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The Impact of Renewable Energy Consumption and Energy Intensity on CO_2 emissions from Fuel Combustions for the Case of Turkey: A Cointegration Analyses

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Abstract

This study aims to investigate the impact of renewable energy consumption and energy intensity on CO_2 emissions from fuel combustions (Mt CO_2), over the period 1971-2015 for the case of Turkey within the framework of Environmental Kuznet Curve (EKC) hypothesis. The results support the presence and validation of EKC hypothesis with the positive impact of renewable energy consumption on CO_2 emission in both short run and long run. Moreover, it also shows that higher level of energy intensity raises CO_2 emission, which indicates that 1% increase in energy intensity increase CO_2 emission by 0.96% in long run, while renewable energy consumption cause to fall in CO_2 emissions by 0.19%. Therefore, policy makers in Turkey should encourage using of renewable energy in both of production and consumption and consider the negative impacts of energy intensity while determining related policies.

1. Introduction

Climate change and pollution due to increase in greenhouse gases (GHG) has a matter of vital importance for the countries due to its effect on industrial strategies and public policies. CO_2 is most well-known and widely used indicator in the literature as a sector-based pollutant. According to the World Bank (2014), $CO_2$is responsible for more than 80 % of total greenhouse gases globally and share of energy sector on global emissions of CO_2 is about 40%. CO_2 is released into atmosphere through the combustion of oil, coal, natural gases mainly used in industrial production. According to the International Energy Agency (IEA) (2018), as globally, energy demand increased by 2.1 % in 2017, while CO_2 emissions raised for the first time since 2015 simultaneously. The report also mentions the importance of the renewable energy, defined as a vital component of a future sustainable energy, on meeting world's growing energy needs and clean air objectives.

Over the recent years, Turkey as a developing country, with almost 78 million populations and its growth rate basic in construction and industry, is highly dependent on energy. According to the Republic of Turkey Ministry of Energy and Natural Resources report written in 2018, primary energy consumption of Turkey has increased by 71.5% in 2016 compared to 2000 while the share of imported energy resources in the primary energy supply reaches to 75%. This recent energy trend and high rate of energy dependence confirms the importance of the energy for the sustainable development of Turkey. When Turkey's final energy consumptions in total analyses in terms of sources, it is highly dependent on oil, natural gas, coal and electricity. The share of these energy sources in total final energy consumption was counted as 85% in 2000, while it reached to 94% in 2016. Therefore, highest share of CO_2 emissions in Turkey comes from energy sector with 72.8%, while total GHG emissions as CO_2 equivalent rises by 135.4% from 1990 to 2016 (Turkish Statistical Institute, 2018). In addition to these, according to the World bank database, the share of renewable energy consumption in Turkey decreased by 45.4% between the years 1990-2015. Within the light of these data, Turkey needs to have significant sustainable development policies within the framework of environment and energy issues. Given the above background, estimating effects of energy intensity and usage of renewable energy on CO_2 emission of Turkey is necessary while taking right actions against the energy related pollution. In this regard, the study is looking for the answers of the following questions; i) Does EKC hypothesis consistent for the case of Turkey?, ii) Does renewable energy consumption has any impact on CO_2 emission of Turkey?, iii) Does energy intensity of Turkey has any impact on CO_2 emission level?

