD), Urban Population (UR), Energy Prices (EP), CO_2 Emissions	1990-2012, 27 Developed Economies	Panel Unit Root, Panel Cointegration, Panel FMOLS, Panel Granger Causality	While REC is negatively associated with CO_2, NREC increases CO_2
Bilgili et al. (2016)	CO_2 Emissions (CO_2), Renewable Energy Consumption (REC), GDP Per Capita (GDPPC), GDPPC2	1977-2010, 17 OECD Countries	Panel Unit Root, Panel FMOLS and Panel DOLS	There is a negative causality linkage from REC to CO_2
Zoundi (2017)	CO_2, GDP Per Capita (GDPPC), GDPPC2, Per Capita Primary Energy Consumption (EC), Total Renewable Electricity Net Consumption Per Capita (REC), Population Growth (POP)	1980-2012, 25 Selected African Countries	Panel Unit Root, Panel Cointegration, Panel DOLS, GMM, PMG and MG	REC has a negative impact on CO_2
Troster et al. (2018)	Oil Prices (OP), Industrial Production Index (IPI), Renewable Energy Consumption (R)	From January 1989 till July 2016, US	Granger-Causality, Quantile Regression	Negative shocks of OP affect on R
Inglesi-Lotz and Dogan (2018)	CO_2, Real GDP, GDP2, Renewable Energy (REN), Non-Renewable Energy (NREN)	1980-2011, 10 Biggest Electricity Generators in Sub-Saharan	Panel Unit Root, Panel Cointegration, Granger Causality, DOLS	Although NREC affects CO_2 positively, REC has a negative impact on CO_2
Shah et al. (2018)	Renewable Energy Investment (REI), Real Oil Prices (ROIL), Real GDP (RGDP), Interest Rate (INTR)	1960-2015, Norway, UK, USA	Time Series Vector Autoregression Model (VAR), Granger Causality, ADF Unit Root	ROIL has no impact on REI in UK while positive impact on REI in Norway and USA
Charfeddine and Kahia (2019)	CO_2, Real GDP Per Capita (GDP), Renewable Energy Consumption (REC), Financial Development (FD), Gross Capital Formation (K), Labor Forces (L)	1980-2015, 24 MENA Countries	PVAR model	REC and FD have the smaller effects on GDP and CO_2
Kahia et al. (2019)	Renewable Energy Consumption (REC), Real GDP (GDP), International Trade (TRADE), FDI, CO_2	1980-2012, 12 MENA Countries	Panel Vector Autoregressive Model	There exists bidirectional causality between REC and GDP, REC and TRA-DE, REC and FDI, REC and CO_2
Deniz (2019)	Renewable Energy Consumption (REC), Oil Prices (OILP), Real Oil Prices (ROILP), Oil Prices Volatility(OILPVOL), GDP Per Capita (GDPPC), CO_2, Trade Openness (TO)	1995-2014, 12 Oil Exporters and 12 Importers Countries	Panel GMM, Random Effect, Fixed Effect	For exporter countries OILP has a positive impact on RE, for importer countries OILP has a negative impact on RE
Apaydın et. al (2019)	Renewable Energy Consumption (RENEW), Real GDP (GDP)	1965-2017, Turkey	Nonlinear Autoregressive Distributed Lag (NARDL), ADF, PP, Ng-P and KPSS Structural Break Unit Root	RENEW affects GDP positively, howe-ver positive and negative shocks of RENEW cause asymmetric impacts on GDP
Mele (2019)	Renewable Energy Consumption (REC), Real GDP (GDP), Real Gross Fixed Capital Formation (K), Labor Force (L)	1990-2017, Mexico	Toda Yamamoto Causality	There exists a unidirectional causality flows from REC to GDP

Note: *LR and SR are long run and short run, respectively.*
Source: *The table is organized by authors.*

3. DATA and METHODOLOGY

In this study, it is aimed that whether there is any relationship between renewable energy consumption, CO_2 emissions, economic growth, and oil prices for selected OECD countries (Australia, Austria, Belgium, Canada, Denmark, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States) over the period 1980-2014.

