Wind Energy And CO2 Emissions: AMG Estimations For Selected Countries

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Wind energy and CO_2 emissions: AMG estimations for selected countries

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Abstract

This study aims to analyze the relationship between wind energy consumption, coal energy consumption, globalization, economic growth and carbon emissions in a selected country group. This analysis was made with the data of 37 countries for the period 2000-2019. In order to examine the long-term relationship between the variables, the AMG method, which makes an estimation by considering the cross-sectional dependence and slope homogeneity, was used in the study. According to the long-term coefficient estimates of the cointegrated variables, wind energy consumption has a statistically significant and negative effect on carbon emissions in the long run. A 1% increase in wind energy consumption reduces carbon emissions by 0.018%. On the other hand, the globalization variable has a statistically significant and positive effect on carbon emissions in the long run. A 1% increase in globalization increases carbon emissions by 0.107%. These findings show the importance of wind energy consumption in reducing carbon emissions. For this reason, policies should be produced to increase wind energy consumption globally and necessary incentives should be provided.

Keywords: Wind energy consumption, fossil energy consumption, CO_2 emissions, AMG, slope homogeneity panel cointegration

1. Introduction

With the industrialization process experienced globally, the increase in the population of countries caused an increase in energy demand. The energy consumption rate increased by 44% in the period 1971-2014).(Eren, Taspinar, and Gokmenoglu 2019) In this period, especially fossil fuel consumption rates reached up to 80% (Bilgili et al. 2017). Increasing industrialization activities increased dependence on fossil fuels. This dependency is particularly concentrated in the consumption of coal resources. All these processes have revealed the risk of decreasing non-renewable energy sources. Along with the problems experienced in resources, environmental problems have also started to emerge (Baek 2016). Problems such as global warming and climate change have occurred with the use of fossil fuels (Ozturk and Acaravci 2010). Such increases in greenhouse gas and CO_2 emissions have become dangerous for human life and living life. The share of CO_2 emissions in greenhouse gas emissions has reached 60% . In 2011, 34,459 million tons of CO_2 emission was emitted and this amount increased the CO_2 emission rate within the greenhouse gas emission by 80%. British Petroleum (BP) Statistical Review of World Energy (BP 2020) CO_2 emission, which was 29.714 million tons in 2009, increased to 34.169 million tons in 2019 (REN21 2020). Advances in the field of economy and energy cause problems in environmental and social areas when the same level of precautions are not taken. Increases in economic costs and the emergence of environmental problems have led global actors to produce alternative policies that take into account the economy and the environment. These policies primarily led to the emergence of new resources in the energy fields. With the use of renewable energy sources, many benefits are provided in social and environmental areas. The rate of renewable energy usage in the world is increasing day by day. This ratio increased to 18.1% between 2008-2017 (REN21 2019).This rate is expected to increase to 60% in 2050, according to the estimation studies of the International Renewable Energy Agency (IRENA) (Gielen et al. 2019). Wind energy is seen as the most promising resource for the future in renewable energy. Wind energy, which is a clean energy source due to not using fossil fuels, is a valuable and preferred type of energy in many aspects. It is estimated that wind energy will meet 5% of the world's energy need by 2025 (Poore 2008). The use of wind energy has many benefits. Its main benefits are; (Aydin 2019);

- In the use of wind energy, greenhouse gas emissions are reduced, so the carbon dioxide generated during the consumption phase is compensated by the carbon dioxide held during the photosynthesis process.
- With the use of wind energy, the supply problem in non-renewable energy sources is eliminated.
- Wind energy has a negative impact on CO_2 emissions.