Most of existing studies mainly focus on the growth and pollution nexus with its linked to energy consumption, rather than focusing on the source of energy. This study makes several contributions to the existing literature. The main contribution of this study is to investigate the impact of renewable energy consumption in air pollution by using EKC hypothesis for Turkey, as an energy dependent developing country, for the period of 1971-2015. Most of the studies in the literature focus on more than one country and uses panel regressions while testing the effect of renewable energy consumption, which ignore cross sectional dependence across countries. For example, Bilgili et al. (2016) analyzed 17 OECD countries for the period of 1977-2010 by using panel Fully Modified Ordinary Least Squares (FMOLS) and dynamic ordinary least square (DOLS). Their findings support the presence of EKC and negative impact of the renewable on CO_2 emissions. However, a study (Lantz and Feng, 2006) using GLS method for the 5 regions of Canada between 1970-2000 does not hold EKC hypothesis and supports positive impact of renewable energy consumption on pollution. In addition to these, Sebri and Ben-Salha (2014) by using ARDL method covering 1971-2010 years for BRICS countries, Dogan and Seker (2016) by using panel granger causality covering 1980-2012 years for 15 European countries, Irandoust (2016) by using VAR model covering 1975-2012 years for four Nordic countries, Jebli et al. (2016) by using VAR model covering 1980-2010 for 25 OECD countries, Moutinho and Robaina (2016) by using panel granger causality covering 1991-2010 years for 20 OECD countries, Ito (2017) by using GMM covering 2002-2011 years for 42 countries, Paramatia et al (2017) by using panel granger causality covering 1991-2012 years for G20 countries analyzed CO_2 emission, growth and renewable energy nexus and reached different conclusions about the impact of renewable energy on pollution. However, the results are not consistent with each other due to differences in sample period, country or region involved, or econometric model and methodology used. Sebri and Ben-Salha (2014), Irandoust (2016), Ito (2017), and Paramatia *et al* (2017) did not investigate the EKC hypothesis on their models, while the findings of Dogan and Seker (2016), Jebli *et al.* (2016), and Moutinho and Robaina (2016) supports the presence of EKC hypothesis. Secondly, this paper is using autoregressive distributed lag (ARDL) cointegration method with (Fully Modified Ordinary Least Squares) FMOLS, (Dynamic Ordinary Least Square) DOLS, and (Canonical Cointegrating Regression) CCR cointegration methods to check the robustness of the results and its reliability while answering the questions. And final contribution of this study is to investigate EKC by testing impact of energy intensity of Turkey in its CO_2 level, while most of the studies in the literature are investing EKC hypothesis by incorporating the fuel energy consumption of the countries rather than using energy intensity.

The rest of the paper is organized as follows; literature is given in the next section. Then, data and methodology are discussed with the models used in the study in Section 3. Section 4 provides empirical results. And finally, some suggestions and conclusions are presented in Section 5.

2. Literature Review

The studies that linked to growth and pollution build on the Environmental Kuznet Curve (EKC) hypothesis developed by Grossman and Krueger (1991) for 42 countries in North American Free Trade Agreement (NAFTA). Grossman and Krueger used sulfur dioxide and smoke as pollution indicator and found that the level of pollutants rises with real income at low levels, but decreases with growth at higher levels of income. More generally, the hypothesis claims that when real income starts increasing at early level of development, the level of CO_2, as an indicator of air pollution, rises until a certain level. This stage is known as scale effect that requires more resources, including energy, to produce more goods. At this stage, more environmental pollution is expected in turn. However, economic growth will also bring positive outcomes for environment with the structural effect. At this stage, structure of economy starts changing from dirty industries to fewer polluting industries gradually. Therefore, environmental pollution increases at a decreasing rate at structural change stage. Technological change dominates technology intensive sectors at the final stage of the structural change. High income economies switch from pollutant industrial to service or information sectors, using alternative energy resources, increasing environmental awareness through education or by laws. As a result, pollution path initially moves along with growth and later as a result of structural and technological effects start decreasing. In the literature, the level of CO_2 emission is regressed on real income and square of real income to represent the EKC hypothesis. Therefore, real income and its square have been used in this study to be consistent with the original EKC hypothesis. Estimation results of cointegration models used in the study indicates presence of EKC hypothesis for the case of Turkey. Therefore, we can conclude that pollution follows the scale effect and structural effect path while growth rate of Turkey rises.