Renewable energy consumption per capita and oil prices which are measured in USD-BAR retrieved from OECD database. As is standard in the energy economics literature, economic growth is measured using GDP per capita in constant prices (2010 $). In addition, as an indicator of environmental degradation, CO_2 emissions metric tons per capita is used-data for GDP and CO_2 emissions obtained by the World Bank Development Indicator database.

To investigate the relationship between renewable energy consumption, CO_2 emissions, economic growth, and oil prices, we follow the empirical model specification of Sadorsky (2009) and Apergis and Payne (2014a) as follows Equation 1:

$$(REN_{it}) = f(CO_{2\,it}, GDP_{it}, OP_{it}) \tag{1}$$

The following model in Equation 1 is written in the logarithmic form as Equation 2:

$$Ln(REN_{it}) = \beta_{i0} + \beta_{i1} LnCO_{2\,it} + \beta_{i2} LnGDP_{it} + \beta_{i3} LnOP_{it} + \varepsilon_{it} \tag{2}$$

Where refers to the renewable energy consumption per capita, CO_{2t} is per capita CO_2 emissions, GDP_t refers to GDP per capita in constant prices, OP_t denotes real oil prices, shows the error term, i=1,2,3,......N means country and t=1,2,3,......T denotes the time.

Overall, in panel data econometrics, underlying assumptions regarding estimators must be tested preliminarily to avoid biased estimations of parameters. In this direction, firstly, the cross-sectional dependency should be tested in order to test whether there is an economic and political dependency among the variables. For this purpose, to test for the presence of such cross-sectional dependence (CD) in our model, it is implemented Breusch and Pagan (1980)'s Lagrange Multiplier (LM) test. The LM test which is useful when T>N, can be expressed as Equation 3:

$$y_{it} = a_i + \beta_i x_{it} + \varepsilon_{it} \qquad i=1\ldots,N, \qquad t=1\ldots,T \tag{3}$$

Here in Equation 3, *i* indicates the cross-sectional unit of the panel, *t* is the time period.
Therefore, LM test statistic can be computed as Equation 4:

$$\mathrm{LM} = \mathrm{T}\sum_{\mathrm{i=1}}^{\mathrm{N-1}}\sum_{\mathrm{j=i+1}}^{\mathrm{N}}\hat{\rho}_{\mathrm{ij}}^{2} \,/\, \chi^2_{N(N-1)/2} \tag{4}$$

From the LM test statistic, existence of cross-sectional dependence (CD) in the model is decided with two hypotheses, which can be represented as:

$i)\ H_0: Cov(\varepsilon_{it}, \varepsilon_{jt}) = 0,$ this null-hypothesis means that there is no cross-sectional dependency across units

$ii)\ H_1: Cov(\varepsilon_{it}, \varepsilon_{jt}) \neq 0,$ this alternative-hypothesis shows that there is a cross-sectional dependency across units (countries)

In the case of N>T, the CD test, which is obtained estimation of the ADF regression derived by Pesaran (2004), is used. In the CD test's calculation, the correlation of each unit with all units without itself is calculated, and the number of correlation in N unit size is calculated up to N*(N-1) (Tatoglu, 2017).

For balanced panel, the CD test can be calculated by the following Equation 5:

$$CD = \sqrt{\left(\frac{2T}{N(N-1)}\right)}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\left(\hat{\rho}_{ij} - 1\right) \sim N(0,1) \tag{5}$$

However, in some cases, due to the reducing strength of the CD test, a modified version of the LM test has developed by Pesaran et al. (2008). So modified LM test's calculation is defined as Equation 6:

$$LM_{adj} = \sqrt{\left(\frac{2}{N(N-1)}\right)} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij} \frac{(T-k)\hat{\rho}_{ij}^2 - \mu_{Tij}}{\sqrt{v_{Tij}^2}} \sim N(0,1) \quad (6)$$

From the Evolution (6), k, μ_{Tij} , and v_{Tij}^2 represent the number of explanatory variables, mean and variance of $(T-k)\hat{\rho}_{ij}^2$, respectively (Pesaran et al., 2008).

