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RESEARCH ARTICLE

Environment, education, and economy nexus: evidence from selected EU countries

Ibrahim Cutcu[1] · **Yildiz Ozkok**[1] · **Filiz Golpek**[1]

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Abstract

Among the most fundamental problems today are environmental problems. As people earn higher incomes as a result of getting a good education, their sensitivity to environmental problems increases. As the income level of both the consumers who have received quality education and the producers who make conscious production increases, their demand for environmental quality and their sensitivity to environmental problems will also increase so it is thought that educational expenditures and policies can affect the number and cost of environmental problems. On the other hand, economic activities comprehensively consume natural resources and impact the ecological quality adversely. Therefore, GDP and the educational expenditures variables are used in the model. The aim of this study is to analyze the relationship between environment, education, and economy during the period of 1998–2017 from selected EU countries (Austria, Italy, the Netherlands, Norway, Poland, Portugal, Romania, and Slovakia). As a result of the panel data analysis, according to the Durbin-Hausman cointegration test result, a long-run relationship between the variables was determined at the level of 1%. According to the results of the Dumitrescu-Hurlin causality test, a unidirectional causality relationship from educational expenditures to ecological footprint at the level of 5%, a unidirectional causality relationship from ecological footprint to renewable energy at the level of 1%, and a bidirectional causality relationship at the level of 1% between ecological footprint and GDP were determined. According to the results of Granger causality test based on the VEC model, a unidirectional causality relationship from ecological footprint to educational expenditures at the level of 5%, and bidirectional causality relationship between ecological footprint and renewable energy (from ecological footprint to renewable energy at the level of 10%; from renewable energy to ecological footprint at the level of 1%) were determined. Based on the findings, it can be concluded that economic and educational policy makers should be aware that they have important consequences on environment.

Keywords Environment · Ecological footprint · Educational expenditures · Renewable energy · GDP · EU countries

JEL classification J24 · Q01 · Q20 · Q43 · Q50 · Q56 · Q58

Introduction

Education has been accepted as a system that plays a very important role in the lives of both societies and individuals since early times. It determines the economic, social, and political structure of countries and ensures their continuity through development. The effect of education on the economy appears in the form of providing economic growth by increasing the quality of the workforce and increasing the wages and national income (GDP). This aspect causes people to be regarded as human capital in the process of economic development, and education to be viewed as a national investment and to emerge as measurable monetary

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✉ Ibrahim Cutcu
ibrahim.cutcu@hku.edu.tr

Yildiz Ozkok
yildiz.ozkok@hku.ed.tr

Filiz Golpek
filiz.golpek@hku.edu.tr

[1] Department of Economics, Hasan Kalyoncu University, Gaziantep, Turkey

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benefits due to its transformation into increasing income (Heckman et al. 2017: 28).

The social and political features of education, on the other hand, are apparent in the form of determining the structure and political order of societies for centuries, on the one hand preserving the various information that the society has and on the other hand systematically developing them and making them usable. With this aspect, education exhibits a structure that is open to developments and creates immeasurable benefits for the individual himself and other members of the society (Vila 2000: 23; Oreopoulos and Salvanes 2011: 160). These nonmonetary benefits can be listed as educated individuals having better employment conditions, being more conscious in their consumption and investment decisions, living healthier and longer, contributing to the increase in the literacy rate, developing citizenship and democracy awareness, and participating in more broadcasting and cultural activities. These benefits also include low crime rates, creating an environment conducive to economic growth, better functioning of the economy and markets, development of freedoms, and increasing sensitivity to the problems of global warming, climate change, and environmental pollution (Dziechciarz-Duda and Król 2013: 83; Romanello 2017: 2). This means that education creates an increase in socially desirable behaviors and a decrease in undesirable ones.

The nonmonetary benefits of education include reducing both the number and cost of social problems. The primary social problems experienced in recent years include climate change, depletion of the ozone layer as a result of the increase in CO_2 emissions, decrease in natural resources, reduction in biological diversity, global warming, and increase in desertification due to decreasing forests. Protecting the environment, helping to eliminate environmental problems, and not facing new environmental problems are only possible with positive behaviors towards the environment. Solving environmental problems is possible not only by using technology or laws but also by changing individual behaviors (Managi et al. 2009: 347).

