EKONOMIA I PRAWO. ECONOMICS AND LAW
Volume 20, Issue 4, December 2021
p-ISSN 1898-2255, e-ISSN 2392-1625
www.economicsandlaw.pl

ORIGINAL ARTICLE
received 10.07.2021; revised 01.12.2021; accepted 31.12.2021
Citation: Kaya, M.V., Yılmaz, S.S., & Özdemir, M.G. (2021). The relationship of economic growth and carbon-dioxide emissions: an application on member countries of Organization of Islamic Cooperation. *Ekonomia i Prawo. Economics and Law*, 20(4), 813–833. https://doi.org/10.12775/EiP.2021.048.

The relationship of economic growth and carbon-dioxide emissions: an application on member countries of Organization of Islamic Cooperation

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Abstract

Motivation: Humanity has benefited from natural resources in production activities throughout history and this pressure on natural resources has increased even more with the efforts of industrialization. In this process, people benefited heavily from fossil fuels in their production and distribution activities, thereby damaging the environment and the atmosphere to a large extent. With the destruction of the environment, it has become important for the countries and the academic circles to measure environmental damage with the increase of economic activities in order to take various measures.

Aim: At this point, in this study, the relationship between economic growth and carbon-dioxide emissions was examined within the scope of 50 countries that are members of the Organization of Islamic Cooperation (OIC). In this process, annual data of the countries concerned between 1995 and 2017 were used; Pedroni Cointegration Analysis, Granger Causality Analysis, Pooled Mean Group Estimator (PMGE) and Mean Group Estimator (MGE) methods were used to measure and estimate the relationship between these two variables. The causality analysis shows that the economic growth is the Granger cause of carbon-dioxide emissions in the country group studied. In addition, the coefficients obtained in PMGE and MGE analyzes were found as 0.43 and 0.33 and were statistically significant and positive. Then, with the help of Hausman Homogeneity Test, it was decided between the two estimators, and it concluded that PMGE Estimator is the more reliable estimator.
Results: The results obtained with the PMGE estimator indicate that the 1% increase in economic growth increased carbon dioxide emission by 0.43%.

Keywords: carbon dioxide emission; economic growth; environment; panel data analysis
JEL: C33; O44; Q56

1. Introduction

In the last fifty years, economists have been discussing the reciprocity relationship between the environment and the economy on a market basis. Mainly, mainstream economic thinkers described these effects as market failures and defined them as “externalities”, on the other hand, they put forward their resolutions in order to internalize externalities through economic interventions, including the market economy perspective. Economic discipline has been able to continue to solve these problems related to environment and market relations in various sub-branches with abstractions. Ecological economics has been a sub-discipline that brings a breath of fresh air to past studies and tries to create a new perspective by adding ethical values to the socio-economy. In addition, environmental taxes, which are taxing harmful social costs and are an environmental protection method, are considered as the most concrete recycling of solutions and interventions regarding the pricing of marginal social cost under the name of emissions taxes and the understanding that “punishment is a price”. Thus, externalities were internalized, and these costs were priced to minimize marginal social costs. Although the economic policies used here attempt to reduce CO2 emissions with negative incentives, how successful environmental taxes are is controversial both at the country level and at the cross-country level.

The essence of environmental taxation, which is one of the measures taken to protect the environment in the long term, is essentially a negative incentive policy to reduce carbon emissions. On the other hand, besides the negative effects of carbon emissions on the environment, its relation with economic growth is one of the relations that economists think about in terms of the results of economic activity and try to make sense of in commodity creation as much as its ecological effect. In this study, the historical development of the study subfields, which includes the attention of economists to environmental impacts, will be given in a way to see the big picture, and then the direction and effect of the relationship between growth and individual energy emission will be explained with Member Countries of Organization of Islamic Cooperation (OIC).

2. Literature review

Environmental disaster and negative environmental exposure are the result of collective decisions of economic agents in the production sector (Dietz & van der Straaten, 1992). Especially in the last decade, environmental awareness has emerged as a field of study both economically and politically (Spash, 1999). Although there is a wide range of literature researching the relationship between economic growth and carbon emissions, it can be easily seen that there are few studies dealing with this topic on base of Islamic Countries. All studies reviewed are given in table 1 in chronological order.

Considering the studies on table 1, it can be clearly seen that almost all of the studies point out that there is a cointegration between economic growth and CO2 emissions and causality one-way or two-way from economic growth to CO2 emissions. Besides it, some studies found N-type relationship while other one's observed U-type relationship. In addition to this, they show that the strongness of the relationship between the two variables varies according to the income group or country group. Unlike the studies below, this study examines the relationship in the context of Islamic countries, and in this respect, the study differs from previous studies.

