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Renewable Energy and Sustainable Development Nexus in Selected OECD Countries

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ABSTRACT

This article investigates the relationship between economic growth, renewable energy consumption, gross fixed capital and total number of labor for 1980-2012 in selected OECD countries in terms of sustainability. Four OECD countries are included in our model in order to differentiate the relationship between nuclear energy consumption and economic growth in more developed OECD countries such as the U.S. and Germany with less developed OECD countries such as Turkey and Italy. According to the results of autoregressive distributed lag approach, the effect of renewable energy consumption on gross domestic product (GDP) is positive in both U.S. and Germany whereas renewable energy consumption has negatively correlated with GDP in Italy and Turkey. It can be concluded that renewable energy consumption has positive effect on economic growth only in more developed countries.

Keywords: Economic Growth, Sustainable Development, Renewable Energy, Autoregressive Distributed Lag Bound Test
JEL Classifications: F43, Q01, Q43, Q56

1. INTRODUCTION

The development indicating an increase in people's lifestyles and quality of life should also aim at meeting people's needs and requests at a satisfactory level to realize this increase. While a part of the world lives in prosperity, the fact that the majority lives in poverty with shortage of food, drink and shelter makes inevitable that certain economic, social and environmental crises occur considering the resource shortage. Issue of establishment of a sustainable development and maintaining this growth has been gaining importance in recent years. Founded in 1968, "The Club of Rome" issued a report in 1972 named "Limits to Growth" in which the possible scenarios possible to occur in near future were discussed. In this report, it is described in detail that raw material and natural resource shortages will be experienced in the world and if usage in such manner continues, a collapse will be experienced throughout the world. The report revealed various growth scenarios and inserted that, without necessary and enough controls were not implemented, the world economy would collapse and along with this, it would be possible to achieve a sustainable economic growth with a strict control mechanism. For these reasons, emphasis was made on the necessity of an economic reform in which increase in national income was not objected. However, considering the point we have achieved so far, national income is still adopted as the main purpose. It should not be forgotten that a clean and habitable environment, clean and drinkable water, biodiversity, a climate without not much changes and a habitable world can be assessed as a natural resource and they are all important for growth and development process. At this point, considering the energy and environmental issues to the transaction to perform a growth and sustainability of this vital importance.

Most people "sustainable development," the phrase "ecologically sustainable or environmentally sensitive development" in the sense that it also uses (Lele, 1991. p. 608; Tolba, 1984). Besides, continuous growth is used in place of "continuous growth" and "continuous change" and sometimes of "successful development" (Lele, 1991. p. 608). Sustainable development is a type of growth in which future generation can meet their current needs without sacrificing their own needs. It includes two basic concepts (WCED, 1987. p. 41):

- The concept of needs; especially basic needs of the world's poorest should be given priority,

- The idea of limitations imposed by technology state and social organizations and for the current environment to meet its current and future needs.

Energy consumption and economic growth nexus is one of the most popular topics in the literature of energy economics (Ozturk, 2010; Payne 2010; Tugcu et al., 2012). Rising environmental pollution and environmental programs along with technological developments and improvements, and faster exhaustion of fossil fuels gave rise to consideration of renewable energy sources that may create less pollution and degradation. In many countries, issues such as energy, energy safety, global warming is discussed and solutions towards such problems are analyzed and arrangements are implemented. Maintaining sustainability can be achieved by increasing quality of life and ensuring the harmony of environment, economy and society to prevent risks for future generations and maintaining such harmony with a social responsibility awareness. Constant increase of the population and unbalanced growth and in parallel increasing energy demand and increases in prices make it necessary to prioritize alternative energy resources and renewable energy.

This paper attempts to investigate empirically the relationship between economic growth, renewable energy consumption, gross fixed capital and total number of labor for 1980-2012 in selected OECD countries such as the U.S. and Germany with less developed OECD countries such as Turkey and Italy. The structure of this paper is organized as follows: In Section II presents theoretical framework, literature and empirical studies. Section III presents the data and methodology used. Empirical results are discussed in Section IV. The final section draws some concluding remarks and suggestions.