The empirical studies concerning pollution and growth nexus or pollution, growth and energy nexus in the case of Turkey provide mixed results. Akbostanci et al. (2009) analyzed the growth and air quality relationship, for Turkey by using cointegration techniques, and for its provinces by using panel data. They found a positive relationship between growth and CO_2 level in Turkey, while finding N-shaped relationship when they used PM10 and CO_2 emissions in her provinces. Their results did not confirm the inverted U shaped EKC hypothesis suggested by Grossman and Krueger (1991). However, Turkey has taken into consideration as a whole in this study without branching it into provinces. Therefore, instead of using panel data analysis, time series cointegration methods are conducted in this study and the results does not reflects regional differences in terms of energy consumption or pollution across provinces. Another study for Turkey is conducted by Ozturk and Acaravci (2010). They used Autoregressive distributed lag model for Turkey over the period 1968-2005 with the variables of CO_2 emissions, energy consumption and economic growth and their finding from linear logarithmic model did not support the EKC hypothesis for Turkey. As mentioned before, even the studies cover Turkey as a case, using different control variables or different time periods may be the reason of having different conclusion. This study also uses renewable energy consumption and energy intensity while testing the EKC by using cointegration methods including ARDL. However, EKC hypothesis is supported in this study for the case of Turkey. Hacioglu (2009) employed bound test for the period of 1960-2005 to examine the nexus between carbon emissions, income, energy consumption and foreign trade, and she concluded that the variables are significant in explaining carbon emissions in Turkey and results are consistent with EKC hypothesis in long run. Trade openness, energy, growth and CO_2 emission nexus were examined by Atici (2009) for Bulgaria, Hungary, Romania and Turkey by using panel data over the period 1980-2002. The results found energy use per capita as a significant driver of air pollution and supported presence of EKC for the region. In addition to these, the results of this study also supports the inverted U-shaped hypothesis for Turkey, in line with the findings of Hacioglu (2009) and Atici (2009), while contradicts the findings of Akbostanci et al. (2009) and the findings of Ozturk and Acaravci (2010). These different outcomes can be explained by different dimension of time, different variables chosen as an indicator of pollution or different methodologies and models estimated.

Renewable energy consumption and energy intensity are other factors, with economic growth, determining the CO_2 emission. According to the report written by The World Bank in 2015, utilizing renewable energy sources are playing crucial role for Turkey to decrease its dependence on imported energy sources, and secure her energy supply. In addition to these it may also provide preventing CO_2 emissions from rises in Turkey. However, the report also emphasize that electricity generated from renewables have to be double in nine years to meet the annual demand rises and to achieve the target of 30% share of renewable energy sources by 2023. Renewable energy resources of Turkey are considered as one of most effective solutions for sustainable and clean energy in the country (Kok and Benli, 2017; Ozturk and Yuksel, 2016). In this regard, Turkey, due to its location and climate conditions, has some advantages in terms of having renewable energy sources, such as wind, solar, hydropower and geothermal energy. Estimates of IEA (2016) shows investments in renewable energy resources and energy efficiency are responsible from 70% of emission reductions globally. The report also emphasizes that energy intensity in Turkey has increased by 7.1%, due to the boom in the energy use in the building, transportation and industry sectors, while energy intensity in IEA countries has decreased by 16.3%, during 2005 to 2015. Turkish government targets of reducing energy intensity by 20% till 2023 as a part of the 2012 energy efficiency strategy, and to achieve this target, it is suggested that Turkey should change its energy consumption structure. In this regard, role of renewable energy cannot be ignored for the Turkish economy. However, the finding of Pata (2018) contradicts with these opinions. He investigated an ARDL model analyzing link between renewable energy consumption, financial development and urbanization for Turkey during 1974-2014 within the framework of EKC and found that alternative and renewable energy consumption has no effect on CO_2 emission of Turkey. The findings of this study suggest using renewable energy to decrease the CO_2 emission of Turkey, while decreasing the energy intensity. These results are also in line with the findings of Kok and Benli (2017) and Ozturk and Yuksel (2016) for the case of Turkey.

Additionally, energy intensity refers to amount of energy used per unit value added in production process and it is calculated as dividing total primary energy supply by real GDP and can be used as a measure of energy efficiency (Aydin and Esen, 2018; Mahmood and Ahmad, 2018). Mahmood and Ahmad (2018) stated that countries with higher energy intensity bear additional cost in terms of polluting the environment. According to the Kavak (2005), low level of energy intensity indicates effective and efficient use of energy resources in generating one unit of income. In this sense, transition from inefficient energy resources causing costly production and environmental damage to efficient energy resources will support the sustainable development and growth for the countries, including Turkey. Metcalf (2006) explains decrease in energy intensity by using two argument; either i) energy saving technologies (energy efficient technologies) resulting less energy usage to produce same amount of income should be adopted, or ii) structural changes shifting from energy intensive industries to less energy intensive productions, such as service or information sectors, should occur. Energy intensity can also be affected by behavioral factors such as population, climate, lifestyles, dependence on energy for cooling and heating purposes etc.