Microeconomics and macroeconomics, the two main branches of economics, have basically built their methodologies on understanding the output effect of the decisions taken by economic actors. With the economic modeling method used frequently in economics and the assumptions established, it builds the economic relations of these actors, who are in search of stable equilibrium, by making decisions that will maximize their own preferences. On the other hand, the ecological economy is a sub-branch of economy, which includes the financial evaluation of positive environmental services and negative externalities, as well as physical assessments of the environmental impacts of the human economy measured by new indicators. This branch gives importance to social indicators in addition to monetary indicators. Studying the relationships between property rights and natural resource management is another key focus of the ecological economy. The ecological economy supports multi-criteria evaluations on cost-benefit analysis and emphasizes the immeasurability of values. That is, Ecological Economics without "traditional macroeconomic growth" has developed an ecological macroeconomics. On the other hand, in the literature, the most cited study examined the relationship between carbon dioxide emissions, which is a greenhouse gas at the center of global warming estimates, and economic development.

Accordingly, the estimates from global panel data suggested the concept of decreasing CO2 marginal emission tendency (MPE — marginal propensity to emit) to economic terminology and showed a decrease in the tendency to emit carbon dioxide as GDP per capita increases (Holtz-Eakin & Selden, 1995). In their study, Holtz-Eakin & Selden (1995) stated that the growth of global carbon dioxide emissions will continue with 1.8 percent per year for the foreseeable future and this rate is not a result that is not sensitive to average output growth. Again, in the study, it is predicted that the emission increase will continue especially in low-income countries. He emphasized on the results of distribution of emission reduction policies as the second factor, which is explained by the fact that it will grow fastest in low-income countries. It was also mentioned in the study that efforts to reduce emissions will have a negative impact on economic growth and impose a burden on low-income countries.

The question of whether carbon emissions diverge from economic growth is one of the main problems that come to mind for the link between environment and economic growth.

This relationship, which ecological economics also tries to measure, is taken as far as the fiction of economic growth to minimize environmental pollution. However, in the last study, Wang & Jian (2020) have focused on the fact that the emission effect in emerging markets is very important in the global carbon emission and found that there is a strong relationship between their economic growth and emissions.

Wawrzyniak & Doryń (2020), in their articles which includes the institutional economics perspective, analyzed effect of carbon dioxide dependent economic growth on the quality of institutions in the scope of 93 emerging and developing countries between 1995–2013. According to them, the effectiveness of governments can affect economic growth with CO2 emissions. In essence, the study has brought a new alternative perspective to the environmental Kuznet curve based on institutional quality. Since it reinterpreted this relationship, he offered a different perspective on the economic growth-emission link. The main purpose of the study was to investigate the effect of GDP per capita on carbon dioxide emissions depending on the quality of institutions. Academics examined the concept of marginal impact of GDP per capita in full and diminishing specialization, possible government effectiveness, government control situation scenarios, and showed effect on growth on its possible path (Wawrzyniak & Doryń, 2020).

In this study, it is measured econometrically whether the effect of CO2 emission trend on economic growth, as stated in theory, is decreasing. On the other hand, since we do not include intervention and economic institutions from an institutional point of view, it essentially causes our study to be examined under ecological economics.

3. Methods

The table 2 contains abbreviations and explanations regarding the variables used in the analysis. The study uses data from 50 countries that are members of the Organization of Islamic Cooperation (OIC). The countries in the scope of the study are given in the table 3.

As of today, Organization of Islamic Cooperation has 57 members. At this point, the availability of data was decisive in the selection of the country in the study. In the study, the model created by Gülmez (2015) was followed in determining the effects of economic growth of countries on carbon dioxide emissions.

3.1. Model, data set and countries

This model can be formulated as follows:

$$LCO_{it} = \beta_0 + \beta_1 LGDPC_{it} + u_{it}. \quad (1)$$

In the model LCO_{it} shows the natural logarithm of Carbon Dioxide Emissions Per Capita for each country. Again, $LGDPC_{it}$ shows the GDP per capita for the countries. The inclusion of this variable in the model was realized by taking its natural logarithm. u_{it} is the error term of the model. The model is arranged in full logarithmic form. Therefore, the coefficients directly express the flexibility. On the other hand, the coefficient of the variable $LGDPC_{it}$ is expected to be positive, based on both early academic studies and theoretical expectations.

Summary statistics on the variables used in the analysis in the table 4 are included. When the statistics are analyzed, it is seen that as a result of taking the natural logarithms of the variables, the size of their ranges have approached each other. The average value of the LCO series is greater than its median. The slope coefficient is –0.04. These two values show that this series is skewed to the left. But the opposite is true for the LGPC series. The average value of this series is less than the median value. Therefore, the series is skewed to the right. The kurtosis value of both series is less than the normal distribution kurtosis value. This means the two series are more flattened than the normal distribution. In addition, Jarque–Bera test statistics are larger than 5.99, indicating that the series do not have a normal distribution. Finally, the number of observations studied is 1150.

3.2. PMGE and MGE method

In this study, the Pooled Mean Group Estimator (PMGE) and Mean Group Estimator (MGE) methods were used to analyze the economic growth and carbon dioxide emission amounts of the countries. These methods, unlike the methods that only provide long-term coefficient estimates, also enable the estimation of short-term coefficients by creating an error correction model.