2. THEORETICAL FRAMEWORK AND LITERATURE

The real wealth of nations consists of human. So development which causing people to feel valuable is a way of life (Razmi and Bazzazan, 2012. p. 449). The term, sustainable development, has entered into agenda in policy circles after publication of Bruntland Commission report in 1987 regarding global environment and development. This report allowed the term "sustainable development" directly enters into politic discourse despite not yet in daily language. However, this report is the first glance on global scale that consider environmental aspects of growth with economic, social and political points of view and that caused a significant progress in scientific researches conducted within the scope of UNESCO's Man Biosphere Program (Redclift, 2005. p. 212-213).

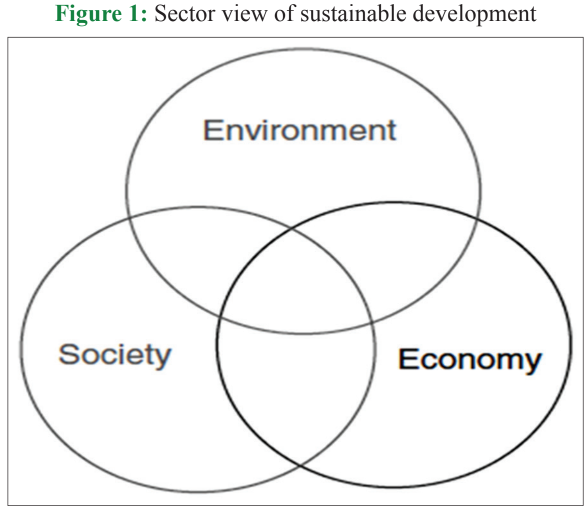
Sustainable development frequently is revealed as divided into three parts including economy, environment and society (Hardi and Zdan, 1997; West Midlands, 2000). These three sectors are usually shown as three interconnected rings (ICLEI, 1996; Plessis, 2000; Barton, 2000). As can be seen in Figure 1, the model has a conceptual simplicity. Although there are not any reasons about why the model is in this form, it generally shows equal-sized rings connected symmetrically. This model has great weaknesses and limitations. The model makes an assumption that economy, society and environment differ from each other and even they are autonomous. This distinction may cause decomposition of basic connections between economy, society and environment. At the same time, there may occur an exchange between these three sectors. Thus, weakness of sustainability may also cause replacement of natural resources and systems by the capital or displacement among them (Neumayer, 1999). As can be seen in Figure 1, certain guidance can be applied by asking questions with a sectoral approach method about how nature of society, policy priorities, decisions can be taken and what they will give rise to (Giddings et al., 2002. p. 188, 189).

Industry is one of the most important parts of the human economy. Industrial systems reveal and determine energy and material flows through the human economy. Although industry is generally regarded as a source of environmental disruptions and resource depletion, it is also widely accepted that industry is an important part of development and wealth acquisition. As a social factor, industry should play in a more prominent role in determination and implementation of sustainable options (Azapagic and Perdan, 2000. p. 244).

Critical objectives for environment and development policies can be monitored from a sustainable development concept that includes the following points (WCED, 1987. p. 49):
- To revive growth
- Change the quality of growth, to meed needs required for jobs, food, water, energy, sanitation and health measures
- To ensure a sustainable population level
- The protection and enhancement of the resource base
- Guidance of technology and management risks, and
- Addressing to environment and economy together in the process of decision-making.

Although there are still so many confusions and contradictions regarding the exact meaning of sustainable development, there is a consensus regarding the fact that sustainable development responds to social, environmental and economic purposes. This model expresses the necessity to combine these three objectives globally with their spatial and temporal aspects for the current and future generations. Intersection of environment, economy and

Figure 1: Sector view of sustainable development



Source: Giddings et al. (2002. p. 189).