According to our knowledge, in environmental economics literature analyzing the nexus between CO_2 emission and growth, there is no study using energy intensity as a proxy for energy use for the case of Turkey. However, Shahbaz *et al.* (2015) investigated the link between energy intensity and CO_2 emission for some African countries by using vector error correction model over the period of 1980-2012. They validated the existence of EKC in most of the countries, but the results were varied for different countries in the case of energy intensity. They found statistically significant positive linked between CO_2 emission and energy intensity in Congo Republic, Gabon, Ghana, South Africa, Botswana, Togo and Zambia, while finding insignificant positive link in Benin, Cameroon, Nigeria and Senegal. Sadorsky (2014) analyzed 16 emerging economies for the year 1971-2009 by using panel data and found significant effect of energy intensity on carbon emission. Another paper, written by Fan et al. (2006) covering over the period of 1975-2000, discussed the impact of technology and population on CO_2 emission by considering energy intensity as a measure of technology, and conclude that the impact of energy intensity differs in different stage of development of countries. According to their results, impact of energy intensity on total CO_2 emission is higher in high income developed countries compared with those of other income levels.

3.Data and Methodology

Under the base of EKC hypothesis, CO_2 emission level is defined as the function of real income (RGDP), square of real income (RGDP2), renewable energy consumption (RNW) and energy intensity (EI), that are given as follow:

$$CO2 = f(RGDP, RGDP2, RNW, EI) \quad (1)$$

Annual data on real income (constant 2010 US dollar) is collected from World Bank Development Indicator Database. Total CO_2 emission from fuel combustion (Mt of CO_2) and total renewable energy consumption (RNW) is obtained from Global Energy Data released by International Energy Agency. Energy intensity is measured as the ratio of total primary energy supply per unit of real GDP. In calculation of energy intensity, total primary energy supply data is gathered from International Energy Agency (2017 edition). In order to test the relationship between growth, renewable energy consumption and energy intensity, the linear model is estimated as given below;

$$\mathrm{L}CO2_t = \mu + \alpha_1 LRGDP_t + \alpha_2 LRGDP2_t + \alpha_3 LRNW_t + \alpha_4 LEI_t + \varepsilon_t \quad (2)$$

All the variables are used in log forms to check the elasticities of CO_2 emission level from fuel combustion with respect to variables. Therefore, L indicates logarithmic forms of the variables, while $\alpha_1, \alpha_2, \alpha_3$ and α_4 represent the respective elasticities. Square of RGDP (RGDP2) in log form is calculated as $(L(GDPPC))^2$. Energy intensity in log $(LTRDB)$ is calculated as $\log(total\ primary\ energy\ supply/real\ income)$. Total final consumption of renewable energy (ktoe) includes sum of energy consumptions from hydro, solar, geotherm, wind, and biofuels as well. According to eq (2) EKC hypothesis can have 4 different shapes as i) Positive linear relationship between growth and CO_2 emission, if $\alpha_1 > 0\ and\ \alpha_2 = 0$, ii) Negative linear relationship between growth and CO2 emission, if $\alpha_1 < 0\ and\ \alpha_2 = 0$, iii) U-shaped relationship between growth and CO2 emission, if $\alpha_1 < 0\ and\ \alpha_2 > 0$, and iv) Inverted U-shaped relationship between growth and CO2 emission, if $\alpha_1 > 0\ and\ \alpha_2 < 0$. In line with the original EKC hypothesis suggested by Grossman and Krueger (1991), we expect positive sign for α_1 and negative sign for α_2. Turning point of income per capita level, where the level of CO_2 emission reaches its maximum, is calculated by the given formula;

$$\eta = \exp(-\alpha_1/(2\alpha_2)) \qquad (3)$$

3.1 Unit Root Tests

In advance to check cointegration, stationarity properties of the variables are checked to find out whether the variables are integrated of order zero (I (0)) or one (I(1)) in their levels and first differences. Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) tests, which are widely used and known, were used to test the null of unit root against the stationarity of the data. Null hypothesis of nonstationary in ADF and PP in their level and first differences are tested and reported in Table 1. As demonstrated in Table 1, the variables are stationary in their first differences. However, this study uses ARDL method and checking the stationarity conditions are not required due to the features of ARDL. ARDL can be employed even if the variables are integrated of order 0, I(0), integrated of order 1, I(1), or mixture, unless they are integrated of order 2, I(2). ARDL cannot estimated if there is any variable that is integrated of order 2. Another advantage of the ARDL is to removing collinearity by allowing the lag of dependent and independent variables. Therefore, it provides both short run and long run estimations simultaneously by employing consistent results removing autocorrelation or omitted variable problems. In addition to all these advantages, while Johansen requires larger samples of data, ARDL preferred in the case of having small sample data, such as a present study, and if there is only single reduced form equation relationship between variables (Pesaran, Smith, and Shin, 2001; Nkora and Uko, 2016).

