VILNIUS TECH
Vilnius Gediminas Technical University

12th International Scientific Conference

BUSINESS AND MANAGEMENT 2022

May 12–13, 2022, Vilnius, Lithuania

ISSN 2029-4441 / eISSN 2029-929X
ISBN 978-609-476-288-8 / eISBN 978-609-476-289-5
Article Number: bm.2022.716
https://doi.org/10.3846/bm.2022.716

GREEN ECONOMY AND SUSTAINABLE DEVELOPMENT *http://vilniustech.lt/bm*

CAN ENVIRONMENTAL SUSTAINABILITY BE ACHIEVED IN OECD COUNTRIES? PANEL ESTIMATION OF ENVIRONMENTAL KUZNETS CURVE THEORY

Sevilay KONYA*

Taşkent Vocational School, Selçuk University, 42960 Taşkent, Konya, Turkey

Received 4 March 2022; accepted 5 April 2022

Abstract. The relationship between the environment and the economy is one of the most frequently encountered issues recently. One of the problems that countries have faced recently is environmental sustainability. Therefore, this study is purposed to examine the relationship between environmental and economic variables. In the example of 24 OECD member countries, the entity of Environmental Kuznets curve theory is examined in the inverse U-link between per capita GDP and per capita carbon dioxide emissions. We analyzed the inverted U-link between CO_2 emissions and per capita GDP in annual balanced panel data covering the period 1980–2014. Westerlund's cointegration test was used for analysis. For long-term parameter estimation, PMG (Pooled Mean Group) estimator methods were applied. Dumitrescu and Hurlin Granger causality test was performed to specify causal connections. As a result of the study, it is pointed out that first of all, electricity consumption has a positive and significant effect on CO_2 emissions in the long run. Secondly, our findings show that environmental degradation is in an inverted U shape in the Environmental Kuznets Curve hypotheses. That is to say, results were obtained verifying the existence of the Environmental Kuznets Curve theory. Eventually, bidirectional causal links are observed between CO_2 emissions and economic growth and between CO_2 emissions and electricity consumption.

Keywords: environmental sustainability, sustainable development, environmental kuznets curve, panel estimation, carbon dioxide emissions, electricity consumption.

JEL Classification: C33, O13, Q43.

Introduction

Kuznets (1955) claimed in his study that there is an inverted-U-shaped relation between income disparity and economic growth. He explained this relationship in several stages in his work. He argued that with industrialization in the first degree of economic development, the wealth and capital accumulation of those who first increased their income from this activity, and thus income inequality emerged. But later on, the benefits of growth will pass over time to others in the form of higher wages and increased income. Thus, income inequality that increases in the first phase of economic development will decrease with the continuation of economic development (Arı & Zeren, 2011, p. 38). Grossman and Krueger (1991, 1995) explained that similar relation to this relationship of Kuznets in the 1990s was found in terms of environmental pollution and per capita income.

The purpose of our article is to research the relevance of the Environmental Kuznets Curve theory in OECD countries. In this context, panel data of 24 OECD countries, whose data can be accessed in the 1980–2014 period, were compiled and analyzed. The unit root test in the variables was researched by Pesaran (2007) CIPS unit root tests. The cointegration relationship can be determined with Westerlund's (2007) cointegration approach. The Pooled Mean Group (Pesaran et al., 1997, 1999) approach is used for long-term parameter estimations. Dumitrescu and Hurlin's (2012) Granger causality test performed causality connections between variables.

The study consists of the following sections: The literature review section summarizes the recent studies on environmental Kuznets Curve (EKC) theory. The data, model, and method section presents the method and data summary used in this article. The empirical results section describes the empirical findings. In the end, the

* Corresponding author. E-mail: *sevilaykonya@selcuk.edu.tr*

conclusion and findings of the study are given in the conclusion part.

1. Literature research

As economists rank environmental data for larger country samples and income levels, there has been increasing evidence that as countries progress, certain criteria of quality of life may break down initially but then progress. Particularly, they identified proof that the equality of environmental degradation for some pollutants and traditionally measured per capita income follows the same inverted U-shaped relation with per capita income and income inequality in the original Kuznets curve. With just a minor change, the original Kuznets Curve shape is transformed to the Environmental Kuznets Curve as shown in Figure 1 (Yandle et al., 2004).

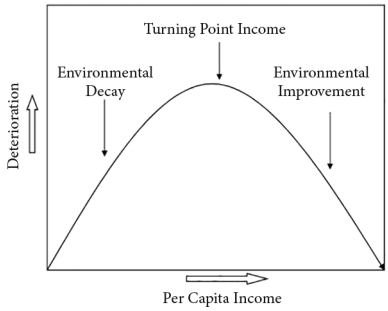

Figure 1. Schematic Representation of the Environmental Kuznets Curve (source: Yandle et al., 2004)

Environmental degradation also tends to get worse before it gets better on a country's development path. While some disruption is inevitable as part of the constant structural changes that accompany economic growth, Environmental Kuznets Curve need not be as steep as it seems in many developing countries. Part of the steep inverted U-shaped relation between growth and environmental degradation comes from policy distortions, such as energy and agrochemical subsidies, protection of industry, and underpricing of natural resources, which are both economically and environmentally destructive (Panayotou, 1993).

There are many studies in the writings about the environmental Kuznets Curve. However, since it is not possible to provide all the literature in our study, recent studies are briefly summarized.

Baležentis et al. (2019) have estimated for EU countries in their panel models, replacing the classical EKC with the EKC model including biomass and other renewable resources. As a result of the study, they found that the coefficient connected with GDP decreased when renewable resources were entered into the model. The study also determined that the effect of biomass on reducing greenhouse gas emissions is higher than the effect caused by other renewable sources.

Destek and Sarkodie (2019), in their study, searched the soundness of EKC hypotheses by researching the relation between financial development, energy consumption, economic growth, and ecological footprint for the 1977–2013 term in 11 newly industrialized countries. As a result of the study, in which they used the heterogeneous panel causality method and the Augment Mean Group (AMG) estimator, they revealed that there is an inverted U-shaped relation between ecological footprint and economic growth. In the causality test, they deduced that there is bilateral causality between the ecological footprint and economic growth.