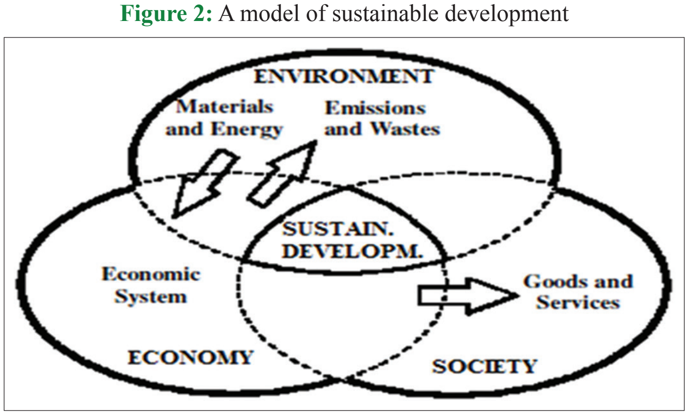
society illustrates a sustainable development. For the reasons such as emissions, environmental wastes and energy reasons, economy and environment are in a constant interaction (Azapagic and Perdan, 2000. p. 243). Future increases that will occur in economic activities may either improve the quality of the environment or make it worse. For that reason, interaction between these two should be established well. This situation is shown in Figure 2 in a basic expression.

Fossil fuels are not created newly and their current stocks will be exhausted eventually. The reserve life of a resource can be defined by dividing known accessible amount by the current usage rate. This definition shows that lives of oil and gas resources are usually only a few decades whereas life of coal is found to be a few centuries. Shortening of lifespan of a fuel reserve and reduction of fuel demand due to increase in fuel prices also verifies the possibility of entrance of more expensive sources and alternatives in the market. Nonetheless, the basic geological facts remain unchanged: Fossil fuel reserves are limited and therefore, present pattern of energy consumption and the growth are not sustainable in the long-term. Also, damages caused by carbon emissions and nuclear materials to the environment and environmental sustainability necessitate development and expansion of renewable energy sources. Renewable energy and efficient use of energy are cheaper than the use of traditional fossil fuels and nuclear fuel (Twidell and Weir, 2006. p. 3). Dependency on fossil fuels has revealed discussions regarding sustainability of the current energy consumption. In this sense, sustainability can be regarded as use of alternative energy resources that reduces environmental effects of carbon emission (Apergis and Payne, 2010. p. 1392).

It is considered that renewable energy is in a synergy with various aspects of sustainable development (Stigllitz, 2002). Therefore, thanks to renewable energy, sustainable growth and development are at the center of policies all over the world. As stated by Bugaje (2006), the following considerations should be taken into account to make renewable energy consumption sustainable and acceptable for other socio-economic parameters of development (Inglesi-Lotz, 2015. p. 1, 2):

- Sustainability of environment by means of appropriate resource management
- Economic sustainability by means of developing infrastructure and services

Figure 2: A model of sustainable development



Source: Azapagic and Perdan (2000. p. 244).

- Social sustainability with helping the poor, providing and maintaining shares, income and rights of women, children's rights
- Administrative sustainability by means of implementation of programs and providing management capacity for maintaining such quality and increasing in time.

Energy consumption plays an important role in economic growth as supplementary of labor and capital in production processes both directly and indirectly. If an increase in energy consumption has a positive effect on economic growth, energy protection oriented policies may have a negative effect on economic growth. There are also a number of reasons concerning the fact that the possibility of an increase in energy consumption as an alternative will have a negative impact on economic growth (Apergis and Payne, 2011. p. 344).

Together with petroleum and natural gas, coal and nuclear energy need can be meet for a while. Most people consider that at today's consumption rate coal will be enough for a few centuries, and the same thing will be valid for nuclear power reactors if they are operated at full capacity. Unfortunately, both coal and nuclear power raise serious environmental problems. Therefore, the wind and solar energy should be supported. Although wind energy is more expensive than coal and nuclear energy, it can be an important energy source with the other two because of political problems (Johnson, 1985. p. 1).