After testing for the existence of cross-dependency among the units in the model, one can proceed to the next stage and test the slope homogeneity. For this reason, the delta () test is used as a homogeneity test developed by Pesaran and Yamagata (2008). The main hypotheses of the test can be expressed such as:

H_o: $\beta_i = \beta$, it indicates that slope coefficients are homogeneous.
H_1: $\beta_i \neq \beta$, it displays that slope coefficients are not homogeneous.

Since the Pesaran and Yamagata (2008) test is an improved version of Swamy (1970) test that is another homogeneity test, first of all, it is also necessary to estimate the following Equation 7:

$$\tilde{S} = \sum_{i=1}^{N} \left(\hat{\beta}_i - \tilde{\beta}_{WFE}\right)' \frac{x_i' M_T x_i}{\tilde{\sigma}_i^2} \left(\hat{\beta}_i - \tilde{\beta}_{WFE}\right) \quad (7)$$

Where β_i and $\tilde{\beta}_{WFE}$ are estimators of pooled least squares and weighted fixed effects in given evolution, respectively. Here also, $\tilde{\sigma}_i^2$ is the estimator of σ_i^2 and M_T is the matrix of T.

In this paper, to determine the causality relationship among variables panel bootstrap causality method improved by Kónya (2006) is preferred. This method leads to revealing the causality relationship between variables with country-specific. Additionally, this causality test is based on the SUR and the Wald test's bootstrap critical values. Thus it is not required pretesting such as unit roots and cointegration. Due to this reason, it allows the simultaneous correlation between countries and using additional information provided by the panel data. Also, in this method, another critical step is to determine the lag length correctly. According to the panel causality approach of Kónya method, models to determine the causality relationship between the variables are expressed via two different evolutions systems. So these Equations can be specified as 8, 9, 10, 11, 12, and 13:

$$Y_{1,t} = \alpha_{1,1} + \sum_{i=1}^{ly_1} \beta_{1,1,i} Y_{1,t-i} + \sum_{i=1}^{lx_1} \gamma_{1,1,i} X_{k,1,t-i} + \epsilon_{1,1,t} \quad (8)$$

$$Y_{2,t} = \alpha_{1,2} + \sum_{i=1}^{ly_1} \beta_{1,2,i} Y_{2,t-i} + \sum_{i=1}^{lx_1} \gamma_{1,2,i} X_{k,2,t-i} + \epsilon_{1,2,t} \quad (9)$$

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$$Y_{N,t} = \alpha_{1,N} + \sum_{i=1}^{ly_1} \beta_{1,N,i} Y_{N,t-i} + \sum_{i=1}^{lx_1} \gamma_{1,N,i} X_{k,N,t-i} + \epsilon_{1,N,t} \quad (10)$$

and

$$X_{k,1,t} = \alpha_{2,1} + \sum_{i=1}^{ly_2} \beta_{2,1,i} Y_{1,t-i} + \sum_{i=1}^{lx_2} \gamma_{2,1,i} X_{k,1,t-i} + \epsilon_{2,1,t} \quad (11)$$

$$X_{k,2,t} = \alpha_{2,2} + \sum_{i=1}^{ly_2} \beta_{2,2,i} Y_{2,t-i} + \sum_{i=1}^{lx_2} \gamma_{2,2,i} X_{k,2,t-i} + \epsilon_{2,2,t} \quad (12)$$

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$$X_{k,N,t} = \alpha_{2,N} + \sum_{i=1}^{ly_2} \beta_{2,N,i} Y_{2,t-i} + \sum_{i=1}^{lx_2} \gamma_{2,N,i} X_{k,N,t-i} + \epsilon_{2,N,t} \quad (13)$$

Where Y represents the renewable energy consumption, X_k refers to the CO_2, GDP, and OP, respectively, which are important determinants of REN. Therefore *N* is the number of countries, *t* is the time dimensions of the panel, and *l* is the optimal lag length. Kónya (2006) suggests that in his original paper for determining the optimal lag length, it can be chosen among 1 and 4. In this framework, in our study, optimal lag length is chosen by the Schwarz Bayesian Criteria.