Developed by Pesaran & Smith (1995), MGE is created using the Autoregressive Distributed Lag Model (ARDL) models for each cross-section. Here, ARDL models are estimated first and then long-term parameters are obtained by taking the average of the long-term parameters obtained from these models.

Thus, long-term parameters are allowed to change from unit to unit. PMGE estimator developed by Pesaran et al. (1999) is a mixture of Fixed Effects estimator and MGE estimator. At this point, the MGE estimator allows constant and slope parameters to change across units, while the constant effects estimator meant to allow constant coefficients to change across units but stipulates the condition of slope parameters to be fixed. PMGE estimator consisting of the combination of these two estimators; it keeps long-term parameters constant, allowing error variances and short-term parameters to change between units.

PMGE is based on the Auto Regressive Distributed Lag (ARDL) model with heterogeneous short-term dynamics. In this context, the unrestricted error correction model can be formulated as follows (Tatoğlu, 2013, p. 245):

$$\Delta y_{it} = \varphi \varepsilon_{it-1} + \beta_i^{'} x_{it} + \sum_{J=1}^{p-1} \Delta y_{it-j} + \sum_{J=0}^{q-1} \partial_{ij} \Delta x_{it-j} + \varepsilon_{it}. \tag{2}$$

where: $\varphi_i = -\left(1 - \sum_{J=1}^{p} \lambda_{ij}\right), \beta_i = \sum_{J=0}^{q} \partial_{ij}, \lambda_{ij}^{*} = -\sum_{m=J+1}^{p} \lambda_{im}, \partial_{ij}^{*} = -\sum_{m=J+1}^{q} \partial_{im}.$

4. Results

In this section, the relationship between economic growth and carbon dioxide emissions will be tackled with the help of panel data analysis within the scope of the relevant countries. For this purpose, firstly, the cross-section dependencies of the variables used in the model will be determined, and then unit root tests related to the relevant variables will be conducted depending on the results of the horizontal cross-section dependence. Then, co-integration analysis will be conducted following determination of the stationarity levels of the variables and the results will be interpreted. Afterwards, causality analyzes will be performed and coefficients will be interpreted by obtaining coefficients for both all countries and individuals ones through PMGE and MGE estimators.

4.1. Cross sectional dependency test

Pesaran (2004, pp. 5–6) in his study derived a homogeneity test that can be used in cases where N>T. This test at the same time has a zero mean in cases where N and T are constant. This test can be used in a wide range of panel data analyzes that are exposed to multiple slope coefficients and error variances.

The table 5 shows the cross-section dependency test results for this test. When Pesaran (2004) CD test results are examined, probability values for each variable are statistically significant at the level of 1%. This means that the H_0 hypothesis that the series does not have a cross-section dependency is rejected and it is accepted that there is the cross-sectional dependency. These test results are to provide information about which unit root tests should be applied.

In panel data studies, unit root tests are divided into two as the first generation and the second generation. First generation tests are based on the assumption that there is no correlation between units, and if there is a correlation between units, the power of these tests weakens. Examples of first-generation tests are Breitung (2000), Choi (2001), Hadri (2000), Harris & Tzavalis (1999), Im et al. (2003), Levin et al.(2002) and Maddala & Wu (1999) tests. For the second-generation tests, Bai & Ng (2004), Moon & Perron (2004), O'Connell (1998), Pesaran (2004; 2007) tests can be given (Tatoğlu, 2013, p. 199). For this reason, Pesaran (2007) CIPS unit root test will be used, which considers cross-sectional dependency.

4.2. Unit root test results

In the panel data analysis, it is important to examine the stationarity levels of the series in order to perform long-run cointegration analyze. In this context, Pesaran (2007) developed the Cross-Sectionally Augmented IPS test by averaging the Horizontal Cross-Sectional Dickey Fuller (CADF) statistics. The table 6 contains the CIPS unit root test results for the variables used in the analysis.

In model with both constant and trend, which can also be seen from the table 6, CIPS test statistics for the LCO series are higher than 5% critical table value for the LCO series. Again, in models with both constant and trend, the CIPS test statistics are higher than 5% critical table value for the level values of LGDPC series. This indicates that the series are not stationary with their level values. However, when the differences of the series are taken, this situation changes and CIPS test statistics take values below all 5% critical table values in both models. This means that both series become stationary when their first differences are taken. Co-integration analysis can be performed for the series with the same level of stationarity.

4.3. Cointegration analysis results

Following with the determination that the series are I(1), a cointegration analysis can be performed in order to determine whether they move jointly in the long term. The table 7 contains the results of Pedroni (1999; 2004) and Westerlund (2007) cointegration tests for the relevant variables.