In parallel to population growth, urban development and industrialization, world's primary energy consumption is gradually increasing. Among the key factors that cause the increase of energy consumption, there are increases in population and income. Applied projections indicate that the world's population in 2030 will rise to 8.3 billion. This case poses the necessity of energy supply for another 1.3 billion people. In Turkey as of the end of 2014, electricity production is observed as 250.4 billion kWh, and consumption is 255.5 billion kWh. In parallel with our country's high economic growth rates achieved in recent years, annual electricity consumption speed in the last 12 years was around 5.67% levels and while our energy consumption was 141.2 billion kWh in 2003, this rate was doubled by 1.81 in 2014 with an amount of 255.5 billion kWh. As of the end of 2014, 79.6% of our electricity production was acquired from thermal reactors, 16.1% from hydroelectric power plants and 4.2% from other renewable energy sources. Within the period of 2003-2014, while electricity production rates from thermal and hydraulic sources did not change much compared to the current rates, electricity production rates from geothermal and wind sources was around 0.1% rates in 2003 but reached to 4.2% as of the end of 2014. Analyzing distribution table as per primary energy sources in Turkish electric energy production, as of the end of 2014, ratio of thermal reactor produced energy in total energy production is 79.62%. Within this rate, while natural gas + liquefied natural gas sourced power plants were in first place with their share of 48.11%, they are followed by coal power plants with a rate of 29.56%. Thermal reactors are followed by hydraulic power plants with a share of 16.14%. As of the end of 2012, it is very important while the share of electricity production from wind power plants was 2.40% in 2012 and this rate raised up to 3.34%. Until 2035, it is projected that most of world energy consumption to be increased by 35% will be supplied from the region we are located. 65% of world oil reserves and 71% of natural gas reserves are found in Caspian Basin and the Middle East and Russia in the Federation surrounding Turkey. Turkey is bearing the feature both as a bridge and terminal in transportation of Middle East and Central Asia productions to world markets with its geographical and geopolitical location (MENR, 2015. p. 3-73). Electricity production per sources in Turkey can be seen in Figure 3.

Ozturk and Acaravci (2011) investigate the short-run and long-run causality issues between electricity consumption and economic growth in the selected 11 Middle East and North Africa countries by using autoregressive distributed lag (ARDL) bounds testing approach. They found that there is no cointegration between the electricity consumption and economic growth in three countries (Iran, Morocco and Syria). But the cointegration and causal relationship is found in four countries (Egypt, Israel, Oman and Saudi Arabia). Jebli et al. (2014) discussed the role of renewable energy consumption and trade by using Environmental Kuznets Curve Analysis for Sub-Saharan Africa Countries over the period 1980-2010. They found an indirect short-run causality running from emissions to renewable energy and an indirect short-run causality from gross domestic product (GDP) to renewable energy. In the long-run real GDP per capita and real imports per capita both have a negative and statistically significant impact on per capita carbon emissions.

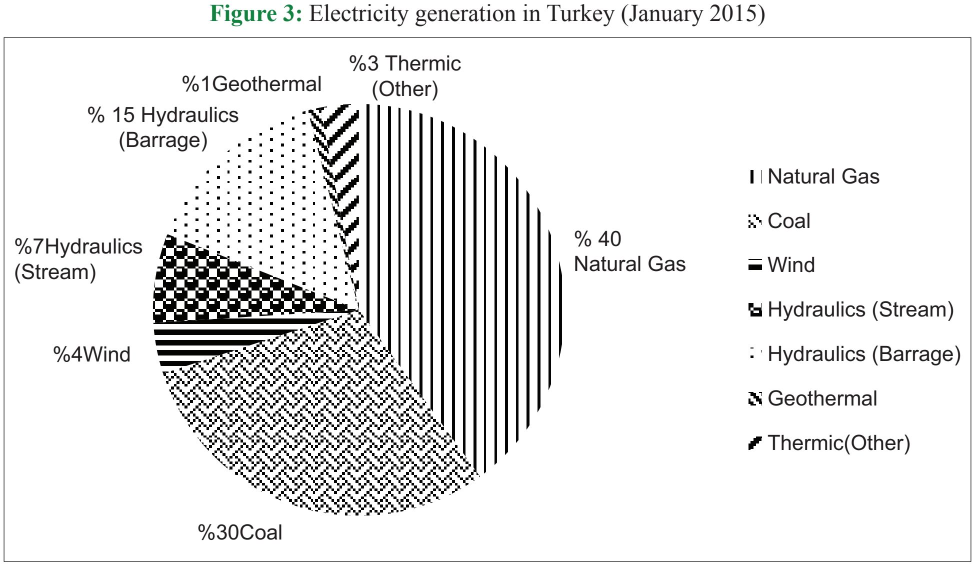
Tugcu et al. (2012) discussed renewable and non-renewable energy consumption and economic growth relationship by using classical and augmented production function in G7 countries for 1980-2009 periods. According to their results, either renewable or non-renewable energy consumption matters for economic growth and augmented production function is more effective on explaining the considered relationship in the long-run. Soytaş and Sarı (2003) reviewed the causality relation between two sets of developing countries and G-7 countries (excluding Chine because of lack of data) by analyzing energy consumption and GDP time series, and found that there is two-way causality in Argentina, there is causality from GDP towards energy consumption in Italy and Korea and in Turkey, Germany, Japan and France, there is a causality from energy consumption to GDP. It was revealed in other four countries, energy saving would be harmful to economic development.