To be an alternative causality test, it includes that: in country i there is a oneway Granger causality running from X to Y if in (8, 9, and 10) not all $\gamma_{1,i}$'s are zero but in (11, 12, and 13) all $\beta_{2,i}$'s are zero, there is a one-way Granger causality from Y to X if in (8, 9, and 10) all $\gamma_{1,i}$'s are zero but in (11, 12, and 13) not all $\beta_{2,i}$'s are zero, there is a two-way Granger causality between Y and X if neither all $\beta_{2,i}$'s nor all $\gamma_{1,i}$'s are zero, and there is no Granger causality between Y and X if all $\beta_{2,i}$'s and $\gamma_{1,i}$'s are zero (Kónya, 2006).

4. EMPIRICAL RESULTS

Likewise, overall in panel data analysis, before determining the causality effect of carbon emissions, economic growth, and oil prices on renewable energy consumption in selected OECD countries, we follow the same strategy: firstly, the cross-sectional dependence is tested. So the results of the cross-sectional dependence test are provided in Table 2.

Table 2. Results for cross-sectional dependence test

Test	REN	CO_2	GDP	OP
LM	271,718***	311,278 ***	345,609	501,370***
CD_{LM}	5,446***	7,585***	9,442***	17,864 ***
CD	12,086***	-2,883**	4,659 **	3,141**
La_{mada}	-1,745**	4,343 ***	-3,085***	-2,899 **
Homogeneity test			**Statistics**	
	34,886***	36,408***	32,663***	24,097***
$_{adj}$	37,594***	39,235***	35,199***	25,968***

Note: **** and ** denote the statistical significance level at the 1% and 5%, respectively.*

It can be seen from Table 2, the null hypothesis of no cross-sectional dependency (for instance, economically, politically, etc.) across the countries is exactly rejected at the significance level 1% and 5%. This finding implies that there is a cross-sectional dependency among the countries.

Table 3. Panel causality between renewable energy and CO_2 emissions

	H_o: $LnCO_2$ Does Not Cause LnREN				H_o: LnREN Does Not Cause $LnCO_2$			
		Critical Values				Critical Values		
Countries	**Statistic**	**1%**	**5%**	**10%**	**Statistic**	**1%**	**5%**	**10%**
Australia	0,092	12,791	8,372	6,126	0,967	14,888	8,015	5,598
Austria	7,575**	7,875	5,171	3,673	0,193	6,583	3,999	2,902
Belgium	0,406	12,065	6,013	4,421	16,192	35,761	26,391	21,522
Canada	11,070**	19,591	10,889	8,589	22,936**	23,976	12,718	8,931
Denmark	0,265	15,068	7,665	4,832	16,878	55,296	38,897	33,236
Greece	0,786	5,926	3,307	2,208	19,645**	23,605	13,605	10,290
Ireland	0,472	4,263	2,440	1,770	10,324**	23,605	13,605	10,290
Italy	12,347***	6,610	4,352	3,097	32,939***	10,702	5,288	3,762
Japan	5,655	33,256	22.000	18,588	10,091	31,403	21,875	18,087
Netherlands	2,947	29,997	18,135	13,227	3,498	11,664	6,216	4,351
New Zealand	1,779	9,858	6,030	4,488	2,715	8,662	6,122	4,639
Norway	0,902	34,495	22,035	15,473	0,114	18,686	10,726	6,880
Portugal	6,885	32,387	23,264	18,626	0,020	11,847	6,404	4,080
Spain	0,659	5,000	2,989	1,828	0,232	6,503	3,672	2,564
Sweden	22,783	122,864	84,046	68,734	3,241	80,712	51,418	44,037
Switzerland	24,500**	33,344	22,001	17,113	23,329	68,650	46,168	34,799
Turkey	2,464	34,642	24,461	20,255	0,366	16,613	11,296	7,987
United Kingdom	0,343	20,533	11,150	7,882	83,352	158,482	121,591	105,060
United States	37,345**	47,972	35,731	30,133	0,586	21,887	11,109	7,307

Bootstrap critical values are taken from 10.000 replications.