Positive developments such as the development of environmental awareness, change in individual behaviors, and increase in social awareness depend on the education policies in the country. Consumers who are not sufficiently conscious of the environment may increase their consumption in a way that harms the environment via the mindset of “more consumption for more happiness.” After all, consumers will only purchase what is good for them, and producers, as a result, will only produce what consumers are willing to pay for (Prıncen 2001: 12). On the other hand, when consumers attain a higher income level by receiving a good education, their demands for environmental quality increase and they prefer politicians who are sensitive to environmental degradation (Farzin and Bond 2006: 218). Educated societies can increase environmental awareness in terms of consumption, as well as provide significant environmental improvements in production. Societies with a high level of education continue their production activities by preserving the ecological balance in many areas from the energy used in production to production techniques that do not harm the environment.

The recent increase in environmental problems around the world has become a research subject that concerns both individuals and society as a whole. Public interest in this subject is based on an effort to clearly understand the causes of environmental degradation. The common thread in studies investigating the effects of economic growth on the environment is that the pressure on the environment will be high in the early stages of economic growth and this pressure will decrease at high income levels (Dinda 2004: 432). Accordingly, environmental pollution increases in the first stages of economic growth and after a certain threshold value, as economic growth increases, the trend reverses and economic growth leads to environmental improvement (Barua and Hubacek 2009: 52; Zhang and Cheng 2009: 2708). In the early 1990s, Grossman and Krueger (1991) explained this situation through the environmental Kuznets curve (EKC) hypothesis, which suggested an inverted U-shaped relationship between economic growth and environmental pollution. According to the theory, environmental pollution rises with increases in economic growth until economic growth reaches the optimum level, while environmental pollution begins to decrease after economic growth reaches a certain level.

During economic growth in developing countries, energy demand is largely provided by fossil fuel consumption. The economic growth model has detrimental consequences on environmental quality to a certain extent. Due to high costs, energy savings and access to renewable energy cannot be achieved in such countries. When growth reaches a certain level, the increase in environmental awareness prompts policy makers and industries to think about less polluting technologies and renewable energy sources, and thus the economic growth model causes a decrease in environmental degradation (Destek and Sinha 2020: 8).

As the scale of production increases with the growth of economies, the amount of natural resources used in production will increase, so more environmental waste will be generated. Using more natural resources in the production process will result in environmental pollution, global warming, and climate change given the technology (Galli 2015: 211). If technologies that cause environmental pollution are used, increasing production depending on the amount of output will further increase environmental pollution. Industry-related environmental pollution does not occur in underdeveloped or developing countries whose economic structure is limited to agriculture. However, in countries whose economic structure is transitioning from the industrial sector to the services and information sector, there will be reductions in environmental degradation and pollution as the services and information sectors use less natural resources compared to the industrial sector (Can et al. 2021: 3360).

The economic growth levels of the countries affect the ecological destruction and are regarded as the factor that reduces the biological capacity of the world and narrows the living spaces to the extent of consumption patterns. Research on environmental problems reveals that especially developed countries use more biologically productive areas than other countries and if these countries continue with the same consumption habits, the capacity of the planet will not be able to bear this burden (Zaidi and Ferhi 2019: 2158). These results generally cause environmental degradation to be associated with economic growth and make sustainable development necessary in countries that can provide economic growth that reduces the damage to the environment (Destek and Ozsoy 2015: 3).

In industrial production, which is included in countries' economic growth targets, the focus has always been on finding energy sources that can be easily accessed and converted to meet the energy demand. This has caused the priority in energy production to always be given to hydrocarbon resources such as coal, oil, natural gas, and nuclear energy. Since these resources are of fossil origin, they take millions of years to replace when consumed, and the damage they have caused to the environment since they were first used has become irreparable. Production structures become dependent on fossil energy types, mainly coal, oil, natural gas, etc. and these lead to increased CO_2 emissions (Lee and Lee 2009: 414; Narayan and Narayan 2010: 662).