Hove and Tursoy (2019) investigated an inverted U-shaped relation between environmental pollutants and national economic indicators. In their study, they analyzed using annual data for a panel of 24 emerging economies worldwide for the term 2000–2017. As a result of the study, they found that a positive change in real per capita GDP decreases consumption of energy fossil fuels and carbon dioxide emissions but increases nitrous oxide.

Örnek and Turkmen (2019), in their study, for the term 1975–2016 investigated with the help of EKC hypotheses whether sustainable energy could be found in developed countries and emerging market economies. They established a quadratic model as an indicator of economic growth per capita income by using and as an indicator of environmental pollution carbon dioxide emissions per capita by using. They estimated the relationship between the variables using current econometric procedures with the help of dynamic panel data analysis, and in consequence of the analysis, they specified that the EKC approximation is well-founded and sustainability in energy is provided in developed countries when the EKC approach is not valid in emerging market economies, so sustainability in energy cannot be achieved.

Tatoğlu and İçen (2019), in their study, added the country and time dimension as well as the income groups of countries as a dimension to the panel data set in order to analyze EKC in a much more detailed and inclusive way and analyzed with three-dimensional panel data models. Consequently, of the study, they were found that EKC is well-founded for low- and high-income groups, but it works differently; found that it is not valid in middle-income countries.

Yao et al. (2019) created a renewable energy consumption rate index to symbolize a country's energy structure and proposed a U-shaped renewable energy Kuznets Curve hypothesis between economic growth and renewable energy consumption rate index. In addition, for the term 1990–2014 they examined the dynamic relationship between the renewable energy consumption rate index and EKC hypotheses using two-panel datasets consisting of seventeen major developed and developing countries as well as six geoeconomic regions of the world. Consequently, of their study, they confirmed the Environmental Kuznets Curve.

Yilanci and Ozgur (2019), investigated the income-pollution relationship with front-load panel rolling window causality in G7 countries (France, Canada, Italy,

Germany, Japan, United Kingdom, and the United States) using a new methodology for the period 1970–2014. As a result of the study, they affirmed the soundness of EKC hypotheses in the United States and Japan. In other countries, however, they found no proof for an inverted U-shaped model of the relation between the measure for environmental degradation is per capita GDP.

Zhang et al. (2019), tested EKC hypotheses using CO_2 emissions data from construction and manufacturing industries from 121 countries for the period 1960–2014. They calculated the turning points for the countries in which the environmental Kuznets curve hypotheses were confirmed. As a consequence of the study, they found that the EKC hypothesis was verified by 95 out of 121 countries.

Altıntaş and Kassouri (2020) studied using ecological footprint and CO_2 emissions as indicators of environmental degradation as target variables, to provide new perspectives on whether EKC hypotheses are related to the environmental pressure indicators used. For the period 1990–2014, using heterogeneous panel data methods with data from 14 European countries they found proof of the susceptibility of the EKC hypotheses to the classification of environmental degradation agent used. As a result of the study, they also obtained results that the ecological footprint is more proper as a suitable environmental instrument that fits the EKC estimation, as opposed CO_2 emissions.

Ansari et al. (2020) used material and ecological footprint from a consumption perspective as a full measure of human pressure on the environment to analyze the economic growth-environment link. They analyzed the EKC hypothesis for 23 Asian countries. They divided these countries into five groups: Western, Central, Southern, Eastern, and Southeast Asian countries were discussed in the period 1991–2017. In their study panel cointegration, PMG, dynamic ordinary least squares (DOLS), and differential panel generalized moment methods were used as methods. As a result of the analysis, they found a mix of results regarding the existence of environmental Kuznets curve when using the ecological footprint; They found that the EKC hypothesis is well-founded for Central and East Asian countries but not for South, West, and Southeast Asian countries. As a consequence of their study, they found that when they use the material footprint indicator outside of Central Asian countries, it supports EKC.

Aydin and Turan (2020) investigated the impacts of energy intensity, economic growth, trade openness, and financial openness on the ecological footprint of the BRICS countries for the period 1996–2016 within the framework of EKC. During the study stages, the effects of trade openness and financial openness on ecological footprint were discussed both separately and as a full using three models. As a result of the study, they determined that the EKC hypothesis is not well-founded in all BRICS countries. Particularly, the singular results found that the EKC model using financial openness was well-founded just for India when the EKC model using trade openness was well-founded for both South Africa and India.

Beyene and Kotosz (2020) used environmental Kuznets Curve hypotheses as a theoretical structure. They investigated the EKC hypotheses for twelve East African countries using the PMG method for the period 1990–2013. Beyene and Kotosz found that the relationship between income per capita and CO_2 emissions was bell-shaped and therefore an expanded version of the original inverted U-shaped curve relation between economic activity and environmental degradation.

Boubellouta and Kusch-Brandt (2020), investigated over the period 2000–2016 EKC hypotheses for e-waste with a panel dataset of thirty European countries. In their study, they used the 2SLS estimator and the generalized moment method (GMM) estimator as a method and the section method to validate the results. They determined that the EKC hypotheses are promoted for e-waste propped in the EU28 + 2 region.

Caravaggio (2020), investigated the environmental Kuznets Curve (EKCd) for deforestation. With a 55-year forest cover data reformed in the periodic national forest inventories of 114 countries clustered in high-, low- and middle-income groups defined by the World Bank, these classifications were examined in both static and dynamic frameworks. The result of the study supported the inverted U-shaped EKC for deforestation.

Dogan et al. (2020) examined the soundness of EKC hypotheses for BRICST (China, Brazil, India, South Africa, Russia, Turkey) countries by considering heterogeneity and cross-sectional dependence using ecological footprint. As a result of the empirical results, they found that the EKC hypotheses were not valid when Russia was excluded due to the absence of annual data covering the period 1980–2014.

Dogan and Inglesi-Lotz (2020), for the 1980–2014 period investigated the importance of the economic structure of European countries in examining the EKC hypotheses in European countries. In consequence of the study, they found that overall CO_2 emissions and economic growth in the group of countries studied appear an inverted U-shaped relationship.

Erdogan et al. (2020) based their work on the theoretical frame of EKC hypotheses to discover the part of the air and urbanization rail transport sector to the emission growth argument. They used for a panel of top ten air passenger transport countries annual time-frequency data for the period 1995–2014 that used robust panel estimators controlling for cross-section dependency in their study. In the wake of the empirical analysis, they found that there is a positive significant relationship between emissions and economic growth.