With the use of wind energy, global effects are observed in the short and long term. The use of wind energy is a type of energy that has an impact on all areas such as economic, political, social and environmental. With the use of this type of energy, significant advantages are obtained in all sectors. Increasing production and energy demands in the world with globalization have an important effect on increasing carbon emissions. When the increasing energy demand in the world is met by wind energy, it eliminates the problems caused by non-renewable energy sources. At the same time, it ensures that they are aware of renewable resources. Decisions made on energy issues around the world affect the economy as well as the environment and so on. It also seems to have effects in areas such as. Among the renewable energy sources, the effect of wind energy in terms of benefit and environmental friendliness is significant. Therefore, this study aims to examine the relationship between wind energy and CO_2 emissions in 37 countries using wind energy. There are very few studies in the literature examining the relationship between wind energy and CO_2 emissions. In the studies carried out, all energy types under the title of renewable energy have been examined together (Apergis and Payne 2011; Destek and Aslan 2020). In this respect, this study is a first in the literature. For the country group used in the study, the relationship between wind energy and CO_2 emissions is examined for the first time. At the same time, the augmented mean group (AMG) estimation method is used for the first time both for this country group and for variables. According to estimates, wind energy has a statistically significant and negative impact on CO_2 emissions in this country group. There is a significant and positive difference between the globalization variable and CO_2 emissions. Based on these findings, policy recommendations that encourage the production and consumption of wind energy should be made for this group of countries. An important contribution will be made in both economic and environmental areas with policies supporting wind energy. The sections that are subject to this study are listed in order. After the introduction of the study, the second section includes the literature section. In the literature section, studies on wind energy, globalization and CO_2 emissions, which are the main variables of the study, are mentioned. In the third part of the study, definitions are made on variables and country group. While the method part is included in the fourth part of the study, the analysis estimates made for the variables are included in the fifth part. The last section contains the results and policy recommendations found in the study.

2. Literature Survey

2.1. Wind Energy and CO_2 Emissions

There are many studies in the literature that examine the impact of renewable energy on carbon emissions. There are very few studies examining the effect of wind energy, which is included in renewable energy, on carbon emissions. In the studies in the literature, decreases in energy resources, climate change and environmental degradation caused by carbon emission are mentioned. Due to such results of non-renewable energy, it has been recommended to carry out studies to increase the use of renewable energy resources (Burg et al. 2018; He et al. 2018; Shao and Rao 2018). Cross-section depression and slop homogeneity problems were ignored in the studies. Differently in our study, we make analyzes that take into account the cross-section dependence and slope homogeneity problems of our variables. Destek and Aslan (2020), examined the relationship between renewable energy and environmental pollution for G7 countries. Wind, solar and hydroelectric variables are examined in renewable energy. In the study, the relationship between renewable energy variables and carbon emission was analyzed by AMG predictor and causality test. As a result of the tests, there is a negative relationship between renewable energy variables and carbon emissions. In other words, an increase in renewable energy consumption causes a decrease in carbon emissions. Sari et al. (2008) examined the relationship between renewable energy (hydroelectric energy, solar, wind energy), industrial production and employment for the USA. Panel ARDL estimator was used with 6-month data for the years 2001-2005. According to the estimation results, increases in income and employment were found to have a positive effect on renewable energy. Ohler and Fetters (2014) examined the causality relationship between economic growth and renewable energy sources (biomass, solar, wind energy) for OECD countries. A bidirectional causality relationship was found between renewable energy and economic growth with the data for the years 1990-2008. Dogan and Seker (2016) examined the impact of trade openness, renewable and non-renewable energy variables on carbon emissions for European Union countries. There is a negative relationship between the data for the years 1980-2012 and renewable energy and CO_2 emissions. There is a positive relationship between commercial openness and non-renewable energy sources and CO_2.