Many factors such as nonenvironmental industrial production, rapid urbanization, and the negative effects of technology increase ecological problems. In this context, scientists who conduct solution-oriented research on environmental problems develop many different methods and techniques for calculating the productivity and amount of natural resources. In this context, the ecological footprint (EF), which was first developed by Wackernagel and Rees (1996) and is accepted as an indicator of sustainability and sustainable development, is important. As examined in recent studies in the literature, Yılancı et al. (2022), Saqib and Benhmad (2021), Udemba (2021), Dogan et al. (2020), Ansari et al. (2021), Destek and Sarkodie (2019), Al-Mulali et al. (2015), and Hervieux and Darné (2015) used the EF variable as an environmental indicator in their studies. The reasons behind this use can be listed as follows: the EF has many sub-components (grazing land footprint, fishing grounds footprint, cropland footprint, forest land footprint, built-up land footprint, and carbon footprint) as an environmental indicator and it is more inclusive compared to others. Due to the stated reasons, the EF was included in the analysis as an environmental indicator in the present study.

Today, the apparent alternatives to fossil fuel–based energy production are geothermal; solar energy; wind, tidal, and wave sources (defined as renewable energy); solid biofuels; biogas; and biodiesels. Renewable energy offers opportunities to prevent global warming by reducing the volume of CO_2 emissions, and to reduce the external dependence of countries that do not have energy resources such as oil and natural gas (OECD, 2017; Ahmad et al. 2021b: 22589). Renewable energy, which is also considered part of total primary energy supply, has an important place as it reduces the dependency of countries on foreign sources and represents an opportunity for economic growth (Ahuja and Tatsutani 2009: 2).

Although the share of energy produced from renewable energy sources is much lower than that from hydrocarbon energy sources, the advantages, such as not being fossil-based, having a minimum level of harm to the environment compared to hydrocarbons, and being able to renew themselves, have an important place in the economic growth of countries when considered together with the increasing population (Kates 1996: 44; Ellabban et al. 2014: 749). It is seen that countries tend to use renewable energy with the intention of reducing both economic and environmental pollution. It does not seem possible for countries to grow economically without the use of energy. However, environmental pollution caused by energy use resulting from economic growth is now taken into account. Since such a cycle will make a clean environment more valuable for society, it has forced researchers to study renewable energy that can minimize environmental pollution rather than using fossil fuels (Dong et al. 2020: 2).

As can be seen in the theoretical framework, which analyzes the relationship between environment, education, and economy, it is of great importance to develop the right policies for these three variables, which have been important for many countries in recent years. Therefore, the research question is "Is there a relationship between environment-education-economy?" Because, as stated in the literature part of the study, the long-run relationship between education-economy or between environment-economy has been discussed in many studies, but there are not enough studies on the education-environment relationship. Educated societies differ in their production and consumption awareness and their approach to environmental problems. Education has a very positive effect on economic growth as it provides a country with economically stronger citizens (Lucas 1988: 36; Romer 1986: 1013). In addition, education is a driving force of economic growth since individuals reach a higher income level with economic growth and want to consume and produce more in order to be happier (Jorgenson 2003: 384). Production and consumption processes, on the other hand, can cause environmental problems unless they are managed properly. In this context, the main motivation of the study was to analyze the relationship between environment, education, and economy and to develop policy proposals based on the findings obtained.