Gormus and Aydin (2020) investigated the relationship between economic growth, consumption of renewable energy, ecological footprint, and innovation as top ten innovative economies (Finland, Denmark, Germany, Korea, Israel, Netherlands, Switzerland, Sweden, United

Kingdom, and the United States) within the framework of EKC hypothesis for 1990–2015 period. As a result of the study, they found that the changeable in the environmental Kuznets curve model act together in the long run. Accordingly, the long-term evaluation results, found that the EKC hypothesis is effective for Israel but not for other countries.

Halliru et al. (2020) investigated the soundness of EKC hypotheses for 6 West African countries during the term 1970 to 2017. In their study, they added biocapacity and human capital as additional deterministic of CO_2 emissions. They used the panel quantile regression method. Whereby of the study, they determined that in low, medium, and high emission countries, inversely the inverted U-shaped EKC hypotheses, a U-shaped relation between carbon dioxide (CO_2) emissions, and economic growth is valid.

Ike et al. (2020), examined the dynamic impact of oil production on carbon emissions in fifteen oil-producing countries, taking into account the role of economic growth, democracy, trade, and electricity generation in the 1980–2010 term. As a result of their study using the New Moments Quantitative Regression Method with fixed effects, they found an inverted U-shaped relation between CO_2 emissions and economic growth in countries with higher emissions, thus obtaining supporting findings for the EKC hypotheses.

Kacprzyk and Kuchta (2020) investigated for the period 1992–2012 the entity of an inverted U-shaped relation between CO_2 emissions and income from fossil fuels for a panel data set consisting of 161 countries. As a result of their studies, they determined that there is an EKC for CO_2 emissions.

Kırman and Kesbic (2020) investigated the existence of the hypotheses suggesting that the relationship between the distribution of income and environmental pollution, known as EKC, is in an inverted-U shape between 1980 and 2014 in Brazil, Argentina, India, China, South Korea, South Africa, Malaysia, Mexico, Poland, Portugal, and Turkey investigated its validity in with panel data analysis. For this purpose, they used per capita carbon dioxide emission (CO_2) as the dependent variable and per capita national income as the independent variable. The stationarities of the variables were performed with the CADF unit root test, then as a cointegration test Gengenbach, Urbain, and Westerlund (GUW) cointegration test, the coefficient estimation analysis of the changeable with the help of the DOLSMG coefficient estimator of the variables for which the entity of a long-term relationship was determined, and the presence of an inverse N-shaped relation between the variables was determined.

Le and Ozturk (2020) investigated the effects of globalization, financial development, institutional quality, and government spending on CO_2 emissions, per capita GDP, and energy consumption in the EKC pattern for forty-seven Emerging Markets and Developing Countries. In the study they investigated the period of 1990–2014, CIPS and CADF unit root tests were applied to verify the stability of the variables because of the cross-section dependence and slope heterogeneity in the panel data. As cointegration tests, Westerlund and Banerjee and Carrion-i Silvestre applied cointegration tests and found the presence of cointegration among the variables. Augmented Mean Group (AMG), Common Correlated Effects Mean Group (CCEMG), and Dynamic Common Correlated Effects (DCCE) estimators were used to estimate heterogeneous parameters. Their findings revealed that globalization, energy consumption, and financial development increase CO_2 emissions. In consequence of the study, they supported the EKC hypothesis for Emerging Markets and Developing Countries.

Maneejuk et al. (2020) examined the relationship between economic development and environmental degradation based upon the EKC hypothesis. In their study, they examined eight major international economic communities covering forty-four countries around the world. The relation between environmental conditions and economic growth was forecast using the kink regression model, which describes the milestone alteration in the relation. As a result of the study, they found that EKC hypotheses are well-founded in namely three of the eight international economic communities, namely Group of Seven (G7), European Union (EU), and Organization for Economic Cooperation and Development (OECD) and.

Renzhi and Baek (2020), analyzed a panel dataset of 103 countries for the term 2004–2014, and as a result, they determined the entity of the EKC based on financial inclusion. They found that the relation between CO_2 emissions and financial inclusion is in an inverted U shape.

Ahmad et al. (2021a) examine previous information gaps in environmental economics writing by integrating innovation shocks into the EKC equation for the term 1990–2014 in twenty-six OECD economies. In their study, they added exports, foreign direct investment, consumption of renewable energy, and per capita GDP as control variables. In consequence of the study, they specified that positive shocks towards innovation increased, but negative shocks deteriorated environmental quality. As a result of the study, they also affirmed the EKC hypotheses in the sampled economies.

Ahmad et al. (2021b) investigated the entity of the EKC theory. That is, the inverse U-shaped link between per capita real GDP and per capita carbon dioxide emissions in a sample of eleven developing countries. Using balanced annual panel data and two alternative estimation techniques over the 1992–2014 period, they examined the possibility of an inverted U-shaped link between CO_2 emissions and per capita real GDP in the relevant sample. As a result of the study, an increase in per capita real GDP and electricity consumption in the long term. They found supporting evidence for an inverted U-shaped connection in the long term, showing that countries tend to reduce long-term carbon dioxide emissions. Country findings have determined the entity of EKC theory for China, Brazil, India, Russian Federation,

Malaysia, Turkey, and Thailand. Nevertheless, Mexico, Indonesia, the Philippines, and South Africa have been shown to fail to give credence to the EKC theory.

Gyamfi et al. (2021) investigated the N-shaped EKC for E-7 countries using variables covering the term 1995–2018 in their study. Long-term results at the end of the study verified the attending of an inverted U-shaped EKC.

Isik et al. (2021) examined the soundness of EKC hypotheses for eight OECD countries. For the analysis, they divided the series of GDP per capita into increases and declines, but solely the increases were taken into account by subtracting the decreases from the model. As a result of the study, in which they used the fixed-effects regression test with common-related effects mean group (CCEMG) estimator and Driscoll Kraay standard errors as a method, it was concluded that the model with the undisaggregated per capita GDP series supported EKC hypotheses for four out of eight countries, whereas the disaggregated model with the disaggregated per capita GDP series supported the hypothesis. They found that it does not support.