2.2. Globalisation and CO_2 Emissions

Studies examining the relationship between globalization and CO_2 emissions are available in the literature. There are many studies in the literature that have a positive effect on the CO_2 emissions of globalization. Cross-section dependence and slop homogeneity relationships between variables were not examined in the studies in the literature. In our study, we made analyzes that take into account the cross-section dependence and slope homogeneity problems of variables. Antweiler et al. (2001) examined the relationship between globalization and environmental pollution in their studies on 44 countries. In the study, a positive relationship was found between globalization and environmental quality. Choi et al. (2010) examined the relationship between globalization, economic growth, and CO_2 emissions for China, Korea, and Japan. As a result of the study, a positive relationship was found between CO_2 emission and globalization variables. Naranpanawa (2011) examined the relationship between the globalization variable and CO_2 emissions for Sri Lanka in the period 1960-2006. A short-term relationship was found between the obtained results and variables. Rahman (2013) examined the relationship between CO_2 emission and globalization for Bangladesh over the period 1972-2009. The study found that the increase in globalization has a positive effect on CO_2 emission. Yıldırım (2013) examined the relationship between globalization, economic growth and CO_2 emissions for 20 developed and developing countries for the period 1990-2009. In the study, it was found that globalization and economic growth positively affect CO_2 emissions. Increases in globalization and economic growth will cause increases in carbon emissions. Gu et al. (2013) examined the relationship between globalization and CO_2 emissions using time series analysis for the period 1981-2010 for the Chinese economy. As a result of the study, a long-term relationship was found between the two variables. A one-way relationship from globalization variable to CO_2 emission was found with the causality test. Zhang et al. (2017) examined the relationship between globalization, economic growth, energy consumption and CO_2 emissions. The study was conducted for the years 1971-2013 on 17 industrialized countries. With the findings obtained, a positive relationship was found between globalization and carbon emission. Liu et al. (2020) examined the relationship between globalization and carbon emissions for G7 countries. A positive correlation has been found between the results obtained and globalization and CO_2 emissions. Similarly, Nguyen and Le (2020) examined in which direction there is a relationship between globalization and CO_2 in Vietnam. ARDL test was used in the study covering the period 1990-2016. With the study, it has been determined that globalization in Vietnam increases CO_2 emissions. A positive relationship was found between the globalization variable and CO_2 emission in studies conducted on different country groups.

3. Data and Emprical Model

3.1. Data

This study covers annual time series data from 2000 to 2019 for 37 countries: Argentina, Australia, Austria, Belgium, Brazil, Canada, China, Czech Republic, Denmark, Egypt, Finland, France, Germany, Greece, Hungary, India, Iran, Ireland, Italy, Japan, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Russian Federation, South Korea, Spain, Sri Lanka, Sweden, Switzerland, Turkey, Ukraine, United States and United Kingdom. These countries were chosen because of the availability of their data. We selected the following variables: wind energy consumption (million tones of oil equivalent per capita), coal energy consumption (million tones of oil equivalent per capita), gross domestic product (current USD per capita), CO_2 (million tones per capita) and total globalization index (KOF index from 0 to 100). Wind energy consumpion, coal energy consumption are obtained from British Petroleum Statistic (2019), gross domestic product from World Development Indicators (2019) and total globalization index from KOF Index of Globalization (2019).

Table 1. Variables' name, symbol, and source

Variables	Symbol	Unit	Source
Carbon emissions per capita	CO_2	million tones	British Petroleum Statistic
Wind energy consumption per capita	WI	million tones of oil equivalent	British Petroleum Statistic
Coal energy consumption per capita	CE	million tones of oil equivalent	British Petroleum Statistic
Total globalization index	TGI	KOF index from 0 to 100	KOF Index of Globalization
Gross Domestic Product per capita	GDP	current US$	World Data Bank

Table 2. Descriptive statistics of the model variables

Variables	Mean	Maximum	Minimum	Std. Dev.	Observations
CO_2	1.910535	3.329646	-0.595082	0.732673	682
WI	-4.866557	-0.590135	-13.50328	2.648024	682
CE	-1.236478	1.021039	-12.27569	1.594268	682
TGI	3.905740	4.480482	2.769138	0.379318	682
GDP	9.792135	11.68540	6.094279	1.216459	682

3.2. Emprical Model

The relationship of CO_2 emissions with wind energy consumption, coal energy consumption, total globalisation and economic growth is written as:

$$CO_2 = f(WI, CE, TGI, GDP) \quad (1)$$

Where CO_2 is per capita CO_2 emissions, WI is wind energy consumption per capita, CE coal energy consumption per capita, TGI is total globalisation, and GDP is gross domestic product per capita. The natural logarithm of all variables is taken. The model used in the analysis is shown in Equation (1),

$$\ln CO_{2it} = \beta_0 + \beta_1 \ln WI_{it} + \beta_2 \ln CE_{it} + \beta_3 \ln TGI_{it} + \beta_4 \ln GDP_{it} + \varepsilon_{it} \quad (2)$$

Where i represents the number of cross-sectional (i.e., 1, 2, 3, 4…N) and T indicates the perion (2000-2019). $\ln CO_{2it}$ represents the dependent variable carbon dioxide emission; β_0 represents the slope intercept; β_1 is the coefficient of wind energy consumption per capita, β_2 is the coefficient coal energy consumption per capita, β_3 is the coefficent of total globalisation and β_4 is the coefficient of economic growth and ε_{it} expresses the error correction term.