Annual data for the period 1998–2017 were used in the study, through which the hypothesis "there is a relationship between environment, education, and economy" was tested. The sample of the study consists of selected EU countries (Austria, Italy, the Netherlands, Norway, Poland, Portugal, Romania, and Slovakia). The main reasons for choosing EU countries in the analyses can be provided as follows: (i) According to World Bank data, the EU is the second largest economy in the world after the USA. (ii) The EU behaved as a world leader in environmental awareness and implemented different climate and energy legislative packages and environmental regulations such as the Kyoto protocol in April 2002, with the subsequent legislation, and the independent EU commitment to reduce overall greenhouse gas emissions by 20% compared with 1990 levels but "are the environmental regulations of the EU efficient enough?" (iii) The EU, the world's largest political and economic organization, constitutes 6% of the world's population. (iv) According to World Bank data, the countries with the highest share of their budgets allocated to EE are in the EU. (v) More importantly, the present study is the first in the literature to examine both the short-run and the long-run relationship between the environment, education, and economy variables in selected EU countries. In the model created to test the determined hypothesis, EF was the environmental variable, the educational expenditures (EE) of the countries included in the sample was the education variable, and the GDP was the economy variable. In addition, the variable of renewable energy consumption (REC), which is known to affect the EF through studies in the literature, was also included in the model as a control variable. In the rest of the paper, firstly, after the theoretical and conceptual framework is given, a literature search on the relevant field is presented and the contribution of the study to the literature is discussed. Afterwards, the relationship between environment, education, and economy is tested with panel data analysis and the results are interpreted. At the end of the study, the analysis findings are discussed, and policy recommendations are given.

Literature review

In recent years, the problems of climate change, environmental sustainability, and threats to human health have become among of the most important issues on the global agenda and have been a policy priority. Scientists are unanimous that humanity is affecting the Earth in profound and in some cases irreversible ways. Under the main headings of social, economic, and environmental sustainability, the concept of sustainable development has gained great importance for the future of the world and humanity. In this context, there are several studies on the factors affecting the environment and how the effects of climate change can be reduced. From this perspective, the nexus between environment, education, and economy is examined in the present study. When the literature on environmental issues, education, and the economy are examined, the long-run relationship between education-economy or between environment-economy has been discussed in many studies, but there are not enough studies on the education-environment relationship. In addition, it is seen that the studies examining a relationship between the three variables have been insufficient. For this reason, it is thought that this novelty of the present study would make significant contributions especially to the environment and education literature.

Due to the stated shortcomings, the variables included in the model within the scope of the literature research were grouped and analyzed separately. In this context, firstly, the literature on the relationship between environment, GDP, and renewable energy was examined, and then studies investigating the relationship between environment and education were evaluated. After the literature review, the relationship between environment, education, and economy was interpreted in general and the contribution of our study to the literature was explained, respectively.

Relationship between environment and economy

One of the most important issues in environmental studies is to select which environmental variable to use in the analyses. Since the increase in CO_2 emissions is considered the most important factor involved in the threat of climate change, the bulk of the studies on the environment have used these emissions as a measure of environmental degradation (Kasperowicz 2015: 91). In the economics literature, the basic indicator used as an economic variable is GDP. In this context, Coondoo and Dinda (2002); Lise (2006); Richmond and Kaufmann (2006); Soytas and Sari (2009); Apergis and Payne (2010); Fodha and Zaghdoud (2010); Pao and Tsai (2011); Niu et al. (2011); Narayan and Popp (2012); and Zamula and Kireitseva (2013) examined the relationship between the environment and the economy using CO_2 emissions, GDP, and energy consumption data.

Recently, it has been observed that economic growth and development have led to the emergence of new energy-efficient and low-carbon technologies. In addition, rather than which variable is often used as a measure of environmental degradation, it is a much more important issue which variable is used for which reasons in recent years. Accordingly, Wackernagel and Rees (1996, 1997) proposed the EF as an indicator of the carrying capacity of regions, nations, and the world, and even extended its scope to be an indicator of sustainability. Therefore, when the studies carried out in recent years were examined, it was seen that the EF was frequently used as one of the most important ways to measure the ecological impact of humanity. Therefore, in the present study, EF is used as a measure of environmental degradation.

When the literature on the factors affecting the EF is examined, it is seen that studies investigating the relationship between EF, GDP, and renewable energy are on the rise. While analyzing the relationship between environment, education, and economy in the present study, as it can be seen in the methods part, the renewable energy variable was included in the model as a control variable, as seen in many studies in the literature, with the thought that it affects environmental factors. In conclusion, studies examining the relationship between EF, GDP, and REC are summarized in Table 1.