Saqib and Benhmad (2021), empirically investigated the EKC hypothesis by searching the relation between economic growth, energy consumption, population growth, and ecological footprint. They used more effective estimation instruments, such as the pooled average group and the augmented average group, to forecast the long-term parameters for twenty-two European countries over the 1995–2015 term. As a result of the study, the relation they found between ecological footprint and income growth supported the soundness of EKC. The long-term predictions of the study were validated through robustness analysis using fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS) methods. Dumitrescu and Hurlin (2012) panel causality test found that there is one-way causality from GDP to ecological footprint and bilateral causality between ecological footprint and energy consumption.

Aydin and Degirmenci (2022) examined the relationship between multi-factor productivity, consumption of renewable energy, research and development expenditures, ecological footprint, and urbanization, and the period 1991–2016, under the EKC hypothesis using Lagrange multiplier (LM) preload. As a research method panel cointegration and augmented mean group (AMG) estimators and LM bootstrap panel cointegration test results for the G7 countries (Canada, Germany, France, Japan, Italy, United Kingdom, and the United States) determined that the changeable in the environmental Kuznets curve model were correlated in the long term. In addition, AMG long-term coefficient estimates revealed that the EKC hypothesis is not well-founded.

Balsalobre-Lorente et al. (2022), investigated the dynamic relationship between foreign direct investment, economic complexity, urbanization, renewable energy, and carbon emissions between 1990 and 2019 in the sample of PIIGS countries. As an empirical analysis method, dynamic ordinary least squares (DOLS) estimator was performed and as a result, they determined that the relation between CO_2 emissions and economic complexity was an inverted U and more N-shaped relation. They supported the existence of the EKC hypothesis in the PIIGS countries.

Bilgili et al. (2022) examined the environment-gender relationship with panel data estimates through the EKC hypotheses in thirty-six Asian countries for the period 1991–2017. As a result of their estimation, they determined that per capita GDP positively affects CO_2 emissions and per capita, CO2 is negatively affected by the square of per capita GDP, thus verifying environmental Kuznets Curve for panel Asian data with 971 observations. In addition, at the end of the article, they determined that they also confirmed the EKC hypothesis by means of panel data models in which GDP and GDP were squared.

Cetin et al. (2022) investigated the entity of the agriculture-based EKC hypotheses in 47 developing countries between 1976 and 2017 using dynamic panel data estimators. As a result of the study, accordingly long-term findings of dynamic ordinary least squares (DOLS) and fully modified ordinary least squares (FMOLS) estimators, determined an inverted U-shaped relation between CO_2 emissions and income. They also found a negative effect of agricultural production on environmental quality. They investigated the control of their results with the PMG estimator. The long-term conclusions of the PMG estimator also yielded findings supporting the entity of agriculture-based environmental Kuznets curve for forty-seven developing countries.

Frodyma et al. (2022), confirmed the soundness of the EKC hypotheses in EU countries for the term 1970–2017 by examining the three environmental Kuznets Curve specifications and checking the soundness of EKC for consumption-based emissions (CBA) and production-based emissions (PBA). Using the ARDL test, their study determined that in most countries, EKC models failed to clarify the relation between income and production-based emissions over the term 1970–2017. They also revealed that the results obtained for consumption-based emissions also reject the EKC hypotheses.

Kar (2022), searched the link between CO_2 emissions and economic growth in Lithuania, Latvia, and Estonia (three Baltic countries). In his study, he checked the validity of EKC hypotheses, consider the role of financial development and energy consumption in the term 1990–2018. In consequence of the study, it was revealed that the inverted U-shaped EKC hypothesis is not well-founded in Lithuania, Latvia, and Estonia (three Baltic countries).

Ochoa-Moreno et al. (2022) examined the relation between tourism and CO_2 emissions over the period 1995–2018 in an example of twenty Latin American countries. They used econometric causality and cointegration techniques to estimate the relation between these variables. To test the compatibility of cointegration vectors, they

performed the dynamic ordinary least squares (DOLS) model for singular countries and the panel dynamic ordinary least squares (DOLS) estimator for country groups. They stated that a U shape was formed that did not promote the ecological Kuznets curve.

Wang et al. (2022) investigated the impacts of urbanization on the combination of environmental quality and economic growth. Depending on panel data from one hundred thirty-four countries for the term 1996–2015, threshold regression models were applied to investigate nonlinear causality between variables. They set urbanization as the threshold variable and analyzed the impacts of economic growth on ecological footprint and CO_2 emissions. As a result of the study, they found a positive relationship between carbon emissions, urbanization, economic growth, and ecological footprint. As a result of the study, the coefficient of the lower-middle-income group is in an inverted U shape. While the ecological footprint is the variable clarified, the coefficient of the high-income group is U-shaped.

The Environmental Kuznets Curve theory has been the subject of debate for many years. The importance of the environment is increasing in terms of ensuring sustainable development, protecting the ecological balance, and preventing environmental pollution. As a result of the literature research, some studies support the environmental Kuznets curve hypothesis as well as studies that are not. Here, the time dimension, sample dimension, and applied method can be shown as the main reason for the difference in results.

2. Data, model, and method

In our study, the EKC hypothesis was examined in order to search the links between carbon dioxide emissions, income, and electricity consumption in 24 OECD countries[1] were used during the 1980–2014 period. Data on per capita GDP (constant 2015 USD$), electrical energy consumption (kWh per capita), and per capita CO_2 emissions (metric tons per capita) are taken offense World Bank Development Indicators.

Table 1. Data and Sources (source: World Bank, 2022)

Data	Description of Data	Source
CO_2	CO_2 emissions (metric tons per capita)	World Bank
GDP	GDP per capita (constant 2015 US$)	World Bank
EC	Electric power consumption (kWh per capita)	World Bank

The data used in the analysis and the source from which the data were obtained are presented in Table 1.

[1] Australia, Austria, Belgium, Chile, Colombia, Costa Rica, Denmark, Finland, France, Greece, Ireland, Italy, Japan, Mexico, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States.

Table 2 shows the expressive structure of the statistics used in the analysis.

Table 2. Results of Descriptive Statistics (source: Author' estimations)

	CO_2	GDP	EC
Mean	7.690388	29924.45	6803.249
Std. Dev.	4.202773	17658.7	5156.546
Min.	.7515078	3146.616	495.5433
Max.	20.78649	84348.39	25590.69
Obs	840	840	840

The mean real GDP per capita was found to be 29 924.45 USD. The minimum value is approximately 3146.62, and the maximum value is 84348.39. The mean of the CO_2 value is 7.69; The EC mean was determined as 6803.249.