3.3. Emprical Methodolgy

Before starting the analysis of the variables, it is necessary to decide which unit root test will be used first. In cases where there is no cross-sectional dependency between series, first generation unit root tests are used. Second generation unit root tests are used when there is cross sectional dependency. In the study, Pesaran scaled LM and Pesaran CD tests suggested by Pesaran (2004) are used to detect cross-sectional dependency (Pesaran 2004). Pesaran scaled LM test was obtained by studying on Breusch and Pagan (1980) LM test (Breusch and Pagan 1980). Breusch and Pagan (1980) LM test becomes more suitable for panel studies with N> T property. Pesaran (2004) proposes an alternative Pesaran CD test in equation (3) with the model residues used in the study. In this test with model residues, more consistent results are obtained for panel cross-sectional dependency (28). In equation (3) $\hat{\rho}_{ij}^2$ shows the correlation coefficient obtained with the model residues.

$$CD = \sqrt{\frac{2}{N(N-1)}} \sum_{i=0}^{N-1} \sum_{j=i+1}^{N} T_{ij} \, \hat{\rho}_{ij}^2 \rightarrow N(0,1) \quad (3)$$

Second generation unit root tests proposed by Pesaran (2007) were used for variables that include cross-sectional dependency (Pesaran 2007). The most suitable test among unit root tests for cross section dependency is the second generation unit root test. Cross Section Generalized Dickey Fuller (CADF) second generation unit root test was used to stationarity the series. This test developed by Pesaran (2007) is called the cross-sectional Im, Pesaran, and Shin (2003) panel (CIPS) test (Im, Pesaran, and Shin 2003). Pesaran (2007) aims to eliminate cross-section dependency asymptotically in panel analysis with this test. Dickey-Fuller (CADF) regressions are used to eliminate cross-sectional dependency. CADF (4) nolu eşitlikte verilmiştir.

$$\Delta y_{it} = \alpha_i + b_i y_{i,t-1} + c_i \bar{y}_{t-1} + \sum_{j=0}^{p} d_{ij} \Delta \bar{y}_{t-j} + \sum_{j=1}^{p} \delta_{ij} \Delta \bar{y}_{t-j} + e_{it} \qquad (4)$$

In Equation (4) $\bar{y}_{t-j}$ is the cross-sectional mean of the lagged levels, $\Delta\bar{y}_{t-j}$ is the cross-sectional mean of the first differences of the individual series. To estimate the CIPS statistic after CADF regression analysis, the t-statistical means ($CADF_i$) of the lagged variables are calculated with equation (5).

$$\text{CIPS} = N^{-1} + \sum_{i=1}^{N} \text{CADF}_i \qquad (5)$$

Cointegration test can be performed for variables that become stationary by taking the difference. Slope parameters and cross-section dependencies tests should be performed before proceeding with the cointegration test. Since the data in the panel has the property of N>T, the estimator suggested by Pesaran and Yamagata (2008) can be used. This estimator determines the slope homogeneity using the weighted fixed effect pooled estimator (WFE), OLS, and deviations from the mean (Pesaran and Yamagata 2008). The estimator suggested by Pesaran and Yamagata (2008) is given in equation (6) and (7).