Relationship between environment and education

When the literature on education is examined, it is seen that the studies mainly focused on the relationship between education and economic growth. Most of these studies conclude that there is a positive relationship between education and economic growth. Schultz (1963), Hicks (1980), Romer (1990), Weiss (1995), Bassanini and Scarpetta (2001), Keller (2006), Blankenau et al. (2007), Kıran (2014), and Mallick et al. (2016) can be given as examples of the studies that examine the relationship between education and economic growth in the literature.

Numerous studies have been conducted in the field of environmental education and awareness. The findings obtained from these studies also support the importance and interest of today's society concerning this issue (Sun et al. 2019: 3668-3669). Some of these studies show a direct link between environmental education and reducing carbon emissions. However, when the literature was examined, it was determined that the relationship between the expenditure on education and the environment is a very new phenomenon in the world and there is a research gap in this field. There are very few empirical studies examining the relationship between environmental degradation and education. When the studies examining the relationship between the environment and education were examined, it was seen that no complete consensus was formed through the findings obtained from the empirical studies on the impact of education on the environment. The reason for this may be that the effects of different education levels on environmental quality differ. In addition, the direction of the said effect changes in the long term (Aytun 2014: 351).

When the studies in the literature are examined, it is seen that different indicators were used as the education variable. There are very few analyses in which EE are used as the education variable. It is seen that CO_2 emissions are mainly modeled as an environmental indicator used in these studies. Therefore, no study is found in which EE is used as the education variable and EF is used as the indicator of environmental degradation in EU countries when looking at the similar works. Thus, it is thought that the present study, which analyzes the relationship between EF and EE, will make a very important contribution to the literature. Studies examining the environment-education relationship are summarized in Table 2.

Econometric analyses and methodology

In the analysis part of this study, the relationship between environment, education, and economy will be tested for selected EU countries (Austria, Italy, the Netherlands, Norway, Poland, Portugal, Romania, and Slovakia). In this context, first of all, the dataset and model of the variables to be used within the scope of the established hypothesis will be introduced. Then, the method to be used will be determined. After the theoretical and conceptual frameworks of the tests to be applied within the scope of the method are presented, the findings obtained from the analyses will be interpreted.

Data and model

In the research, the hypothesis "*There is a relationship between environment, education, and economy*" was tested with panel data analysis for selected EU countries. In the analyses, the annual data during the period of 1998–2017 were used, especially due to the data constraints in EE and the common data problem. In this context, although the EU countries were chosen as the country sample in the study, only eight countries, i.e., Austria, Italy, the Netherlands, Norway, Poland, Portugal, Romania, and Slovakia, could be included in the analysis. Therefore, the findings to be obtained will be evaluated and interpreted for these countries.

The variables of the model determined in accordance with the established hypothesis are given in Table 3. The variables included in the model were determined in accordance with previous studies in the literature section. In this context, the EF, which is the most widely used indicator of environmental degradation in the literature recently and is regarded as the most comprehensive since it incorporates many environmental factors, was determined as the dependent variable. As independent variables, GDP, which is the main economic variable, was used as the economic variable and the ratio of public EE to GDP was used as the education variable in the model.