The model used in the study was being constituted similarly to the model used by Apergis and Payne (2010), Wang, Zhou, Zhou, and Wang (2011), Aytun, Akın, and Algan (2017).

$$CO_{2it} = \alpha_{it} + \beta_{1i} GDP_{it} + \beta_{2i} GDP_{it}^2 + \beta_{3i} EC_{it} + \varepsilon_{it}. \quad (1)$$

In the equation, countries i represent time t. ε_{it} represents the error term. In the model, β_1 and β_2 represent the long-term coefficients showing the effect of income on CO_2 emissions. β_3 represents the long-run coefficient showing the impact of electricity consumption on CO_2 emissions. In our study, the data are used in level structures.

If β_1 coefficient is positive and β_2 coefficient is negative, there is an inverted U-shaped functional relation between GDP and CO_2 emissions (supporting the EKC hypothesis). In addition, it is generally accepted in the writing that energy consumption increases carbon dioxide emissions. Therefore, the sign of the β_3 coefficient is supposed to be positive (Aytun et al., 2017, p. 6).

In our study, it will first be specified whether there is a cross-section or not. The CIPS unit root test will be applied to specify the stationarity of the variables. Westerlund's cointegration test will be applied to determine whether there is a cointegration relation between the changeable. The Pooled Mean Group (PMG) estimator will be used for long-term coefficient-number estimation. Dumitrescu and Hurlin's (2012) causality test was performed to determine causal connections.

3. Empirical results

Results of the Cross Section Dependency test of the variables are shown in Table 3.

As can be seen in Table 3, we checked each of the series for cross-sectional dependence as part of our analysis. The cross-sectional dependence for all variables cannot be denied. That is to say, there is a cross-sectional dependence between the variables. The results of the unit root test CIPS are shown in Table 4.

Table 3. Results of Cross Section Dependency Test (source: Author' estimations)

	CO_2	GDP	EC
CD_{lm}	2922.249 (0.0000)	8344.795 (0.0000)	7274.502 (0.0000)
CD_{lm}	112.6319 (0.0000)	343.4307 (0.0000)	297.8760 (0.0000)
CD	13.40315 (0.0000)	91.13503 (0.0000)	83.78919 (0.0000)
LM_{adj}	112.2789 (0.0000)	343.0778 (0.0000)	297.5231 (0.0000)

Table 4. Results of Unit Root Test CIPS (source: Author' estimations)

Level					
Variable	Lag	Constant		Constant &Trend	
		Statistic	P-value	Statistic	P-value
CO_2	0	–3.715	0.000	–3.177	0.001
	1	–2.656	0.004	–3.270	0.001
	2	–0.149	0.441	–0.725	0.234
	3	0.780	0.782	0.292	0.615
	4	2.685	0.996	2.188	0.986
GDP	0	4.569	1.000	5.659	1.000
	1	–0.659	0.255	1.041	0.851
	2	–0.393	0.347	2.685	0.996
	3	–1.014	0.155	2.530	0.994
	4	–0.980	0.164	2.806	0.997
GDP^2	0	6.225	1.000	8.666	1.000
	1	0.687	0.754	4.065	1.000
	2	0.467	0.680	3.985	1.000
	3	0.222	0.588	3.701	1.000
	4	0.632	0.736	4.382	1.000
EC	0	–3.925	0.000	–1.482	0.069
	1	–1.186	0.118	–0.736	0.231
	2	–0.821	0.206	0.207	0.582
	3	–1.767	0.039	–0.950	0.171
	4	0.307	0.621	0.902	0.817
First Difference					
Variable	Lag	Constant		Constant & Trend	
		Statistic	P-value	Statistic	P-value
ΔCO_2	0	–20.390	0.000	–19.959	0.000
	1	–13.415	0.000	–12.233	0.000
	2	–7.916	0.000	–5.800	0.000
	3	–7.226	0.000	–5.266	0.000
	4	–3.493	0.000	–1.724	0.042
ΔGDP	0	–9.237	0.000	–8.313	0.000
	1	–7.139	0.000	–6.235	0.000
	2	–3.446	0.000	–2.297	0.011
	3	–2.183	0.015	–1.772	0.038
	4	–0.234	0.407	0.089	0.535

End of Table 4

Level					
Variable	Lag	Constant		Constant &Trend	
		Statistic	P-value	Statistic	P-value
ΔGDP^2	0	–8.291	0.000	–7.702	0.000
	1	–5.378	0.000	–5.209	0.000
	2	–2.128	0.017	–1.934	0.027
	3	–1.063	0.144	–1.264	0.103
	4	1.298	0.903	1.101	0.865
ΔEC	0	–18.117	0.000	–17.444	0.000
	1	–12.100	0.000	–11.244	0.000
	2	–5.486	0.000	–3.728	0.000
	3	–4.244	0.000	–2.592	0.005
	4	–2.296	0.011	0.344	0.635

When Table 4 is examined, stationarity is achieved for CO_2 emissions with both including a constant and trend and constant a lag length of 0 and 1 in the model. When the first difference of the variable is taken, stationarity is achieved at all lag lengths. When the first difference of GDP and GDP^2 variables is taken, stationarity is achieved. While the level value for the EC variable is stationary at 0 lag length in the model containing both constant and constant & trend terms, the first difference is taken to provide stationarity at all lag lengths in the constant model. In the model with EC variable constant and trend, stationarity was achieved at lag lengths of 0, 1, 2, 3.

After determining the stability of the variables, the Westerlund cointegration test was applied to determine whether the variables were cointegrated or not. Table 5 shows the results of the Westerlund cointegration test.

Table 5. Results of Cointegration Test Westerlund (source: Author' estimations)

Statistics	Value	Z-value	P-value
G_t	–2.356	–3.095	0.001
G_a	–7.069	0.582	0.720
P_t	–11.670	–3.982	0.000
P_a	–7.327	–2.371	0.009

In the Westerlund cointegration test, the H_0 hypothesis is established as no cointegration. According to the test statistics of G_t, P_t and P_a, the H_0 hypothesis is refused. It was precipitated that there is a cointegration relation between the variables CO_2, GDP, GDP^2 and *EC*.