Ocal et al. (2013) examine coal consumption and economic growth relationship in Turkey in the years 1980-2006 using asymmetric causality tests. The estimation results show that no causality for coal consumption and growth relationship in Turkey. This indicates that coal consumption does not affect growth and neutrality hypothesis is confirmed in Turkey. Sinha (2015) examines energy efficiency and economic growth in India for 1971-2010 periods using vector error correction model. The empirical results obtained from this paper indicate that unidirectional causality exists from economic growth to energy waste in short run and long run too. Apergis and Danuletiu (2014) investigate relationship between renewable energy and economic growth for 80 countries. It has been seen that from this paper renewable energy is important for economic growth and also economic growth encourages use of more renewable energy source.

Apergis and Payne (2010) analyzed causality relationship between renewable energy consumption and economic growth in 13 countries in Europe and Asia for the period 1992-2007 and concluded that there was a two-way causality in both short and long-term. Menegaki (2011) analyzed the causality relationship between economic growth and causality using data from 1997 to 2007 periods for 27 European counties and acquired empirical findings confirmed the causality between renewable energy consumption and GDP. Hung-Pin (2014) analyzed short and long-term causality relationship between renewable energy consumption and economic growth in nine OECD countries using data from the 1982 to 2011 period and revealed that in five countries there was co-integration and causality relationship (America, Japan, Germany, Italy and England). In addition, it was concluded that renewable energy-saving policies in France, Denmark, Portugal and Spain did not have any effects on economic growth.

Shafiei et al. (2013) analyzed effects of renewable and non-renewable energy consumption on economic activities in

Figure 3: Electricity generation in Turkey (January 2015)



Source: CEE (2015).

comparison and concluded that both energy sources had an actuator role for economic growth in OECD countries. However, comparing their effects, non-renewable resources were still observed as the dominant energy source. Causality analyses showed that there existed a two-way causality from economic growth to both renewable and non-renewable energy consumption both in short and long-terms. Apergis and Payne (2011) analyzed the relationship between renewable energy consumption and economic growth in six Central American countries using the data for the 1980-2006 periods, and found out that there was a two-way causality between renewable energy consumption and economic growth in both short and long-term. Sadorsky (2009) analyzed the relationship between renewable energy consumption and income for the developing countries and concluded that increases in real income per capita had a positive and statistical meaningful effect on renewable energy consumption per capita. An increase of 1% in real income per capita increases renewable energy consumption per capita around 3.5% in the long-term.

3. MODEL AND DATA

Based on above discussions, real income described as a function of renewable energy consumption, labor force and real gross fixed capital formation. The time series version of this model can be written as follows:

$$\ln GDP_t = a_0 + a_1 \ln REN_t + a_2 \ln K_t + a_3 \ln L_t + \varepsilon_t$$

Where *GDP* represents GDP per capita of 2005 U.S dollars, *REN* represents combustible renewable and waste (percentage of total energy), *K* represents real gross fixed capital formation of constant 2005 U.S dollars, *L* represents total labor force in million.

The data used in this study consists of yearly observations between 1980 and 2012 for four OECD countries such as US, Germany, Italy and Turkey. Data on GDP per capita, combustible renewable and waste (percentage of total energy) and real gross fixed capital are sourced from World Development Indicators (2015) of World Bank, data on total population is sourced from OECD database.