Table 1: Unit Roots Test Results

		Level		*First differences*	
ADF	**Variables**	**Intercept**	**Intercept & trend**	**Intercept**	**Intercept & trend**
	LCO2	-1.836543 (0)	-3.582625** (0)	-7.515427*** (0)	-5.683983*** (1)
	LRGDP	0.187695 (0)	-2.517604 (0)	-6.352476*** (0)	-6.323827*** (0)
	LRGDP2	0.351080 (0)	-2.309247 (0)	-6.324787*** (0)	-6.325259*** (0)
	LRNW	-0.622578 (0)	-3.090533 (0)	-5.951610*** (0)	-6.254363*** (1)
	LEI	-1.510296 (0)	-2.449592 (0)	-7.069640*** (0)	-7.533014*** (0)
PP	LCO2	-2.481629	-3.593970**	-8.358409***	-10.40289***
	LRGDP	0.185518	-2.694154	-6.349998***	-6.321014***
	LRGDP2	0.370070	-2.484919	-6.325112***	-6.322404***
	LRNW	-1.004047	-3.773546**	-5.971464***	-7.462445***
	LEI	-1.712570	-2.423751	-7.069640***	-8.065976***

*, ** and *** denote rejection of the null hypothesis at the 1%, 5% and 10% levels, respectively. Lag lengths based on SIC is given within the parenthesis.

3.2 Bound Test for Cointegration

Testing for cointegration is the next necessary step to prove the existence of long run equilibrium among variables. When the variables are cointegrated, it means they convergence to equilibrium over time. According to Pesaran et al. (2001), if there is a single long run relationship, this shows existence of single reduced form relationship between dependent and independent variables, and it supports using ARDL method. In the case of having multiple long run relationship, ARDL method cannot be used. Pesaran and Shin (1999) suggested bound test and related F statistics based on the number of the independent variables (k), which are 4 in the study. In the bound test approach, unrestricted conditional error correction model (UECM) is constructed by taking each variable as a dependent variable as given below;

$$\Delta Y_t = \beta_0 + \beta_1 t + \delta_1 Y_{t-1} + \sum_{j=1}^{4} \lambda_j V_{it-1} + \sum_{i=1}^{p} \phi_i \Delta Y_{t-i} + \sum_{j=1}^{4} \sum_{i=0}^{p} \varphi_{ji} \Delta V_{jt-i} + \epsilon_t \quad (4)$$

V is the vector of independent variables, p is the lag length, and Δ is the first difference operator. Here, lag length is selected as 1 by both of Akaike information criteria (AIC) and Schwarz Criterion (SBC). The null of no cointegration, in other words no long run relationship, is tested as $H_0: \delta_1 = \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = 0$, against the alternative $H_1: \delta_1 \neq \lambda_1 \neq \lambda_2 \neq \lambda_3 \neq \lambda_4 \neq 0$. Critical values of F statistics are provided by Pesaran et al. (2001) under three different scenarios as provided in the Table 2. There are three conclusions that can be reached through calculated F statistics; i) when calculated F statistics > the upper bound (which refers critical values for I(1) series) , reject null hypothesis of no cointegration, ii) when calculated F statistics < the lower bound (which refers critical values for I(0) series), do not reject the null hypothesis, ii) when lower bound < calculated F statistics < upper bound, the test is inconclusive. According to the results reported in Table 2, calculated F statistics for three different cases are above the upper bounds at 5% significance, which indicate the existence of long run relationship (cointegration) among variables. Then, in the light of the results, long run elasticities without structural break dummies are estimated using the following ARDL model;

$$\mathrm{Y_t} = \beta_0 + \sum_{i=1}^{p} \beta_i Y_{t-i} + \sum_{j=1}^{4} \sum_{i=0}^{p} \gamma_{ji} V_{jt-i} + \epsilon_t \quad (5)$$