As can be seen from the table 7, probability values are lower than 5% in all Westerlund cointegration tests and 6 of Pedroni cointegration tests. This indicates that in both tests, the H_0 hypothesis that there is no cointegration between the series is rejected and it is concluded that the series are cointegrated in the long run.

4.4. Causality analysis results

After determining that the series are cointegrated, the relationship between countries' growth rates and carbon dioxide emissions in the relevant period were examined with the help of Granger Causality and Dumitrescu & Hurlin (2012) causality analyzes. The causality analysis results are given in table 8.

According to the causality analysis results, the probability values for both tests are statistically significant at the level of 5%. This means that there is a two-way causality between economic growth and carbon dioxide emissions of countries.

4.5. PMGE and MGE results

The table 9 shows the PMGE and MGE analysis results showing the general short and long run coefficients for the model used in the study. As can be seen from the estimation results, all of the coefficients obtained from PMGE and MGE analyzes are statistically significant at 1% level. As a result of both analyzes, the coefficients of ec, which is the error correction term, are negative and statistically significant. These findings point out that there is a long-term relationship between economic growth and carbon dioxide variables between 1995 and 2017 within the scope of the countries included in both models. According to the PMGE model, a deviation between the two variables will come to equilibrium after approximately three and a half periods (1/0.2764647=3.617). For the MGE model, this period is approximately 2.5 periods. On the other hand, the coefficient of the LGDPC variable for the PMGE model was 0.66 for the long term and 0.44 for the short term. When it comes to the MGE model, 1% increase in economic growth increases the carbon dioxide emission 0.89% in the long term and 0.33% in the short term.

At this point in the literature, Hausman Test is conducted regarding which model results are more reliable. The table 10 shows the results of the Hausman test. As can be seen from the table 10, the probability value of Hausman Test statistics was calculated as 0.33. This value indicates that null hypothesis cannot be rejected at 5% statistical significance level. Therefore, it is concluded that there is no systematic difference between the coefficients and the MGE estimator is a more valid and reliable estimator. However, in order to be compared, the results related to the MGE estimator will be given in the tables 9 and 11.

The table 11 shows the long-term and short-term coefficient estimates for each country calculated with the PMGE and MGE estimators and obtained for the model of the study. As can be seen from the table 11, the PMGE estimator provides a single coefficient estimate for all countries in the long run, while the MGE estimator gives individual results for each country, both in the long run and in the short run. The estimated long-term coefficient for the economic growth variable with the PMGE estimator was found to be 0.6608871, and this value is the same as the model estimated above. According to this result, 1% increase in the economic growth variable in the long-term increases carbon dioxide emission by 0.66%. When error correction parameters are evaluated within the scope of related countries, error correction parameter is negative in all 50 countries. However, the error correction parameter of 27 countries is statistically significant at the level of 5%. In countries where error correction parameter is statistically significant; when these parameters are analyzed in terms of magnitudes, three countries with the highest values found were Ivory Coast (0.67), Togo (0.65) and Kuwait (0.61) respectively. For Turkey, this parameter was estimated to be 0.34. it means that in case a deviation that may occur between the two variables, this relation will come again to equilibrium in about three periods for Turkey (1/0.34=2.9411). According to the results of the forecast, such a deviation will correct in the Ivory Coast, Togo and Kuwait in about 1.5 periods.

On the other hand, considering the statistical significance of the coefficients, the coefficients of Bahrain (2.40), Albania (1.82), Niger (1.61), Ivory Coast (1.45), Indonesia (1.41), Egypt (1.35) Pakistan (1.05), Tunisia (0.71), Gabon (0.63) and Turkey (0.41) are statistically significant at the 5% level. If situations of the countries are assessed ¬in terms of magnitudes of coefficients, as can be seen above, among the countries whose coefficients are statically significant, Bahrain has the highest coefficient while the lowest coefficient belongs to Turkey. Coefficients estimates point out that 1% increase in economic growth during the period studied in the relevant countries increases in carbon dioxide emissions by 2.40% in Bahrain and 0.41% in Turkey. This case, in the sense that the production increases converted to less carbon dioxide for countries in scope, can be interpreted as a positive sign for Turkey.

5. Conclusion

In the last two centuries, the economic growth efforts and industrialization activities of the countries have caused the pollution of the environment and the air even if it has increased the welfare of the humanity. Thus, this issue has become a focus of interest for the governments and academicians of many countries in terms of investigating the effects of these increases in the production of goods and services on the environment. In this study, the relationship between economic growth and carbon dioxide emissions of the countries within the scope of 50 countries that are members of the Organization of Islamic Cooperation was examined with this motivation. The data set of the study covers the annual data between 1995 and 2017, and the coefficients of this relationship are estimated by PMGE and MGE estimators.