4. METHOD AND FINDINGS

This study utilizes cointegration analysis and causality test for examine the relationship between GDP per capita, renewable energy consumption, gross fixed capita and total labor force. In order to examine the long-run relationship existence we used cointegration tests such as ARDL approach developed by Peseran et al. (2001) ARDL estimation method is the most suitable approach when the order of integration of variables is different. Additionally, Peseran and Shin (1997), argues that ARDL approach has consistent results against autocorrelation and endogeneity problems. The ARDL version of our model is;

$$dGDP_t = c_0 + \sum_{i=1}^{n} \beta_{0,i} dGDP_{t-i} + \sum_{i=1}^{n} \beta_{1,i} dREN_{t-i} + \sum_{i=1}^{n} \beta_{2,i} dK_{t-i} + \sum_{i=1}^{n} \beta_{3,i} dL_{t-i} + \delta_0 GDP_{t-1} + \delta_1 REN_{t-1} + \delta_2 K_{t-1} + \delta_3 L_{t-1}$$

The null hypothesis tested which implies non-existence long-run relation among variables H_0: $\delta_0 = \delta_1 = \delta_2 = \delta_3 = 0$ against the alternative hypothesis H_0: $\delta_0 \neq \delta_1 \neq \delta_2 \neq \delta_3 \neq 0$.

We use Schwarz Bayesian criteria to determine appropriate lag structure for ARDL procedure for the specification implies that $GDP_t = f(REN_t, K_t, L_t)$. The *F* statistic bound test results are shown in Table 1. Appropriate ARDL model for US is (1,1,2,0) and F statistic is 5.82 which exceed upper bound critical value (equal to 3.77) obtained from Peseran et al. (2001), Table CI(iii). Suitable ARDL models are (1,0,1,1), (1,0,1,1) and (1,0,1,0) with F statistics are 4.54, 6.57 and 4.48 for Germany, Italy and Turkey respectively. Consequently, the null hypothesis is rejected thus it is concluded that long-run relationship exist among variables. Also, the important issue is to check stability properties. In order to examine the stability properties we used CUSUM and CUSUMQ tests. As a shown in Figure 4, each statistics lies between bounds for all countries so it can be said that the parameters are stable.

After testing the stability properties the important issue is to check diagnostic tests. Diagnostic test results are shown in Table 2. In order to examine the normality behavior of estimated residuals we utilize Jarque–Berra statistics and the results confirm the normality

Table 1: ARDL models and bound F-test

Countries	Model	F statistics	Critical values (5%) I (0)	Critical values (5%) I (1)
US	(1,1,2,0)	5.82	3.23	4.35
Germany	(1,0,1,1)	4.54	3.23	4.35
Italy	(1,0,1,1)	6.57	3.23	4.35
Turkey	(1,0,1,0)	4.48	3.23	4.35