Table 1 Summary literature review of relationship between EF and GDP, REC

Study	Country	Period	Variables	Method	Main results
York et al. (2005)	139 countries	1999	EF, GDP	Cross-national variation	Wealth leads to greater overall environmental impacts for nations
Bagliani et al. 2008	141 countries	2001	EF, BC	OLS and WLS analysis	Absence of an inversion in trend in ecological footprint when GDP per capita rises
Caviglia-Harris et al. (2009)	146 countries	1961–2000	EF, real per capita GDP	EKC	No evidence of an EKC relationship between per capita output and the EF
Feng and Wu (2011)	China	1996–2008	EF, GDP	Panel data analysis	The relationship between ecological footprint and per capita GDP accorded with the EKC characteristics of reversed U shape.
Al-Mulali et al. (2015)	93 countries	1980–2008	GD, EF, EC, TRD, UR, financial development	GDPP square, EKC	Inverted U-shaped relationship between the ecological footprint and GDP growth
Al-Mulali and Ozturk (2015)	14 Middle East and North African countries	1996–2012	EF, EC, urbanization, TRD, IO, PS	Panel data analysis	Industrial development caused the environmental degradation
Al-Mulali et al. (2016)	58 developed and developing countries	1980–2009	REC, GDP, URB, TRD, EF	GMM, EKC framework	REC has a positive impacton EF
Aşıcı and Acar (2016)	116 countries	2004–2008	GDP per capita, EF, BC	Panel data analysis	The negative impact of economic growth on the environment at initial stages of economic growth turns to positive as countries become richer.
Dogan and Şeker (2016)	15-EU countries	1980–2012	CO_2, Real GDP, REC, NREC, TRD	Panel DOLS	EKC (Inverted U-shaped)
Öztürk et al. 2016	144 countries	1980–2008	EF, tourism, EC, TRD, URB	Panel data analysis	The number of countries that have a negative relationship between the ecological footprint and its determinants (GDP growth from tourism, energy consumption, trade openness, and urbanization) is more existent in the upper middle- and high-income countries.
Charfeddine and Mrabet (2017)	15 Middle East and North African countries	1995–2007	EF, real GDP, energy use, URB, political institutional index variable, fertility rate, life expectancy at birth	Panel data analysis	Strong evidence for bidirectional causality among the EF, real GDP and energy-use variables
Uddin et al. (2017)	EF contributing 27 countries	1991–2012	EF, GDP per capita, FD, TRD	FMOLS and DOLS	The positive impact of real income on EF of consumption per capita.

Table 1 (continued)

Study	Country	Period	Variables	Method	Main results
Bello et al. (2018)	Malaysia	1971–2016	EF, carbon footprint, water footprint, CO_2, GDP, URB, hydropower, fossil fuel consumption	ARDL, VECM Granger causality	Inverted U-shaped relationship between environmental degradation and real GDP
Destek et al. (2018)	15-EU countries	1980–2013	EF, GDP, TRD, REC, NREC	MG-FMOLS, MG-DOLS, and DCCE-MG	No EKC
Liu and Kim (2018)	44 countries	1990–2016	EF, GDP, FDI	Panel Vector Autoregression	Positive relation of FDI, and GDP with EF, while FDI bidirectional but GDP unidirectional
Alola et al. (2019)	16-EU countries	1997–2014	EF, GDP, NREC, REC, TRD, FR	Panel ARDL	1% increase in the share of REC in total energy consumption raises environmental deterioration by approximately 0.04% in the long run
Aydin et al. (2019)	26-EU countries	1990–2013	EF, GDP	Panel data analysis	Mixed results
Destek andSarkodie (2019)	11 newly industrializedcountries	1977–2013	EF, GDP, EC, credit of private sector	AMG, Heterogeneous panel causality	Increase in economic growth decreases EF. Bidirectional causality between GDP and EF
Fatima et al. (2019)	Pakistan	1990–2016	Renewable electricity output, energy use, human capital, GDP per capita	VECM Granger causality	The causal association running from aggregated energy use and renewable energy generation to economic performance was exposed in a long term as well as short term.
Hassan et al. (2019)	Pakistan	1990–2014	EF, GDP, natural resources (rents), BC, human capital, URB	ARDL and VECM Granger causality	GDP inverted U relation; no causal relation found
Danish et al. (2020)	BRICS	1992–2016	GDPP, REC, URB, NRR, EF	FMOLS and DOLS	Increasing renewable energy decreases ecological footprint
Altıntaş and Kassouri (2020)	14 European countries	1990–2014	CO_2 emissions, EF, GDP per capita, REC	IFE, Panel data analysis	REC is an environmentally friendly source
Aziz et al. (2020)	Pakistan	1990–2018	GDP, EF, FOR, REC	QARDL	GDP has a positive long-run effect on EF and REC minimizes EF
Destek and Sinha (2020)	24 OECD countries	1980–2014	GDP, EF,REC, TRD, NREC	EKC framework, panel data methodologies	EKC hypothesis does not hold because they found the U-shaped relationship between economic growth and ecological footprint. Increasing REC reduces ecological footprint
Sharif et al. (2020)	Turkey	1965Q1–2017Q4	EF, NREC, REC, GDP	QARDL	Directional causal relationship between GDP and EF, EKC hypothesis holds