Here, all the variables are same as defined above. Given that a long run relationship exists, the next step to estimate short run model (Error Correction Model) is undertaken as given below;

$$\Delta \mathrm{Y_t} = \beta_0 + \sum_{i=1}^{p} \beta_i \Delta Y_{t-i} + \sum_{j=1}^{4} \sum_{i=0}^{p} \gamma_{ji} \Delta V_{jt-i} + \delta ECM_{t-1} + \epsilon_t \quad (6)$$

In this equation, ECM_{t-1} is the one lagged error correction term. δ is the speed of adjustment toward the equilibrium that are obtained from running long term cointegration model, and its value should be between 0 and -1 to support the existence of convergence. ECT is obtained by ordinary least square method from the equation as given below;

$$ECM_t = LCO2_t - \hat{\alpha}_0 - \hat{\alpha}_1 LRGDP_t - \hat{\alpha}_2 LRGDP2_t - \hat{\alpha}_3 LRNW_t - \hat{\alpha}_4 LEI_t \qquad (7)$$

The following section explains the long run and short run estimation results obtained from ARDL model. Stability tests and diagnostics tests conducted to ensure the goodness of fit of models are also be discussed in coming section.

Table 2: Bound Test Results at %5 level

k=4		**Lower Bound I(0)**	**Upper Bound I(1)**
F_{iii} (Unrestricted intercept and no trend)	6.238609	2.86	4.01
F_{iv} (Unrestricted intercept and restricted trend)	5.948811	3.05	3.97
F_v (Unrestricted intercept and unrestricted trend)	7.133189	3.47	4.57

4.Empirical Results

It has been applied ARDL model specifications to have long run and short run estimation results after proving the existence of cointegration among variables. The representation of long run model reported in Table 3 can be written as;

$$LCO2 = -113.65 + 9.0551 LRGDP - 0.1489 LRGDP2 - 0.1922 LRNW + 0.9675 LEI \quad (8)$$

The coefficients of all variables are statistically significant and all shows elasticities, due to using log-log model specification. The coefficient of LRGDP indicates the income elasticity of CO_2 emissions in Turkey and 1% increase in real GDP (RGDP) will raise CO_2 emission by 9.05%. The sign of coefficient of LRGDP2 is negative, and its value is 0.14. This value implies that 1% increase in RGDP after its turning point will lead 0.15% decrease in CO_2 emission level. Once again, estimated positive sign of RGDP and estimated negative sign of RGDP2 proves the existence of inverted U-shaped EKC hypothesis for Turkey, which corroborates with the findings of Atici (2009), Halicioglu (2009), Dogan (2016), Pata (2018) for Turkey. However, it contradicts with results obtained by Oztürk and Acaravci (2010) and Akbostanci et al. (2009). Using different sample periods, empirical specifications, and using different dependent and independent variables can be the reasons of having different conclusions in the studies.

The main interest of the paper is the impact of the renewable energy consumption in CO_2 emission. And estimated coefficient of renewable energy consumption, which can be called as renewable energy elasticity of CO_2 emission, is found as negative. Its value can be interpreted as; 1% increase in renewable energy consumption cause to fall in CO_2 emissions by 0.19%. Therefore, it is suggested to use renewable energy resources, instead of using fossil fuel energy sources such as oil, coal, gas etc., to make positive contribution to the environment in terms of pollution. These results contradict to study conducted by Pata (2018), but consistent with the findings of Bilgili et al. (2016) for 17 OECD countries, Zambrano et al. (2018) for Peru. The findings of Zambrano et al. (2018) do not support the inverted U shaped EKC for Peru, while it supports positive impacts of renewable energy consumption on environmental quality.

Table 3: Long run Estimation Result with Constant (Dependent Variable: LCO2)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LRGDP	9.055131	1.808768	5.006243	0.0000
LRGDP2	-0.148973	0.034075	-4.371962	0.0001
LRNW	-0.192225	0.071947	-2.671754	0.0109
LEI	0.967536	0.142183	6.804867	0.0000
C	-113.6549	25.18557	-4.512699	0.0001

The coefficient of energy intensity is 0.96 and highly significant which implies that 1% increase in energy intensity will lead to 0.96% increase in the CO_2 emissions in the long run.