Table 6 shows the panel error correction model estimation results obtained with the PMG estimator. The error correction parameter is negative-significant. There is a long-run relationship between the variables. Accordingly, approximately 20% of the imbalances that occur in one period will be corrected in the next period. In the long term, every 1% increase in GDP raises

Table 6. Results of PMG Estimator (source: Author' estimations)

Variable	Coefficient	Std. Error	P>|z|
ec			
GDP	.0003502	.0000595	0.000
GDP^2	–5.86e-09	6.81e-10	0.000
EC	.0004225	.0001092	0.000
Short term			
ect	–.1957466	.0348795	0.000
constant	.0623166	.1120977	0.578
d.GDP	.000058	.0001232	0.638
$d.GDP^2$	–3.84e-09	4.10e-09	0.349
d. *EC*	.0012803	.000249	0.000

CO_2 emissions by approximately 0.0003%. 1% increase in GDP^2 decreases CO_2 emissions by approximately 5.86%. It has been determined that the impact of electricity consumption on CO_2 emissions, in the long run, is positive and significant. Findings from the PMG estimator are consistent with the Environmental Kuznets curve assumption. Results supporting the Environmental Kuznets curve were found in the study.

Figure 2 shows the long-run coefficients obtained from the PMG estimator.

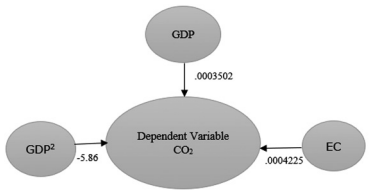

Figure 2. Figure Representation of Long-Run Coefficients Obtained from PMG Estimator (source: Created by the author)

Table 7. Results of Panel Causality Test of Dumitrescu and Hurlin (2012)

	W-Bar statistics	Z-bar statistics	P-value
CO_2 → GDP	16.9965	9.2336	0.0000
GDP → CO_2	15.1086	7.0536	0.0000
CO_2 → GDP^2	18.1866	10.6077	0.0000
GDP^2 → CO_2	14.2568	6.0700	0.0000
CO_2 →EC	3.1611	7.4863	0.0000
EC → CO_2	13.3382	5.0094	0.0000

Table 7 shows the Dumitrescu and Hurlin panel Granger causality conclusions. In the causality test, the lag length was chosen according to the AIC information criterion. According to the test results, the basic hypotheses stating that there is no causal relation between the variables were rejected. A bidirectional causality test was found between CO_2 emissions and GDP, CO_2 emission and GDP^2, CO_2 emission, and EC in at least one unit.

Figure 3 shows the results Dumitrescu and Hurlin Causality test.

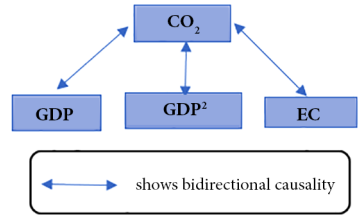

Figure 3. Figure Representation of Results Dumitrescu and Hurlin Causality Test (source: Created by the author)

Conclusions

The relations between the environment, the economy, and energy have been the subject of discussion for many years. The main question of our study is whether the Environmental Kuznets Curve theory is valid in OECD countries.

When the literature review is evaluated in general, the Environmental Kuznets Curve hypothesis has been retested due to changes and developments in econometric applications. It is seen that studies with or without cross-sectional dependence and heterogeneity in panel data models are within the scope of the literature. As a result of the applied econometric methods, the results supporting and not supporting the Environmental Kuznets Curve Hypothesis were determined. It is seen that the result obtained in this context has different characteristics according to the time dimension, sample dimension, and the applied method. We aim to contribute to the literature for the method we applied and the sample group discussed.

In our study, the validity of Environmental Kuznets Curve hypotheses for the term 1980–2014 in 24 OECD countries was investigated. In the study, the cointegration relationship was determined between the series in which the Westerlund cointegration test was applied. It has been determined that the Environmental Kuznets curve is in an inverted U shape for the example of 24 OECD countries. Consequently, of the study, we obtained supporting findings for the Environmental Kuznets Curve for the entire panel we discussed. At the end of the PMG estimator, we determined that the effect of electricity consumption on carbon dioxide emissions was positive and significant. In the end, Dumitrescu and Hurlin's panel causality test was performed to determine the causal connections between the variables in our study. As a result of the causality test, a causal relationship was found between economic growth and carbon dioxide emissions, between CO_2 emissions and the square of economic growth; and between electricity consumption and carbon dioxide emissions. From the evidence of the study, can be finalized that the environmental degradation will gradually reduce with the enhancement in the income level.

For sustainable development, energy policies that reduce environmental pollution should be implemented.

The limitations of our study are the sample, time dimension, and the method used. The application of different methods, the similarity of the study with different samples, and different time dimensions will make important contributions to the literature.

The literature will be useful to study with unit root tests, cointegration tests, and causality tests, in which cross-sectional dependence and heterogeneity are taken into account. The validity of AMG (Augment Mean Group), CCEMG (Common Correlated Effects Mean Group), MG (Mean Group), DFE (Dynamic Fixed Effects) methods, and Environmental Kuznets curve methods can be investigated.

In the same breath, the use of different energy variables instead of the electrical energy consumption variable will make important contributions to the environmental Kuznets literature.

References

Ahmad, M., Khan, Z., Rahman, Z. U., Khattak, S. I., & Khan, Z. U. (2021a). Can innovation shocks determine CO_2 emissions (CO2e) in the OECD economies? A new perspective. *Economics of Innovation and New Technology*, *30*(1), 89–109. https://doi.org/10.1080/10438599.2019.1684643

Ahmad, M., Muslija, A., & Satrovic, E. (2021b). Does economic prosperity lead to environmental sustainability in developing economies? Environmental Kuznets curve theory. *Environmental Science and Pollution Research*, *28*, 22588–22601. https://doi.org/10.1007/s11356-020-12276-9

Altıntaş, H., & Kassouri, Y. (2020). Is the environmental Kuznets Curve in Europe related to the per-capita ecological footprint or CO_2 emissions? *Ecological Indicators*, *113*, 106187. https://doi.org/10.1016/j.ecolind.2020.106187

Ansari, M. H., Haider, S., & Khan, N. A. (2020). Environmental Kuznets curve revisited: An analysis using ecological and material footprint. *Ecological Indicators*, *115*, 106416. https://doi.org/10.1016/j.ecolind.2020.106416