Table 1 (continued)

Study	Country	Period	Variables	Method	Main results
Sharma et al. (2020)	South and Southeast Asian countries	1990–2015	REC, URB, population, FOR, NREC, GDP, EF	Panel ARDL	REC restores environmental quality
Afshan and Yaqoob (2021)	China	1990–2017	EF, eco-innovation, natural resource, FD, GDP, GDP^2	QARDL	There is a uni-directional causality from natural resource to EF, in the short run GDP and GDP^2 is significant to impact environmental degradation and in long-run there is inverted U-shaped relationship among the economic activity and the ecological condition
Ahmad et al. (2021a)	28 Chinese provinces	1998–2016	CO_2 emissions, FDI, GDP, population	Panel cointegration	FDI and GDP exhibited heterogeneities in terms of their influence on CO_2 emissions. EKC hypothesis was supported in five provinces, while sixteen of the provinces were confirmed non-EKC.
Ansari et al. (2021)	A sample of top renewable energy consuming countries	1991–2016	REC, EF, economic growth, globalization, URB	Panel cointegration tests	REC reduces the ecological footprint in the long run.
Chandio et al. (2021)	China	1990–2015	CO_2 emissions, REC, NREC, GDP per capita, agricultural value-added, FOR	ARDL, FMOLS, VDM, Granger causality test	REC reduces CO_2 emissions, while NREC and economic development increase the level of CO_2 emissions.
Jiang et al. (2021)	China	1981–2018	Natural resources (rents), GDP per capita, capital, TRD	QARDL, Granger causality test	Natural resource rent is lower than the values of GDP. A higher level of natural resource lowers development in China's financial perspective.
Ikram et al. (2021)	Japan	1965Q1–2017Q4	Economic growth, economic complexity, EF	QARDL	Asymmetric positive relation between economic growth and environment both in the short-run and long-run
Pata (2021)	U.S.	1980–2016	CO_2, EF, ECI, globalization,REC, NREC	Combined cointegration test	EKC holds
Satrovic et al. (2021)	Gulf Cooperation Council (GCC) region	1990–2019	CO_2 emissions per capita, Electric power consumption, Per capita GDP, Urban population, Democratic accountability index	EKC	For the whole panel, the EKC was found existent, but the country specific findings verified the EKC only in Saudi Arabia a Bahrain.

Table 1 (continued)

Study	Country	Period	Variables	Method	Main results
Afshan et al. (2022)	27 OECD countries	1990–2017	EF, ecological innovation, RET, GDP per capita	Heterogeneous panel causality, MM-QR	Increase in RET is likely to diminish the environmental hazards and stringent environmental policy index has a negative and significant effect on the EF
Ahmad and Wu (2022b)	G-20 economies	1985–2017	EF, CPI, GDP, population, NRD, ecological efficiency, patent applications, total trademark applications, industry value added, energy use efficiency, technological progress index.	PQR	Natural resource dependence contributes negatively and significantly to ecological efficiency and t technological progress exhibits a positive and statistically significant contribution to ecological efficiency
Ahmad and Wu (2022b)	OECD	1990–2017	EF, GPG, economic globalization index, eco-innovation, human capital index, FD, GDP	PQR, FMOLS, DOLS, panel cointegration	EF reveals highest correlation with GDP (69.2%).