During the analysis, firstly, cross-sectional dependency tests related to the variables used in the model were performed. According to Pesaran (2004) test results, it was concluded that there is a cross-sectional dependency between the series within the period examined. Following this determination, Pesaran (2007) CIPS unit root tests, one of the second-generation unit root tests, were applied to find out the stationarity levels of the series and it was concluded that both series were I(1). Afterwards, the cointegration relationship between the series was determined by Pedroni (1994) and Westerlund (2007) tests. Then, with the help of Granger Causality and Dumitrescu & Hurlin (2012) causality analysis, the causality direction and presence among the variables were investigated. The results of the analysis indicate that two-way causality exists between economic growth and the carbon dioxide variable within the country group under consideration and within the period studied.

In the end of the analysis section, the coefficients regarding the direction and size of the relationship between the two variables were estimated through PMGE and MGE methods. The Hausman Homogeneity test, which of these methods produces more valid results, shows that the long-term parameters of PMGE estimators satisfy homogeneity conditions.

In the parameter estimates obtained with PMGE method, error correction parameters were negative and significant for generally all countries. This result indicates the existence of a relationship in balance in the long term if there is a deviation between the variables in the short term. According to PMG results, the long-term coefficient of the economic growth variable was found to be 0.66 for all countries and this coefficient is statistically significant at the level of 5%. This coefficient indicates that the 1% increase in economic growth during the period examined increased the countries' carbon dioxide emissions by an average of 0.66%. On the other hand, when the short-term parameter estimates for the countries are examined, the coefficients of Bahrain (2.40), Albania (1.82), Niger (1.61), Ivory Coast (1.45), Indonesia (1.41), Egypt (1.35), Pakistan (1.05), Tunisia (0.71), Gabon (0.63) and Turkey (0.41) were statistically significant at the 5% level.

When sorted in the order of magnitude of the coefficients, among the countries who's their coefficients are statistically significant, Bahrain has the highest coefficient, and the lowest coefficient belongs to Turkey. A 1% increase in economic growth that occurred during the period examined in the countries concerned by this coefficient increases carbon dioxide emissions 2.40% in Bahrain and 0.41% in Turkey. These findings can be interpreted as a positive sign for Turkey compared to countries in scope in terms of transformation of production to less carbon dioxide.

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Acknowledgements

Author contributions: authors have given an approval to the final version of the article. Authors contributed to this work as follows: M.V.K. developed the concept and designed the study, S.S.Y. collected the data and analysed and interpreted the data, M.G.Ö. prepared the draft of the article, M.G.Ö. revised the article critically for important intellectual content.

Funding: this research was fully funded by the BC GRUP AS, Turkey.

Appendix

Table 1.
Literature review

Authors	Range/date	Sample size/country	Method	Results
Sancar & Polat (2021)	2000–2016 annually	Turkey, Brazil, Mexico, China, India and South Africa	Dumitrescu–Hurlin Causality Test	There is a two-way causality relationship between economic growth and CO2 emissions.
Konat (2021)	1960–2016 annually	Turkey	Dynamic Ordinary Least Squares (DOLS)	There is a long-term cointegration between economic growth and CO2 Emissions.
Atgür (2021)	1971–2014 annually	China	Johansen Cointegration, Vector Error Correction Model (VECM)	There is a long-term and significant relationship between economic growth and energy consumption and carbon emissions in China. Economic growth and energy use positively affect carbon emissions.
Wang & Jiang (2020)	2000–2014 annually	China	Logarithmic Mean Divisia Index	China's CO2 emissions increased with rapid economic growth.
Raza & Shah (2018)	1991–2016 annually	G7 countries	Fully Modified Least Squares (FMOLS), DOLS, Panel Causality	Economic growth increases the CO2 emission.
Bekar (2018)	1977–2014 annually	Turkey	Toda–Yamamoto and Dolado–Lütkepohl VAR Causality	There is a one-way and positive causality relationship from CO2 emissions to economic growth in Turkey.
Pata (2018b)	1974–2013 annually	Turkey	ARDL (Autoregressive Distributed Lag)	There is a long-run relationship between GDP and CO2 emissions.
Pata (2018a)	1974–2014 annually	Turkey	ARDL Bounds Test	As GDP increases in Turkey, per capita CO2 emissions continue to increase.
Alper & Alper (2017)	1985–2014 annually	Turkey	ARDL Bounds Test	Economic growth and energy consumption caused environmental pollution to increase.
Ghorashi & Rad (2017)	1972–2012 annually	Iran	GMM	The positive bidirectional causality relationship between CO2 emissions and economic growth.
Alam et al. (2016)	1970–2012 annually	India, Indonesia China, Brazil	Autoregressive Distributed Lag Bound Test	For all four countries, CO2 emissions have increased statistically significantly with increases in energy and consumption income.
Topalli (2016)	1980–2010 annually	India, China, Brazil, South Africa	VECM	The increase of GDP by 1% raises CO2 emission almost by 0.55% in related countries.
Chaabouni et al. (2016)	1995–2013 annually	51 countries	Generalized Method of Moments (GMM)	For 51 Countries, there is a two-way causality between GDP and CO2 emissions.
Pata & Terzi (2016)	1972–2011 annually	Turkey	Dolado–Lütkepohl (DL) VAR Granger Causality	Economic growth increases CO2 emissions.
Uysal & Yapraklı (2016)	1968–2011 annually	Turkey	Hatemi–J Cointegration Test	There is a cointegration between GDP Per Capita and CO2 emissions.