Note: ***** *and* ** *denote the statistical significance at the 1% and 5%, respectively.*

The findings of the panel causality between renewable energy and CO_2 emissions are presented in Table 3. As we see from Table 3, we found a bidirectional causality running between renewable energy consumption and CO_2 emissions for Canada and Italy. Furthermore, the unidirectional causality exists running from CO_2 emissions to renewable energy consumption in Austria, Switzerland, and United States. And also, it is obtained that there is a unidirectional causality running from renewable energy consumption to CO_2 emissions for Greece and Ireland. But it has been found no causality relationship between CO_2 emissions and renewable energy consumption for the rest of other countries.

Table 4. Panel causality between renewable energy and economic growth

	H_o: LnGDP Does Not Cause LnREN				H_o: LnREN Does Not Cause LnGDP			
		Critical Values				Critical Values		
Countries	**Statistic**	**1%**	**5%**	**10%**	**Statistic**	**1%**	**5%**	**10%**
Australia	0,411	7,593	4,498	3,375	0,001	20,045	10,497	6,878
Austria	3,608	26,245	20,092	17,339	1,387	10,604	6,523	4,703
Belgium	10,162**	11,695	9,524	8,371	2,527	10,787	5,710	3,900
Canada	0,828	15,796	11,795	9,547	3,680	70,482	45,609	36,941
Denmark	2,394	9,417	6,489	5,059	0,073	11,392	5,376	3,809
Greece	1,308	10,107	7,275	5,747	2,232	23,042	12,253	8,235
Ireland	0,854	12,520	8,858	7,478	0,016	10,770	5,556	3,709
Italy	11,585***	10,973	7,873	7,002	61,016***	47,689	34,466	27,680
Japan	11,121	83,293	63,217	50,126	1,245	66,990	35,596	27,688
Netherlands	17,864	31,426	26,037	23,630	5,730*	12,192	6,338	4,151
New Zealand	9,291	28,932	22,267	18,526	0,267	17.695	10,918	7,723
Norway	5,514	17,919	8,310	5,756	0,067	24,798	15,449	10,266
Portugal	12,979	92,336	69,887	59,495	0,036	33,374	19,498	14,702
Spain	2,341	17,661	13,481	11,490	9,659	34,935	21,473	16,499
Sweden	17,832	68,600	53,811	45,377	0,454	62,253	34,385	25,248
Switzerland	9,942*	17,931	11,713	9,788	11,171	44,301	25,116	16,840
Turkey	13,917	33,511	25,582	20,929	2,864	10,702	6,169	4,265
United Kingdom	0,112	5,679	4,169	3,348	0,006	7,116	4,398	2,960
United States	0,017	3,357	1,927	1,448	4,122	14,380	10,166	8,008

Bootstrap critical values are taken from 10.000 replications.

***Note:** ***, **, and * denote the statistical significance level at the 1%, 5%, and 10%, respectively.*

Table 4 reports the results for causality linkages between renewable energy consumption and GDP. The causality results show that there is a feedback causality among renewable energy consumption and GDP in Italy; although there is a oneway causality runs through GDP to renewable energy consumption in Switzerland and Belgium, there exists a unidirectional causality running from renewable energy consumption to GDP for the Netherlands, no causality exists for the others.