$$S = \sum_{i=1}^{N} (\beta_i - \beta_{WFE})' \frac{(x_i' M_\tau x_i)}{\sigma_i^2} (\beta_i - \beta_{WFE}) \qquad (6)$$

$$\Delta = \sqrt{N} \left(\frac{N^{-1} S - k}{\sqrt{2k}} \right) \qquad (7)$$

In equation (6), β_i is obtained from the OLS estimate. β_{WFE} is the coefficients obtained from the WFE estimation. M_τ shows the Identity matrix. x^i indicates the processor that is sensitive to deviation from the mean containing explanatory variables. k is the number of regressors and σ_i^2 is the estimate of σ_i. Cointegration estimation for variables are used estimators proposed by (Pedroni 2001) and (Kao 1999). However, these methods do not take into account the cross-sectional dependency and slope homogeneity. The method developed by Westerlund (2007) takes into account slope homogeneity and cross-section dependency. Equation no (8) includes the Westerlund (2007) estimator (Westerlund 2005).

$$\Delta z_{it} = \delta_i d_i + \theta_i \left(z_{i(t-1)} + \pi_i' y_{i(t-1)} \right) + \sum_{j=1}^{m} \theta_{ij} \Delta z_{i(t-j)} + \sum_{j=0}^{m} \varphi_{ij} \Delta y_{i(t-j)} + \omega_{it} \qquad (8)$$

The θ_i term in equation (8) is the adjustment used to express the rate at which variables return to long-term equilibrium. Based on OLS estimates, Westerlund (2005) suggests 2 panel statistics based on error correction and panel cointegration statistics with 2 groups of mean statistics. Fully modifieded ordinary least squares (FMOLS) method developed by OLS and (Pedroni 2001), can be used to estimate the long-term coefficients of cointegrated variables. The FMOLS method ignores the dependence and slope homogeneity between panel sections while estimating. Cointegration estimation can be made by taking the average of the coefficients estimated for each section in the panel data. Estimates made by ignoring the dependence between sections may cause erroneous and inconsistent results as (Pesaran and Smith 1995) stated. It is an estimator created by the common corelated effect mean group (CCEMG) (Pesaran 2006), which estimates by considering the cross section dependency and slope homogeneity. CCEMG, which makes important predictions in the presence of cross-section dependency and slope homogeneity, includes linear combinations of cross-sectional means of observed common effects and variables. In equation (9) y_{it} and x_{it} represent the observable elements. f_t is the heterogeneous factor with the unobserved common factor, b_i is the country coefficient estimates, e_{it} is the error term, and the $\alpha_i$is the cut-off term.

$$y_{it} = \alpha_{li} + b_i x_{it} + c_i f_t + \alpha_i \bar{y}_{ti} + \beta_i \bar{x}_{ti} + e_{it} \tag{9}$$

There is augmented mean group (AMG) prediction analysis developed by (Bond and Eberhardt 2013) and (Eberhardt and Teal 2010) and similar to CCEMG. Both estimates use cross-section averages for all variables. Unlike AMG, it uses dynamic processes for common factors that are unobservable for different reasons. Long-term coefficients CCEMG and AMG are expected to be cointegrated with the predicted variables. Cointegration estimation for the variables uses the estimator suggested by (Pedroni 2001).

4. Estimation Results

Before testing the existence of a long-term relationship between variables, cross-section dependency tests of variables should be performed. Table 3 contains the cross section dependence test results of the variables. Since the probe value (0.0000) is less than 0.05 for all tests in the table, "no cross-sectional dependence", which is included as the H0 hypothesis, is rejected. It is understood from the test results that there is a cross-sectional dependence between variables.

Table 3. Result of cross-sectional dependence

Variables	Breusch-Pagan LM		Pesaran scaled LM		Pesaran CD	
	CD statistics	Prob.	CD statistics	Prob.	CD statistics	Prob.
lnCO_2	7967.352*	0.0000	200.0558*	0.0000	19.19634*	0.0000
lnWI	10902.22*	0.0000	280.4706*	0.0000	103.7094*	0.0000
lnCE	5470.586*	0.0000	131.6448*	0.0000	21.81181*	0.0000
lnTGI	4591.219*	0.0000	111.5947*	0.0000	15.44467*	0.0000
lnGDP	9975.682*	0.0000	255.0837*	0.0000	98.57682*	0.0000

Note: Table values give CD test statistics, probability values in parentheses. (*) signify at 1% level.