Authors	Range/date	Sample size/country	Method	Results
Albayrak & Gökçe (2015)	1975–2010 annually	Turkey	Johansen Cointegration, VECM	As the income level increases, environmental pollution and destruction increase initially, and after higher income levels, environmental improvement begins.
Gülmez (2015)	2000–2012 annually	24 OECD countries	DOLS, Panel Granger Causality	There is a cointegration relationship between economic growth and air CO2 Emissions in the long run and unidirectional causality from economic growth to CO2 Emissions.
Gündüz (2014)	1960–2018	18 OECD countries	Pooled Mean Group Estimator (PMGE)	There is a cointegration relationship between environmental pollution and economic growth.
Aytun (2014)	1981–2001 annually	83 countries	FMOLS	Economic growth caused carbon emissions to increase.
Saatçi & Dumrul (2011)	1950–2007 annually	Turkey	Kejriwal Cointegration Test	There is a long run relationship between economic pollution and economic growth.
Çetin & Seker (2014)	1980–2010 annually	Turkey	ARDL Bound Test	There is a long run relationship between economic growth and CO2 Emissions.
Burnett et al. (2013)	1981–2003 monthly	US	DOLS	Economic growth makes emissions intensities to drive.
Şahinöz & Fotourehchi (2013)	1994–2010 annually	26 OECD countries	Panel Fixed and Random Effects	There is an increasing linear relationship between GDP and CO2 emissions.
Sarısoy & Yıldız (2013)	1992–2009 annually	30 countries	Panel Fixed Effects and Granger Causality	CO2 emissions increase with the rise in income.
Dal et al. (2013)	1960–2010 annually	Turkey	DOLS	Economic growth increases carbon emissions in long run.
Ayşe & Zeren (2011)	2000–2005 annually	17 Mediterranean countries	Fixed and Random Effect Models	Economic growth makes carbon emissions increased.
Aşıcı (2013)	1970–2008 annually	213 countries	Panel Fixed-Effects Instrumental Variable	Income per capita has positive relationship with per capita pressure on nature.
Boopen & Vinesh (2011)	1975–2009 annually	Mauritian	Ordinary Least Squares (OLS), Decomposition-Based Vector Autoregressive	Economic and human activities have increasingly negative environmental impacts on the country.
Roca et al. (2001)	1973–1996 annually	Spain	Seemingly Unrelated Regression	Economic growth increased economic pollutants.

Source: Own preparation.

Table 2.
Definitions of variables

Variable Name	Abbreviations	Explanation of variables
CO2 emission per capita	LCO	This variable is calculated as the natural logarithm of the carbon dioxide emissions per capita of the countries. Carbon dioxide emissions per capita are obtained by dividing the annual total carbon dioxide emission data of the countries by the population. The unit of measure is tons.
economic growth rate	LGDPC	This variable was calculated by taking the natural logarithm of GDP per capita. (2010, USA Dollar).

Source: Own preparation based on Ritchie & Roser (2020), World Bank (2021).

Table 3.
Countries covered

No	Countries	No	Countries	No	Countries
1	Albania	18	Guyana	35	Oman
2	Algeria	19	Indonesia	36	Pakistan
3	Azerbaijan	20	Iranian	37	Saudi Arabia
4	Bahrain	21	Iraq	38	Senegal
5	Bangladesh	22	Jordan	39	Sierra Leone
6	Benin	23	Kazakhstan	40	Suriname
7	Brunei	24	Kuwait	41	Tajikistan
8	Burkina Faso	25	Kyrgyz Republic	42	Togo
9	Cameroon	26	Lebanon	43	Tunisia
10	Chad	27	Malaysia	44	Turkey
11	Comoros	28	Maldives	45	Turkmenistan
12	Ivory Coast	29	Mali	46	Uganda
13	Egypt	30	Mauritania	47	UAE
14	Gabon	31	Morocco	48	Uzbekistan
15	Gambia	32	Mozambique	49	West Bank and Gaza
16	Guinea	33	Niger	50	Yemen
17	Guinea–Bissau	34	Nigeria		

Source: Own preparation.

Table 4.
Summary statistics

Statistics	LCO	LGDPC
average	0.160905	7.769830
median	0.321890	7.624422
maximum	3.567640	11.08006
minimum	–4.154016	5.371408
standard deviation	1.780777	1.320297
skewness	–0.042330	0.538677
kurtosis	2.066902	2.436554
Jarque–Bera	42.06309	70.82862
number of observations	1150	1150

Source: Own preparation.