From the coefficients of RGDP and RGDP2, it is possible to calculate turning points in real income, where the level of CO_2 emission reaches its maximum, by using the given formula;

$$\eta = \exp(-9.0551/(2(-0.1489))) \quad (9)$$

After discussing the long run coefficients, the next step is to interpret the short run coefficients obtained from ARDL. Table 4 reports the error correction model. The estimated significant positive coefficient of $\Delta LRGDP$ and estimated negative coefficient of $\Delta LRGDP2$ confirms the existence of EKC hypothesis in short run as well in Turkey. Again, the coefficient of $\Delta LRNW$ is negative and significant at 5% significance level, while ΔLEI has negative coefficient at 1% significance. All the coefficient signs of respective variables are same as obtained from long run equation and significant. The coefficient of ECM_{t-1} , which is used as ECMC(-1) in the model, has a negative sign, as expected for convergence, and statistically significant 1% level. However, it is quite a few large with the value of 0.9286. This implies that 92% of the deviations from equilibrium in CO2 emission due to the shock in last year adjust back to the long run equilibrium in the current year.

Table 4: Error Correction Model (Dependent Variable: DLCO2)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DLRGDP	17.38195	3.305948	5.257782	0.0000
DLRGDP2	-0.305375	0.061806	-4.940845	0.0000
DLRNW	-0.204164	0.098099	-2.081193	0.0442
DLEI	1.140327	0.097082	11.74602	0.0000
C	0.000114	0.004196	0.027215	0.9784
ECMC(-1)	-0.928654	0.157337	-5.902339	0.0000
R-squared	0.901175	Mean dependent var		0.046099
Adjusted R-squared	0.888172	S.D. dependent var		0.054848
S.E. of regression	0.018341	Akaike info criterion		-5.033180
Sum squared resid	0.012784	Schwarz criterion		-4.789881
Log likelihood	116.7300	Hannan-Quinn criter.		-4.942953
F-statistic	69.30366	Durbin-Watson stat		1.810453
Prob(F-statistic)	0.000000			

As a last stage of estimations, stability of the estimated parameters and goodness of fit also tested. Cumulative Sum of recursive residuals (CUSUM) and Cumulative Sum of Recursive Residuals of Square (CUSUMQ) statistics, as can be seen from the table, fall inside the critical bounds at 5% significance, which implies that all coefficients are stable. Goodness of the ECM model is tested against autocorrelation and heteroscedasticity. White test and Breusch-Pagan-Godfrey tests is used to detect heteroscedasticity problem if any. F statistics for the null of homoscedasticity become 0.6177 (p value is 0.6870) and 0.5112 (p value is 0.9390) in Breusch-Pagan-Godfrey tests and White test, respectively. Therefore, we do not reject the null hypothesis and can conclude that there is no evidence of heteroscedasticity. In addition to these, Breusch-Godfrey Serial Correlation LM test is conducted to check null of no autocorrelation and we do not reject null hypothesis with the value of F statistics 0.5360 (p value is 0.5897). Regression Specification Error Test (RESET), as a general functional form misspecification test, is also applied and F becomes 0.0298 with 1 and 37 degrees of freedom. The p value is 0.8637 which implies that we do not reject null, and overall, there is no evidence for nonlinearity and functional form misspecification.

Table 5: FMOLS, DOLS, and CCR Estimation Results with Constant (Dependent Variable: LCO2)

Method: Fully Modified Least Squares (FMOLS)

Variable	Coefficient	Std. Error	t-Statistic	**Prob.**	
					R^2=0.9988, Adj.R^2=0.9987
LRGDP	8.423972	1.819084	4.630887	0.0000	S.E. of Reg=0.0201, DW=1.5654
LRGDP2	-0.137478	0.034228	-4.016579	0.0003	Mean Dep.Var= 4.9179
LRNW	-0.212348	0.076911	-2.760971	0.0087	S.D. Dep. Var=0.5595 Sum Squared Resid=0.0158
LEI	1.080755	0.132559	8.153033	0.0000	Long-run variance=0.0004
C	-103.0350	25.08352	-4.107676	0.0002	

Method: Dynamic Least Squares (DOLS)