After the presence of cross section dependency between variables, second generation unit root test was applied which takes into account the cross section dependency. Table 4 contains the stationarity test results for which both the level and the differences of the variables are taken. When the differences of non-stationary variables are taken in level values, they become stationary.

Table 4. Result of CIPS panel unit root test

CIPS Variables	At level with trend	First difference with trend
lnCO_2	-2.463	-4.270*
lnWI	-2.477	-3.982*
lnCE	-2.675	-4.672*
lnTGI	-2.076	-3.316*
lnGDP	-2.297	-3.283*

Not: Critical table values for CIPS N = 37 T = 20. It was determined according to the Schwarz information criteria. "*" Indicates the 1% significance level.

The data in Table 5 shows the homogeneity coefficients of the variables. According to the test results for all variables, the slopes of the variables are heterogeneous since the significance levels are less than 0.05.

Table 5. Result of slope homogeneity test

	Test statistic	p-value
Delta_tilte	20.172*	0.000
Delta_tilde_adj	24.404*	0.000

"*" Indicates the 1% significance level.

Cointegration tests of variables whose stability is provided can be done. In order to test the cointegration between variables, Pedroni and Kao cointegration tests were applied. The results in Tables 6 and 7 show the Pedroni and Kao cointegration statistics values. Since most of the place tests are significant in the Pedroni cointegration test, there is a cointegration relationship between variables. Since the significance level of the Kao cointegration test is less than 0.05 significance level, the variables are cointegrated. Since this study takes into account cross-section and slope homogeneity, Westerlund (2007) test, which includes more precise measurements, was also used. Table 6 includes Westerlund cointegration statistics values. With the obtained results, a cointegration relationship between the dependent variable and the explanatory variables was determined.

Table 6. Result of Westerlund's cointegration tests

	t-Staistic	Prob.
ADF	-1.7502*	0.0400

Notes: "**" Indicates the 5% significance level.

Table 7. Pedroni Residual Cointegration Test Results

	Weighted Statistic	Prob.		Test Statistic	Prob.
Within-Dimension			**Between-Dimension**		
Panel v-Statistic	-0.324473	0.6662			
Panel rho-Statistic	3.446701	0.9994	Group rho-Statistic	5.918501	1.0000
Panel PP-Statistic	-6.047254*	0.0000	Group PP-Statistic	-9.474912*	0.0000
Panel ADF-Statistic	-6.225483*	0.0000	Group ADF-Statistic	-7.586712*	0.0000

Notes: "*" Indicates the 1% significance level.

Table 8. Kao Residual Cointegration Test Results

	t-Staistic	Prob.
ADF	-3.464312*	0.0003

Notes: "*" Indicates the 1% significance level.

After the existence of the cointegration relationship of the variables, the long-term relationship and coefficient values of the variables were tried to be tested. Table 9 contains the results of 3 different tests showing the long-term relationship between variables. These tests are AMG, FMOLS and OLS tests.

Table 9. Result for long-run analyses

	AMG		**FMOLS**		**OLS**	
Variables	**coefficient**	**prob.**	**coefficient**	**prob.**	**coefficient**	**prob.**
lnWI	-0.0187479	0.003*	-0.055611	0.0000*	-0.074634	0.0000*
lnCE	0.2840405	0.000*	0.318544	0.0000*	0.2301465	0.0000*
lnTGI	0.1079838	0.095***	0.092721	0.0000*	0.054796	0.1725
lnGDP	0.1162592	0.000*	0.158214	0.0000*	0.421039	0.0000*

"*" 1%, "***" 10%, Indicates the significance level.