Apergis, N., & Payne, J. E. (2010). The emissions, energy consumption, and growth nexus: Evidence from the commonwealth of independent states. *Energy Policy*, *38*(1), 650–655. https://doi.org/10.1016/j.enpol.2009.08.029

Arı, A., & Zeren, F. (2011). CO2 Emisyonu ve Ekonomik Büyüme: Panel Veri Analizi. *Yönetim ve Ekonomi Dergisi*, *18*(2), 37–47. https://dergipark.org.tr/tr/download/article-file/146063

Aydin, M., & Degirmenci, T. (2022). *Renewable energy consumption, multifactor productivity, research and development expenditure, urbanization, and ecological footprint in G7 countries: Testing the Environmental Kuznets Curve hypothesis with panel cointegration.*

Aydin, M., & Turan, Y. E. (2020). The influence of financial openness, trade openness, and energy intensity on ecological footprint: Revisiting the environmental Kuznets curve hypothesis for BRICS countries. *Environmental Science and Pollution Research*, *27*, 43233–43245. https://doi.org/10.1007/s11356-020-10238-9

Aytun, C., Akın, C., & Algan, N. (2017). Gelişen Ülkelerde Çevresel Bozulma, Gelir ve Enerji Tüketimi İlişkis. *Ömer Halisdemir Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, *10*(1), 1–11. https://doi.org/10.25287/ohuiibf.297156

Baležentis, T., Streimikiene, D., Zhang, T., & Lobikiene, G. (2019). The role of bioenergy in greenhouse gas emission reduction in EU countries: An Environmental Kuznets Curve modelling. *Resources, Conservation and Recycling*, *142*, 225–231. https://doi.org/10.1016/j.resconrec.2018.12.019

Balsalobre-Lorente, D., Ibáñez-Luzón, L., Usman, M., & Shahbaz, M. (2022). The environmental Kuznets curve, based on the economic complexity, and the pollution haven hypothesis in PIIGS countries. *Renewable Energy*, *185*, 1441–1455. https://doi.org/10.1016/j.renene.2021.10.059

Beyene, S. D., & Kotosz, B. (2020). Testing the environmental Kuznets curve hypothesis: An empirical study for East African countries. *International Journal of Environmental Studies*, *77*(4), 636–654. https://doi.org/10.1080/00207233.2019.1695445

Bilgili, F., Khan, M., & Awan, A. (2022). Is there a gender dimension of the environmental Kuznets curve? Evidence from Asian countries. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-022-02139-3

Boubellouta, B., & Kusch-Brandt, S. (2020). Testing the environmental Kuznets Curve hypothesis for E-waste in the EU28+2 countries. *Journal of Cleaner Production*, *277*, 123371. https://doi.org/10.1016/j.jclepro.2020.123371

Caravaggio, N. (2020). A global empirical re-assessment of the Environmental Kuznets curve for deforestation. *Forest Policy and Economics*, *119*, 102282. https://doi.org/10.1016/j.forpol.2020.102282

Cetin, M., Bakirtas, I., & Yildiz, N. (2022). Does agriculture-induced environmental Kuznets curve exist in developing countries? *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-021-18065-2

Destek, M. A., & Sarkodie, S. A. (2019). Investigation of environmental Kuznets curve for ecological footprint: The role of energy and financial development. *Science of The Total Environment*, *650*(2), 2489–2489. https://doi.org/10.1016/j.scitotenv.2018.10.017

Dogan, E., Ulucak, R., Koçak, E., & Isik, C. (2020). The use of ecological footprint in estimating the Environmental Kuznets Curve hypothesis for BRICST by considering cross-section dependence and heterogeneity. *Science of The Total Environment*, *723*, 138063. https://doi.org/10.1016/j.scitotenv.2020.138063

Dogan, E., & Inglesi-Lotz, R. (2020). The impact of economic structure to the environmental Kuznets curve (EKC) hypothesis: Evidence from European countries. *Environmental Science and Pollution Research*, *27*, 12717–12724. https://doi.org/10.1007/s11356-020-07878-2

Dumıtrescu, E. I., & Hurlın, C. (2012). Testing for Granger noncausality in heterogeneous panels. *Economic Modelling*, *29*(4), 1450–1460. https://doi.org/10.1016/j.econmod.2012.02.014

Erdogan, S., Adedoyin, F. F., Bekun, F. V., & Sarkodie, S. A. (2020). Testing the transport-induced environmental Kuznets curve hypothesis: The role of air and railway transport. *Journal of Air Transport Management*, *89*, 101935. https://doi.org/10.1016/j.jairtraman.2020.101935

Frodyma, K., Papież, M., & Śmiech, S. (2022). Revisiting the Environmental Kuznets Curve in the European Union countries. *Energy*, *241*, 122899. https://doi.org/10.1016/j.energy.2021.122899

Gyamfi, B. A., Adedoyin, F. F., Bein, M. A., & Bekun, F. V. (2021). Environmental implications of N-shaped environmental Kuznets curve for E7 countries. *Environmental Science and Pollution Research, 28*, 33072–33082. https://doi.org/10.1007/s11356-021-12967-x

Gormus, S., & Aydin, M. (2020). Revisiting the environmental Kuznets curve hypothesis using innovation: New evidence from the top 10 innovative economies. *Environmental Science and Pollution Research*, *27*, 27904–27913. https://doi.org/10.1007/s11356-020-09110-7

Grossman, G. M., & Krueger, A. (1995). Economic growth and the environment. *Quarterly Journal of Economics*, *110*(2), 353–377. https://doi.org/10.2307/2118443

Grossman, G. M., & Krueger, A. (1991). *Environmental impacts of a North American free trade agreement* (NBER Research Working Paper, No 3914). Cambridge. https://www.nber.org/system/files/working_papers/w3914/w3914.pdf

Halliru, A. M., Loganathan, N., Hassan, A. A. G., Mardani, A., & Kamyab, H. (2020). Re-examining the environmental Kuznets curve hypothesis in the economic community of West African states: A panel quantile regression approach. *Journal of Cleaner Production*, *276*, 124247. https://doi.org/10.1016/j.jclepro.2020.124247

Hove, S., & Tursoy, T. (2019). An investigation of the environmental Kuznets curve in emerging economies. *Journal of Cleaner Production*, *236*, 117628. https://doi.org/10.1016/j.jclepro.2019.117628