Table 5.
Pesaran (2004) CD test results

Variable	CD-test	P-value	Correlation	Absolute (correlation)
LCO	45.79	0.000	0.273	0.519
LGDPC	71.40	0.000	0.425	0.693

Note:

H_0 hypothesis express that there is no cross-sectional dependency, CD~N (0,1).

Source: Own preparation.

Table 6.
CIPS unit root test results

Variable	Levels values				First differences			
	critical values			CIPS test statistic	critical values			CIPS test statistic
	1%	5%	10%		1%	5%	10%	
with constant								
LCO	–2.23	–2.11	–2.04	–2.20	–2.23	–2.11	–2.04	–4.51
LGDPC				–1.89				–3.74
with constant and trend								
LCO	–2.73	–2.61	2.54	–2.22	–2.73	–2.61	2.54	–4.51
LGDPC				–1.91				–3.92

Note:

The lag length was determined by the F-test according to the general to specific method.

H_0: The series is not stationary.

Source: Own preparation.

Table 7.
Panel Westerlund and Pedroni cointegration tests

Westerlund				Pedroni					
Statistics	Value	Z-value	p-value	Statistics	Value	p-value	Statistics	Value	p-value
G_t	−3.16	−10.89	0.000	panel v	1.96	0.025	group rho	−1.30	0.096
G_a	−8.62	−1.86	0.031	panel rho	−3.05	0.001	group PP	−4.71	0.000
P_t	−17.7	−7.25	0.000	panel PP	−4.40	0.000	group ADF	−4.57	0.000
P_a	−9.18	−0.441	0.000	panel ADF	−4.84	0.000	–	–	–

Source: Own preparation.

Table 8.
Granger and Dumitrescu–Hurlin causality analysis results

	Granger		
Null Hypothesis	Observations	F-statistic	Probability
LGDPC is not Granger cause of LCO.	1050	6.23769	0.002
LCO is not Granger cause of LGDPC.		13.5691	0.000
	Dumitrescu–Hurlin		
Null Hypothesis	W-statistic	Zbar-statistic	Probability
LGDPC is not homogeneously cause of LCO.	4.80399	6.74677	0.000
LCO is not homogeneously cause of LGDPC.	3.36913	2.90262	0.003

Source: Own preparation.

Table 9.
PMGE and MGE analysis results for all countries

		Model: $LCO_{it} = \beta_0 + \beta_1 GDPC_{it} + u_{it}$		
Period	Variables	Coefficients	Standard errors	p-value
		PMGE		
long-run	$LGDPC_{it}$	0.6609	0.0368	0.000
short-run	ec	−0.2765	0.0281	0.000
	$LGDPC_{it}$	0.4339	0.1059	0.000
	constant	−1.360	0.1465	0.000
		MGE		
long-run	$LGDPC_{it}$	0.8941	0.2247	0.000
short-run	ec	−0.4166	0.0288	0.000
	$LGDPC_{it}$	0.3398	0.1035	0.001
	constant	−2.882	0.4982	0.000

Source: Own preparation.

Table 10.
Hausman test results for long-term homogeneity

Variable	(b) MG	(B) PMG	(b−B) Difference	sqrt (diag(V_b−V_B) S.E.
$LGDPC_{it}$	0.8941	0.6609	0.2333	0

Notes:
b: consistent under H_0 and H_a, obtained from MGE.
B: inconsistent under H_a, efficient under Ho, obtained from PMGE.
H_0: difference in coefficients not systematic.

$$chi^2(1) = (b-B)'\left[\left(V_b - V_B\right)^{-1}\right](b-B) = 0.91.$$

Prob>chi²=0.3399.

Source: Own preparation.