Variable	Coefficient	Std. Error	t-Statistic	Prob.	
					R^2=0.9993, Adj. R^2=0.9988
LRGDP	9.206063	2.783293	3.307616	0.0029	S.E. of Reg=0.0179, DW=1.5585,
LRGDP2	-0.151720	0.052350	-2.898197	0.0077	Mean Dep.Var = 4.9222
LRNW	-0.163426	0.112738	-1.449612	0.1596	S.D. Dep. Var=0.5342 Sum Squared Resid=0.0080
LEI	0.762979	0.287419	2.654589	0.0136	Long-run variance=0.0004
C	-119.2042	39.18825	-3.041836	0.0055	

Method: Canonical Cointegrating Regression (CCR)

Variable	Coefficient	Std. Error	t-Statistic	Prob.	
					R^2=0.9987, Adj. R^2=0.9986
LRGDP	8.135508	1.956708	4.157752	0.0002	S.E. of Reg=0.0203, DW=1.5458 Mean Dep.Var= 4.9179
LRGDP2	-0.132019	0.036798	-3.587664	0.0009	S.D. Dep. Var=0.5595 Sum Squared Resid=0.0161
LRNW	-0.197351	0.075880	-2.600819	0.0131	Long-run variance=0.0004
LEI	1.071870	0.148552	7.215444	0.0000	
C	-99.49975	27.02089	-3.682326	0.0007	

Finally, FMOLS, DOLS and CCR cointegration methods have been employed to check robustness of ARDL estimation results (Table 5). All cointegration methods support the presence of inverted U-shaped EKC for Turkey, with positive and significant coefficient of LRGDP and negative and significant coefficient of LGDP2. The income elasticities of CO_2 emission is almost same as obtained from ARDL estimation, which are 9.05 and 0.15 for LGDP and LGDP2 respectively, with the values of 8.42 and 0.14 in FMOLS, 9.20 and 0.15 in DOLS and 8.14 and 0.13 in CCR. The coefficient of total renewable energy consumption is negative and significant in both FMOLS and CCR estimations, but insignificant in DOLS method, although it has negative sign, as same in ARDL. The value of renewable energy elasticity of CO_2 emission is 0.21, 0.16, and 0.19 in FMOLS, DOLS and CCR methods respectively. These results support the conclusions we derived from the ARDL model with the value of 0.19, which means that 1% increase in renewable energy consumption will decrease CO_2 emission in Turkey by 0.19%. Furthermore, the elasticity of CO_2 emission with respect to energy intensity is inelastic in both ARDL and DOLS cointegration models, with the highly significant positive values of 0.96 and 0.76, which both are less than 1. However, due to having values greater than 1, in both FMOLS and CCR models with the values of 1.08 and 1.07 respectively, energy intensity elasticity of CO_2 emission become elastic. Again, the results obtained regarding energy intensity in the models supports the findings from ARDL method.

5.Conclusion

This paper examines the long run relationship between CO_2 emission, real income, renewable energy consumption and energy intensity in Turkey by using the data covering the period of 1971-2015. ARDL method is used to capture both short run and long run estimation results simultaneously. Empirical results support the inverted U shaped EKC hypothesis for the case of Turkey. Estimated long run income elasticity of CO_2 emission is 9.0551. Estimated renewable energy consumption elasticity of CO_2 emission is -0.1922 and energy intensity elasticity of CO_2 emission is 0.9675. Briefly, increase in renewable energy consumption decreases the CO_2 emission, while energy intensity rises CO_2 emission level.

As a result, strong support of the governments is needed for investing and using renewable energy resources in both industrial production and household usage in order to meet increasing energy demand and keeping environment clean. Public policies can be classified as short-term and long-term policies and be ranked accordingly. Overall strategy should consider both energy diversification and environmental quality within the sustainable development framework. Turkey should find alternative energy resources providing energy saving policies and strategies like wind, sun and geothermal energy projects.

Finally, public awareness is also crucial for Turkey for implementing effective energy policies. Government or public authorities should train the managers in different sectors and provide consultancy services for companies. Energy consumption in the buildings should be promoted to achieve sustainable development in Turkey. To decrease the fossil fuel consumption, government should increase the research and development activities through providing financial supports to design products in the areas of renewable energy resources or energy inefficiency.

However, energy intensity can be different at sector level depending on their energy requirements. This study uses yearly based aggregate data and ignores the regional differences within the country and does not focus on the industrial or sectoral differences. Therefore, further studies should analyze these sectoral differences with considering all greenhouse gases by collecting disaggregated data at initial stage.

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