The second column of Table 9 contains the FMOLS test results. According to FMOLS results, wind energy reduces carbon emissions. A 1% increase in wind energy use reduces carbon emissions by 0.055%. Coal, globalization and growth increase carbon emissions. There is a significant relationship between all variables and carbon emissions. The third column of Table 9 contains the OLS test results. According to OLS test results, there is a negative relationship between wind energy and carbon emissions. A 1% increase in wind energy use reduces carbon emissions by 0.074%. There is a significant relationship between CO_2 emission and CO_2 emission of all variables except the globalization variable. Increasing use of coal, globalization and growth variables cause increases in carbon emissions. In this study, AMG was also preferred for the estimation of long-term coefficients. The AMG test takes into account the problems of cross section and slope homogeneity. Therefore, AMG test, which gives more consistent results than FMOLS and OLS results, was also used in the study. Three tests showing the long-term relationship and coefficients gave similar results. According to AMG test results, there is a statistically significant and long-term relationship between the dependent variable CO_2 emission and wind energy consumption, coal energy consumption, total globalization and growth. Wind energy consumption has a negative and significant effect on carbon emissions. A 1% increase in wind energy use reduces carbon emissions by 0.018%. In other words, the increase in wind energy use in the long term causes the level of carbon emission to decrease. There is a significant and positive relationship between the globalization variable, another independent variable, and the carbon release. A 1% increase in the globalization variable increases the carbon emission by 0.10%. Coal and growth variables affect carbon emissions significantly and positively.

5. Conclusion and policy implications

Increasing production and consumption levels in the globalizing world in the 21st century have led countries to search for new in many areas. In these pursuits, steps have been taken towards meeting the energy demand, which is the basis of the production sector. Countries have met the energy needs of the current generation system from non-renewable energy sources until a certain period. The increasing population in the world and the increasing demands accordingly have led to the search in the field of renewable energy. Renewable energy sources, which have many advantages both economically and environmentally, have attracted the attention of international institutions and organizations. The low cost of renewable energy resources, its minimum impact on environmental pollution and the reduction of dependence on energy imports are the reasons why countries prefer this type. Wind energy is an important renewable energy source among renewable energy sources in terms of energy cost and environmental impact. Wind energy is more advantageous than other renewable energy sources both in terms of raw material and economical. It is expected that wind energy will become even more advantageous in terms of the future. By 2025, wind energy is expected to meet 5% of the world's energy need. Wind energy has a significant reduction in environmental air pollution and carbon emissions. The benefit of wind energy indicates that it will have more demand in production and consumption areas on a global scale. The study examines the relationship between wind energy, globalization, fossil fuel and economic growth variables and CO_2 emissions in the group of countries using wind energy. The AMG estimation method, which solves the cross-section depence and slop homogeneity problems, was used for the long-term coefficient estimation between variables. For the analysis, data from 2000-2019 from 37 country groups were used. Cross-sectional dependence of all variables is specified. The second generation unit root test, CIPS test, is used for unit root testing. In the Westerlund cointegration test, it was determined that the variables are cointegrated. The long-term coefficients of the cointegrated variables were estimated using the AMG method. According to the estimates, it was found that wind energy has a statistically significant and negative effect on CO_2 emissions in 37 country groups. 1% increase in wind energy reduces CO_2 emission by 0.018%. On the other hand, a significant and positive relationship has been found between globalization and CO_2 emissions. A 1% increase in the globalization variable increases the carbon emission by 0.10%. Coal and growth variables affect carbon emissions significantly and positively. These results show that the group of countries using wind energy has reduced carbon emissions. With the results obtained, it is understood how important wind energy, which is a renewable energy source, is both economically and environmentally. Therefore, as in this country group, importance should be given to wind energy, which is a type of renewable energy all over the world. For this, policies and projects required for low-cost, more efficient and environmentally friendly wind energy should be established. With such projects, it should be aimed to reduce the costs even more and to keep the efficiency to be obtained at the highest level. These countries, which have an important contribution to the world product, can act jointly with public and private enterprises in order to create environmental awareness in societies. With all the initiatives made, new research and development investments will increase and new green resources will be added to renewable energy resources. The positive effects of all initiatives made with public and private enterprises can be observed in both social and economic terms. Most importantly, all initiatives made as country groups can be an important effort to leave a more livable world to future generations.

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and material

All data generated or analysed during this study are included in this published article [and its supplementary information files].

Competing interests

The authors declare that they have no any competing interests.

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Authors' contributions

TG and EU analyzed and interpreted the data, and contributed equally to the writing of the article. The author(s) read and approved the final manuscript.

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