Table 5. Panel causality between renewable energy and oil prices

	H_o: LnOP Does Not Cause LnREN				H_o: LnREN Does Not Cause LnOP			
		Critical Values				Critical Values		
Countries	**Statistic**	**1%**	**5%**	**10%**	**Statistic**	**1%**	**5%**	**10%**
Australia	0,440	5,926	2,744	1,745	0,910	100,829	78,193	66,749
Austria	9,262**	10,677	8,252	6,917	67,719	282,605	239,091	219,142
Belgium	16,187	34,043	25,386	21,753	73,679	538,976	436,871	399,487
Canada	0,000	1,950	1,089	0,772	3,105	192,355	116,638	91,269
Denmark	0,303	9,953	5,415	3,869	111,202	417,367	332,225	308,496
Greece	7,681**	9,989	7,253	6,031	70,772	298,407	247,620	225,987
Ireland	0,034	19,808	10,787	8,673	80,694	439,663	374,100	343,199
Italy	11,164***	11,034	7,551	5,819	254,540	528,057	448,798	421,566
Japan	0,998	5,100	3,869	3,029	158,267**	206,047	154,356	133,868
Netherlands	0,003	15,526	10,239	8,022	281,624	531,944	465,303	436,681
New Zealand	1,017	9,933	6,776	5,426	44,389	207,112	160,174	132,660
Norway	0,087	6,320	3,307	2,118	6,267	43,550	22,047	15,019
Portugal	1,729*	2,969	1,838	1,435	135,832	219,064	167,597	138,439
Spain	8,377**	9,301	6,841	5,608	129,505	421,124	357,697	331,717
Sweden	2,809	16,118	11,706	10,394	34,159	238,481	198,207	182,089
Switzerland	3,068*	5,623	3,461	2,782	4,477	156,062	112,331	90,779
Turkey	0,952	7,708	5,242	4,134	112,867	190,055	152,214	139,261
United Kingdom	0,210	5,155	3,384	2,290	130,172	504,292	437,706	404,835
United States	6,208***	4,837	3,757	3,148	97,961**	176,768	125,250	90,962

Bootstrap critical values are taken from 10.000 replications.

Note: ****, **, and * denote the statistical significance level at the 1%, 5% and 10%, respectively.*

Finally, the findings for the causal linkage among renewable energy consumption and oil prices are also shown in Table 5. The results in Table 5 state that there is a bidirectional causality running between renewable energy consumption and oil prices in the USA, while the unidirectional causality exists running from oil prices to renewable energy consumption in Austria, Greece, Italy, Portugal, Spain, and Switzerland, there is a oneway causality running through renewable energy consumption to oil prices just in Japan.

5. DISCUSSION and CONCLUSION

In a global context, the global warming issue has become the most crucial agenda all over the world in the last two decades. Thus, the scope of countries' energy policies is getting more critical day by day. With regard to this phenomenon, the scholars attempt to investigate the relationship between renewable energy consumption, economic growth, CO_2 emissions, and oil prices. With this approach, this paper presents evidence about the causal impacts of CO_2 emissions, economic growth, and oil prices on renewable energy consumption for selected OECD countries by using Kónya (2006)'s panel bootstrap causality method from 1980 through 2014.

We have separated to investigate impacts of causal links individually between variables as such: renewable energy consumption and CO_2 emissions; renewable energy consumption and economic growth; renewable energy consumption and oil price. Firstly, the results of the study indicate that there is a feedback causality between renewable energy consumption and CO_2 emissions for Canada and Italy, however, there exists a one-way causality running from CO_2 emissions to renewable energy consumption for Austria, Switzerland and United States, and it is found that causality exists from renewable energy consumption to CO_2 emissions in Greece and Ireland. Secondly, another causality test findings present that two-way causality is obtained between renewable energy consumption and economic growth for Italy, whereas in Switzerland and Belgium, there is a unidirectional causality linkage from economic growth to renewable energy consumption, in the Netherlands, there exists a one-way causality going from renewable energy consumption to economic growth. In the last test results, we found the findings as follows: i) Although, in the United States, there exists feedback causality among the renewable energy consumption and oil prices, in Japan, just only oneway causality flowing from renewable energy consumption to oil prices is taken. ii) in Austria, Greece, Italy, Portugal, Spain, and Switzerland, there is causality from oil prices to renewable energy consumption.

Our findings are in line with the results of Sadorsky (2009), Apergis and Payne (2014b), and Deniz (2019). Sadorsky (2009), in his study using FMOLS and DOLS estimators, found that economic growth, CO_2 emissions, and oil prices in G-7 countries have significant impacts on renewable energy consumption, and the direction of these impacts varies from country to country. According to the results of the analysis conducted by Apergis and Payne (2014b) for 25 OECD countries, there is a two-way relationship between renewable energy consumption, economic growth, CO_2 emissions, and oil prices in the short and long run for all panel group. Deniz (2019), in her analysis for 12 oil exporters and importers, while the impact of oil prices on renewable energy consumption is positive for oil importers, it is negative for oil exporters.