Table 11.
PMGE and MGE analysis results

Model: $LCO_{it} = \beta_0 + \beta_1 GDPC_{it} + u_{it}$

ID	Countries	PMGE Long-run coefficient $LGDPC_{it}$	PMGE Short-run coefficient $LGDPC_{it}$	PMGE Short-run *ec*	MGE Long-run coefficient $LGDPC_{it}$	MGE Short-run coefficient $LGDPC_{it}$	MGE Short-run *ec*
1	Albania	1.8259***	−0.1213	1.2205***	1.6178***	−0.4475***	1.8259***
2	Algeria	1.0283	−0.3701**	1.1027	1.5938	−0.2710	1.0283
3	Azerbaijan	0.0492	−0.0471	0.0251	0.1308	−0.8106***	0.0492
4	Bahrain	2.4092**	−0.3857**	1.0182	2.3292*	−0.3930**	2.4092**
5	Bangladesh	1.0759	−0.0524	1.3140***	−0.5472	−0.5427**	1.0759
6	Benin	0.9211	−0.0316	5.1912***	−0.0126	−0.2719*	0.9211
7	Brunei	−0.9961	−0.1817	−1.8341	−0.776	−0.2561	−0.9961
8	Burkina Faso	0.7221	−0.0579	1.7362***	0.3008	−0.3872**	0.7221
9	Cameroon	−0.1735	−0.3703**	1.8128**	−0.5399	−0.4131***	−0.1735
10	Chad	0.2777	−0.2627**	1.4225***	0.0496	−0.9347***	0.2777
11	Comoros	1.2459	−0.5727***	2.1848**	0.3863	−0.7192***	1.2459
12	Ivory Coast	1.4576**	−0.6736***	1.0080**	1.1794	−0.7548***	1.4576**
13	Egypt	1.3540**	−0.3787***	0.6781***	1.3744*	−0.3855**	1.3540**
14	Gabon	0.6305**	−0.0819	1.6615***	0.4300	−0.2148	0.6305**
15	Gambia	−0.2279	−0.0143	−3.8922	−0.1544	−0.0372	−0.2279
16	Guinea	0.1773	−0.2658**	0.5163	0.2786	−0.2571*	0.1773
17	Guinea-Bissau	0.1952	−0.4252**	0.4095	0.2353	−0.4462**	0.1952
18	Guyana	0.6648	−0.3527**	0.6106***	0.6554	−0.3687*	0.6648
19	Indonesia	1.4181***	−0.4349***	0.3863	1.6307***	−0.3814**	1.4181***
20	Iranian	−0.2122	−0.1517*	1.0770***	−0.2799	−0.2434	−0.2122
21	Iraq	0.0653	−0.3790**	0.6524	0.0657	−0.3804**	0.0653
22	Jordan	0.8444	0.0363	−4.3485	0.9182	−0.0228	0.8444
23	Kazakhstan	0.1497	−0.5776***	0.6163***	−0.0222	−0.6561***	0.1497
24	Kuwait	−0.1417	−0.6106***	0.6064***	−0.1289	−0.6282***	−0.1417

		Model: $LCO_{it} = \beta_0 + \beta_1 GDPC_{it} + u_{it}$					
		PMGE			MGE		
ID	Countries	Long-run coefficient $LGDPC_{it}$	Short-run coefficient $LGDPC_{it}$	Short-run *ec*	Long-run coefficient $LGDPC_{it}$	Short-run coefficient $LGDPC_{it}$	Short-run *ec*
25	Kyrgyz Republic	0.3103	−0.3748**	0.9538***	0.4060	−0.4222**	0.3103
26	Lebanon	0.8259*	−0.0890	0.8149	0.8292	−0.0838	0.8259*
27	Malaysia	0.6057*	−0.4090**	0.8203***	0.4469	−0.5081***	0.6057*
28	Maldives	0.3689	−0.1347	2.1997***	−0.2782	−0.5470***	0.3689
29	Mali	0.8289	−0.4439**	0.6136	0.8199	−0.4413**	0.8289
30	Mauritania	−0.3203	−0.0899	1.4538***	−0.5111**	−0.2642**	−0.3203
31	Morocco	0.0870	−0.2201	0.8325***	0.0887	−0.3681	0.0870
32	Mozambique	−0.8307	−0.0157	3.0220	0.3966	−0.1412	−0.8307
33	Niger	1.6128**	−0.0706	5.2092***	0.5913	−0.2519**	1.6128**
34	Nigeria	1.2926	−0.2713*	−0.1516	1.2287	−0.2811*	1.2926
35	Oman	−1.1773*	−0.1767**	3.9090	−1.5162*	−0.1797**	−1.1773*
36	Pakistan	1.0526***	−0.2850***	0.5776**	1.1177***	−0.2622**	1.0526***
37	Saudi Arabia	0.3660	−0.1748	1.0356	0.3329	−0.1922	0.3660
38	Senegal	1.1062	−0.4438**	1.3932***	0.4785	−0.5496***	1.1062
39	Sierra Leone	0.0583	−0.1661	1.4130**	−0.0740	−0.2323	0.0583
40	Suriname	−0.1049	−0.1926*	−0.2495	−0.4297	−0.4396**	−0.1049
41	Tajikistan	−0.8504	−0.3146***	0.7828*	−0.8618	−0.2887*	−0.8504
42	Togo	−0.4134	−0.6531***	0.8221	−0.5285	−0.6520***	−0.4134
43	Tunisia	0.7165**	−0.5886***	0.6084***	0.5012	−0.6689***	0.7165**
44	Turkey	0.4124**	−0.3492**	0.7528***	0.3159	−0.4133**	0.4124**
45	Turkmenistan	0.3313	−0.0686	0.3871***	0.4974*	−0.5144**	0.3313
46	Uganda	0.3545	−0.0424	1.6713***	−0.1163	−0.5610***	0.3545
47	UAE	0.0997	−0.5540***	0.2848	0.0962	−0.6629***	0.0997
48	Uzbekistan	−0.729	0.0186	−0.5278***	1.3680	−0.7409***	−0.729
49	West Bank and Gaza	0.6508	−0.4005**	0.3004	0.7383	−0.4021**	0.6508
50	Yemen	0.2790	−0.5494***	0.6024*	0.3377	−0.5388***	0.279

Note:

*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Source: Own preparation.