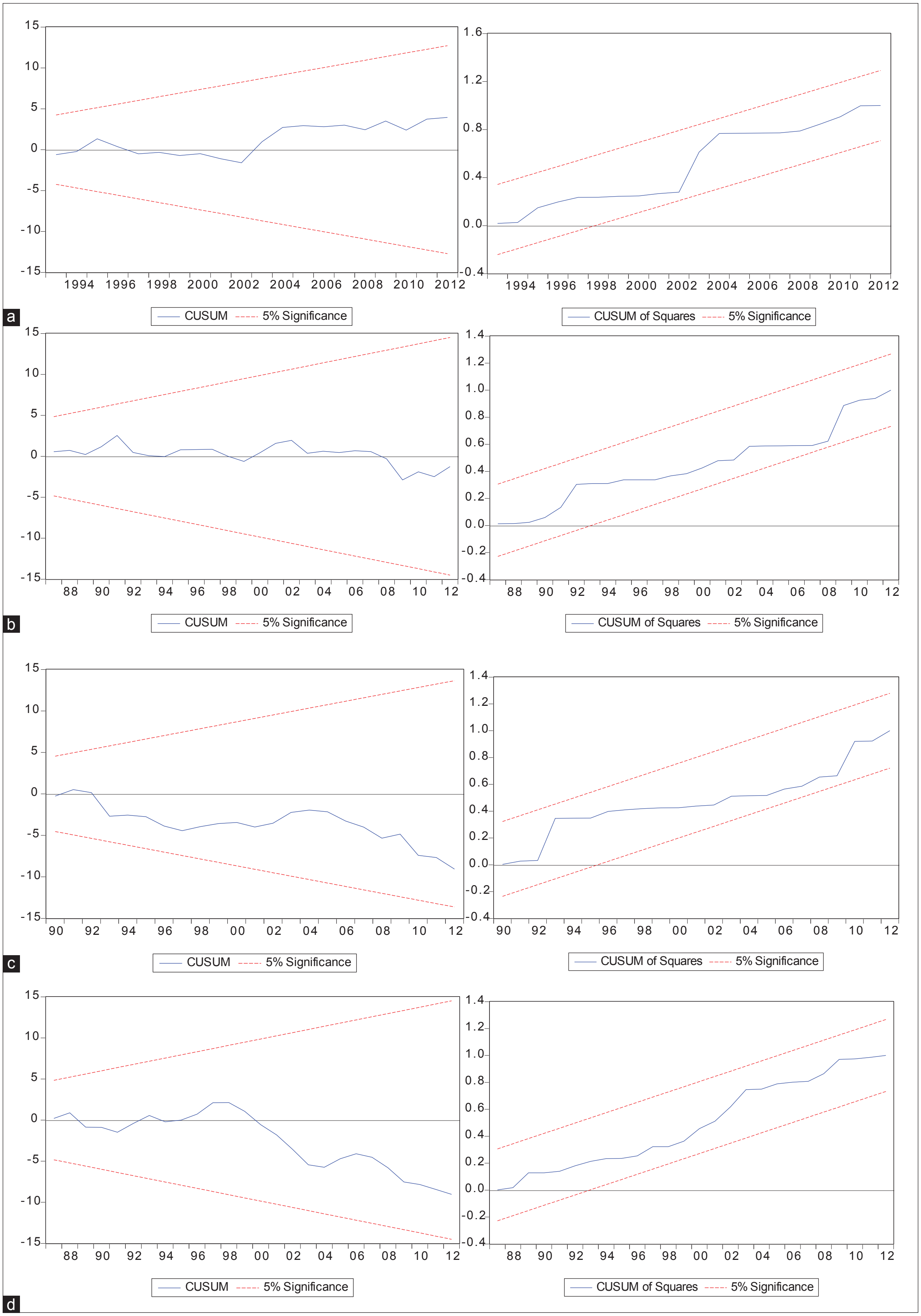
Critical values are obtained from (Pesaran et al., 2001), ARDL: Autoregressive distributed lag

Table 2: Estimated ARDL test and diagnostic tests

Variables	Coefficient			
	US	Germany	Italy	Turkey
Long run results				
Constant	−3.614***	−6.787*	1.485***	6.490***
lnREN	0.237***	0.088***	−0.102***	−0.275***
lnK	0.524***	0.739**	0.117	0.079***
lnL	1.027***	−0.161	−0.035	0.049
Short run results				
Constant	−0.001	0.006***	−0.372***	−0.001
DlnREN	−0.011	0.002	−0.030***	−0.180***
DlnK	0.266***	0.401***	0.447***	0.128***
DlnK (−1)	−0.029*	-	-	-
DlnL	0.071**	0.036	−0.495**	0.020
ECT_{t-1}	−0.204***	−0.544***	−0.372***	−0.439***
Diagnostic tests				
ARS	0.957	0.867	0.912	0.874
Normality	1.379 [0.503]	0.617 [0.734]	0.701 [0.704]	2.105 [0.348]
Serial	2.347 [0.486]	0.590 [0.562]	2.041 [0.153]	2.227 [0.130]
Arch	1.519 [0.237]	0.070 [0.793]	0.106 [0.746]	0.194 [0.662]
Ramsey	0.060 [0.808]	0.232 [0.634]	0.034 [0.853]	0.460 [0.504]

*,** and ***Indicate statistical significance at 10, 5 and 1% level respectively. Diagnostic tests results based on F-statistic, numbers in brackets are *P* values. ARS: Adjusted R-squared. ARDL: Autoregressive distributed lag

Figure 4: CUSUM and CUSUMQ tests (dependent variable: gross domestic product), (a) US, (b) Germany, (c) Italy, (d) Turkey



behavior. The result of Breusch–Godfrey LM test is rejecting serial correlation for the equations. ARCH test results support that residuals are homoscedastic for all countries and Ramsey-Reset test confirms the correct functional form.