Isik, C., Ongan, S., Ozdemir, D., Ahmad, M., Irfan, M., Alvarado, R., & Ongan, A. (2021). The increases and decreases of the environment Kuznets curve (EKC) for 8 OECD countries. *Environmental Science and Pollution Research*, *28*, 28535–28543. https://doi.org/10.1007/s11356-021-12637-y

Ike, G. E., Usman, O., & Sarkodie, S. A. (2020). Testing the role of oil production in the environmental Kuznets curve of oil producing countries: New insights from Method of Moments Quantile Regression. *Science of The Total Environment*, *711*, 135208. https://doi.org/10.1016/j.scitotenv.2019.135208

Kacprzyk, A., & Kuchta, Z. (2020). Shining a new light on the environmental Kuznets curve for CO_2 emissions. *Energy Economics*, *87*, 104704. https://doi.org/10.1016/j.eneco.2020.104704

Kar, A. K. (2022). Environmental Kuznets curve for CO_2 emissions in Baltic countries: An empirical investigation. *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-022-19103-3

Kırman, A., & Kesbiç, C. (2020). Yükselen Piyasa Ekonomilerinde Çevresel Kuznets Eğrisi' nin Geçerliliği. *Sosyal Bilimler Araştırma Dergisi*, *9*(3), 93–104. https://dergipark.org.tr/tr/pub/ssrj/issue/56126/756955

Kuznets, S. (1955). Economic growth and income inequality. *American Economic Review*, *45*(1), 1–28. https://assets.aeaweb.org/asset-server/files/9438.pdf

Le, H. P., & Ozturk, I. (2020). The impacts of globalization, financial development, government expenditures, and institutional quality on CO_2 emissions in the presence of environmental Kuznets curve. *Environmental Science and Pollution Research*, *27*, 22680–22697. https://doi.org/10.1007/s11356-020-08812-2

Maneejuk, N., Ratchakom, S., Maneejuk, P., & Yamaka, W. (2020). Does the Environmental Kuznets Curve Exist? An International Study. *Sustainability*, *12*(21), 9117. https://doi.org/10.3390/su12219117

Ochoa-Moreno, W. S., Quito, B., Enríquez, D. E., & Álvarez-García, J. (2022). Evaluation of the environmental Kuznets curve hypothesis in a tourism development context: Evidence for 15 Latin American countries. *Business Strategy and The Environment*. https://doi.org/10.1002/bse.3012

Örnek, İ., & Türkmen, S. (2019). Gelişmiş Ve Yükselen Piyasa Ekonomilerinde Sürdürülebilir Enerji: Çevresel Kuznets Eğrisi Yaklaşimi. *Çukurova Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, *28*(3), 109–129. https://doi.org/10.35379/cusosbil.591118

Panayotou, T. (1993). *Empirical tests and policy analysis of environmental degradation at different stages of economic development* (World Employment Programme Research Working Paper). http://www.ilo.org/public/libdoc/ilo/1993/93B09_31_engl.pdf

Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics*, *22*(2), 265–312. https://doi.org/10.1002/jae.951

Pesaran, M. H., Shin, Y., & Smith, R. P. (1997). *Estimating long-run relationships in dynamic heterogeneous panels* (DAE Working Papers Amalgamated Series 9721).

Pesaran, M. H., Shin, Y., & Smith, R P. (1999). Pooled mean group estimation of dynamics heterogeneous panels. *Journal of the American Statistical Association*, *94*(446), 621–634. https://doi.org/10.2307/2670182

Renzhi, N., & Baek, Y. J. (2020). Can financial inclusion be an effective mitigation measure? evidence from panel data analysis of the environmental Kuznets curve. *Finance Research Letters*, *37*, 101725. https://doi.org/10.1016/j.frl.2020.101725

Saqib, M., & Benhmad, F. (2021). Does ecological footprint matter for the shape of the environmental Kuznets curve? Evidence from European countries. *Environmental Science and Pollution Research*, *28*, 13634–13648. https://doi.org/10.1007/s11356-020-11517-1

Tatoğlu, F., & İçen, H. (2019). Çevresel Kuznets Eğrisinin Çok Boyutlu Panel Veri Modelleri ile Analizi. *Anadolu İktisat ve İşletme Dergisi*, *3*(1), 26–38. https://dergipark.org.tr/tr/pub/anadoluiid/issue/44361/541320

Wang, Q., Wang, X., & Li, R. (2022). Does urbanization redefine the environmental Kuznets curve? An empirical analysis of 134 Countries. *Sustainable Cities and Society*, *76*, 103382. https://doi.org/10.1016/j.scs.2021.103382

Wang, S. S., Zhou, D. Q., Zhou, P., & Wang, Q. W. (2011). CO_2 emissions, energy consumption and economic growth in China: A panel data analysis. *Energy Policy*, *39*(9), 4870–4875. https://doi.org/10.1016/j.enpol.2011.06.032

Westerlund, J. (2007). Testing for error correction in panel data. *Oxford Bulletin of Economics and Statistics*, *69*(6), 709–748. https://doi.org/10.1111/j.1468-0084.2007.00477.x

World Bank. (2022). *World Bank development indicators*. https://databank.worldbank.org/source/world-development-indicators

Yandle, B., Bhattarai, M., & Vijayaraghavan, M. (2004). Environmental Kuznets Curves: A review of findings, methods, and policy implications. *PERC Research Study*, *2*(1), 1–38.

Yao, S., Zhang, S., & Zhang, X. (2019). Renewable energy, carbon emission and economic growth: A revised environmental Kuznets Curve perspective. *Journal of Cleaner Production*, *235*, 1338–1352. https://doi.org/10.1016/j.jclepro.2019.07.069

Yilanci, V., & Ozgur, O. (2019). Testing the environmental Kuznets curve for G7 countries: evidence from a bootstrap panel causality test in rolling windows. *Environmental Science and Pollution Research*, *26*, 24795–24805. https://doi.org/10.1007/s11356-019-05745-3

Zang, Y., Chen, X., Wu, Y., Shuai, C., & Shen, L. (2019). The environmental Kuznets curve of CO_2 emissions in the manufacturing and construction industries: A global empirical analysis. *Environmental Impact Assessment Review*, *79*, 106303. https://doi.org/10.1016/j.eiar.2019.106303