In contrast, Al-mulali et al. (2013) reached different findings than ours in their estimates for various income groups. For example, there is a unidirectional relationship from economic growth to renewable energy consumption in Italy, from renewable energy consumption to economic growth in Belgium, and a feedback relationship between economic growth and renewable energy consumption in the Netherlands. It is predicted that this situation may arise from using the indicator of electricity consumption as renewable energy consumption. In our study, the aggregate level of renewable energy consumption is used to reveal the relationship. As stated below, it is possible to obtain different results by using other components of renewable energy.

As a result of our analysis, more causality relationships are found between renewable energy consumption and oil prices. According to the IEA World Energy Balance Report (2018), transportation has been the largest grown sector in OECD over the period 1971-2016. This increase outstands, particularly in Mexico, Poland, Turkey, and the United States. In relation to this trend, countries' different economic structures determine countries' energy use at a national level. Mainly, oil is precisely used in transport despite electricity and gas preferred for residential and services, and coal is generally used to produce electricity. Only the smaller part of it is used in final consumption. In 2016, the transportation sector dominantly depended on oil products; the share of electricity of total energy consumption accounted for 37% in residential while accounted for 53% in commerce/services. Oil consumption still has a dominant share (93%) in the transportation sector, although the rapid growth of biofuels since the 2000s. Thus countries are more sensitive about the fluctuation in oil prices. In addition to this issue, demand for non-renewable energy is the main contributor to CO_2 emissions globally. The immediate solution for reducing CO_2 emissions is non-renewable energy sources should be replaced with renewable energy.

The findings indicate some issues that should be taken into account in terms of energy efficiency. The increase in global energy demand (especially fossil energy) due to many reasons, especially population and economic growth, makes it challenging to reduce environmental pollution. At this point, increasing energy efficiency via shifting from fossil fuels to renewable energy becomes a necessity (Van Dril et al., 2011).

However, scholars, politicians, and people demand a cleaner environment, which is not so easy to realize thanks to several factors such as high cost and long time requirement. As mentioned in IEA (2018) report, governments have a fundamental role in determining the investment composition of energy. Today, 40% of energy capital belongs to state-owned enterprises. This process is not sustainable for a long time. The optimal financial balance should be established between government and private investment. Individually, countries can not achieve more profound levels of decarbonization world through the government budget. Governments should encourage private sectors to invest in green energy for finance and rules, administration, tax reduction, etc.

In today's economy, where the impact of renewable energy use on the environment is highly discussed, the concept of a sustainable environment is directly identified with renewable energy. In addition, it is very important to benefit from renewable energy sources by getting optimal efficiency and diversifying the renewable energy sources. In this context, in terms of renewable energy policies, the following factors can be developed not only for OECD countries but also all over the world:

- Stabilized economic growth is needed for a sustainable and clean environment.
- International legal and administrative sanctions should be increased, especially for countries that create environmental pollution due to their production structure.
- Global cooperation should be strengthened to improve the renewable energy sector.
- Technology and other resource transfers from developed countries to underdeveloped and developing countries should be flexible in order to enhance the renewable energy infrastructure.
- Economic and political stability should be ensured for renewable energy investments.
- Countries that are mostly dependent on primary energy sources, such as oil, should front to renewable energy to avoid negative impacts of price fluctuations in oil.
- The government should implement appropriate incentive systems for attracting foreign renewable energy enterprises.

The study has some limitations. Firstly, the aggregated level of the renewable energy variable is used for empirical analysis. Future research may explore the impact of each type of renewable energy separately. Secondly, the study examines the causality relationship between renewable energy consumption, oil prices, economic growth, and environmental pollution. In addition, the coefficient estimation can provide important findings. Thus, it may help to develop policy recommendations from various perspectives. Future research also on the relationship between renewable energy consumption, economic growth, CO_2 emissions, and oil prices can be implemented, particularly in developing countries, considering government roles on energy policies.

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