The long-run and short-run results are displayed in Table 2. The results show that renewable energy consumption is positively correlated with GDP for both US and Germany however, it has negative effect on GDP for Italy and Turkey in the long-run. In the short-run the coefficient of renewable energy consumption is statistically significant for only Germany and Italy. It can be said that increased energy consumption leads to increase in GDP for more developed countries such as US and Germany.

The effect of gross fixed capital on GDP is positive for U.S, Germany and Turkey and total labor is positively correlated with GDP for only U.S in the long-run. In the short-run, the parameter of capital is statistically significant and positive for all countries. Also we can see error correction term is significant and negative for all countries therefore it can be said that the dynamics of the model converge in the long-run.

In order to examine causality relation among variables we utilize Toda and Yamamoto (1995) procedure. Toda and Yamamoto approach provides to test long-run causal linkages and the main advantage of this test is it can be applied to series with arbitrary integration orders (Nazlıoglu and Soytas, 2011). Toda and Yamamoto procedure uses modified Wald test to the restriction on parameters of VAR model with k degrees of freedom order when a VAR model ($k + d_{max}$) estimated. In this model, k=2 (optimum lag length) and $d_{max}=1$ (maximum integration order) therefore we estimate VAR(3) model for U.S, Germany and Turkey also k=1 (optimum lag length) selected so VAR(2) model estimated for Italy.

The results of the long-run causality test are illustrated in Table 3. According to the results, renewable energy consumption causes GDP for only United States. The null hypothesis "no Granger causality from REN to GDP" is accepted for Germany, Italy and Turkey. On the other hand it can be seen that GDP causes renewable energy consumption for United States and Italy.

5. CONCLUSION

This article investigates the relationship between economic growth, renewable energy consumption, gross fixed capital and total number of labor for 1980-2012 in selected OECD countries such as U.S, Germany, Italy and Turkey. First, we utilized ARDL bound test approach to determine the cointegration between variables and investigate short-run and long-run coefficients of variables. Toda and Yamamoto procedure also applied in order to investigate the direction of causality.

Empirical results of ARDL approach reveal that there are cointegration relationships between variables for all countries.

Table 3: Results for long-run causality test

Countries	REN → GDP		GDP → REN	
	Wald statistics	Causal	Wald statistics	Causal
U.S	5.379**	Yes	5.883**	Yes
Germany	0.522	No	0.419	No
Italy	0.113	No	16.268***	Yes
Turkey	0.037	No	3.516	No

*,** and *** denote significance at 10, 5 and 1% level respectively, GDP: Gross domestic product

In the long-run, renewable energy consumption positively affects economic growth in U.S and Germany however, negatively affects in Italy and Turkey. The effect of gross fixed capital on economic growth is positive for all countries except of Italy and the labor positively correlated with economic growth for only U.S in the long-run. In the short-run, the coefficient of renewable energy consumption is statistically significant and negative just for Italy and Turkey. Similarly gross fixed capital has positively affected economic growth for all countries. In addition to error correction terms are statistically significant for all countries and this result indicates that adjustment from short-run to long-run exists.

Toda and Yamamoto test results show the long-run causality relationship between variables. According to results, bidirectional causality between renewable energy consumption and economic growth in U.S and this feedback causal relationship indicates renewable energy conservation policies may be harmful on economic growth. Also there is unidirectional causality from economic growth to renewable energy consumption in Germany. Neutrality relationship exists for Turkey and Italy in the long-run. It can be said that the governments of Germany, Italy and Turkey can apply renewable energy consumption policies since this policy will not restrict economies of these countries in the long-run however Germany can apply conservation policies just in the long-run. When the results of long-run causality test is evaluated with ARDL bound test results, it can be seen the results are consistent each other.

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