ARDL, autoregressive distributed lag model; *QARDL*, quantile ARDL; *MG*, mean group; *AMG*, augmented mean group; *OLS*, ordinary least squares; *FMOLS*, fully modified ordinary least squares; *DOLS*, dynamic ordinary least squares; *MM-QR*, method of moment quantile-regression; *VECM*, vector error correction model; *WLS*, weighted least squares; *BC*, biocapacity; *IFE*, interactive fixed effects; *GMM*, generalized method of moment approach; *EKC*, environmental Kuznets curve ; *DCCE-MG*, dynamic common correlated effects-mean group; *BRICS*, Brazil, Russia, India, China, and South Africa; *EU*, European Union; *OECD*, Organization for Economic Co-operation and Development; *EF*, ecological footprint; *EC*, energy consumption; *PS*, political stability; *REC*, renewable energy consumption; *NREC*, non-renewable energy consumption; *GPG*, green productivity growth ; *CPI*, consumer price index; *NRD*, natural resource dependence; *TRD*, trade openness; *FD*, financial development; *IO*, industrial output; *URB*, urbanization; *FOR*, forest area; *PQR*, panel quantile regression; *NRR*, natural resource rent ; *FR*, fertility rate; *RET*, renewable energy transition; *FDI*, foreign direct investment

Table 2 Summary literature review of relationship between education and CO2 emission

Study	Country	Period	Variables	Method	Main results
Romuland (2011)	85 countries	1970–2004	CO_2 per capita, investment rate, TRD, population growth rate, political institutions, average schooling years, GDP	Panel data and GMM-System estimation	In developing countries, there is no convergence, and that education is not a factor in CO_2 growth, while in developed countries, there is a convergence for per capita CO_2 emissions.
Uddin (2014)	Bangladesh	1974–2010	CO_2 emission, EE, GDP growth	Johansen cointegration test	Strong positive relationship among environmental pollution, educational expenditure and economic growth
Aytun (2014)	10 Emerging countries	1971–2010	Economic growth, EC, education level and CO_2 emissions	Panel cointegration analysis	When the secondary education level is high, the CO_2 emissions increase; as the tertiary education level increases CO_2 emissions decreases
Aytun and Akın (2015)	Turkey	1971–2010	CO_2 emission, EC, GDP, primary, secondary and tertiary school enrolment	Bootstrap Causality Analysis	No causality between primary, secondary school enrollment and CO_2emission s, but causality relationship found from tertiary school enrollment towards to EC and CO_2 emissions
Baiocchi et al. (2010)	United Kingdom	2004	Education (degree or equivalent), CO_2 emission, different social factors	A Regression Based on Input−Output Model	Education seems to reduce emissions
Hassan et al. (2022)	BRICS	1989–2016	Economic growth, EP, primary school enrolment, Gini index, globalization index	Panel cointegration test	The expansion and improvement of education had a positive impact on environmental quality, directly and indirectly

TRD, trade openness; *EC*, energy consumption; *EP*, energy poverty

Table 3 Data set and sources

Abbreviation	Variable	Source
EF	Ecological footprint	Global Footprint Network
EE	Government expenditure on education, total (% of GDP)	World Bank
GDP	National income (USD)	World Bank
REC	Renewable energy consumption (% of total final energy consumption)	World Bank

As seen in the literature tables, all the variables used in the model are the most preferred variables and there will be no common data problem. When these variables are evaluated, as seen in the literature, variables such as trade openness, financial development, industrial output, and foreign direct investment are also used as an economy variable, apart from GDP. However, GDP was used in the model as an economy variable (see Table 1), as seen in many studies in the literature, in order to avoid common data problems for the EU countries during the 1998–2017 period, and because GDP is the most inclusive variable in the economics literature. As can be seen in Table 2, average schooling years, education level, primary, secondary, and tertiary school enrollment, and education degree variables were used as the education variable. However, in order to avoid common data problems as in GDP, the ratio of public educational expenditures to national income (EE) is included in the model. In addition, the EE variable is more inclusive as an education variable, and it is thought to be more explanatory and meaningful when evaluated in terms of national income-expenditure over EU countries. Moreover, when the literature is examined (see Table 1), it is seen that many variables such as energy use, carbon footprint, water footprint, CO_2 emissions, fossil fuel consumption, and energy consumption are effective on environmental indicators and are included in the model as control variables. However, REC, which is the most frequently used among these variables and shown as one of the most important indicators for environmental problems, was included in the model as a control variable.

Considering the relationship between the variables included in the model and the country sample (selected EU countries) used in the analysis, it is seen that there are many common and important points. First of all, considering the EKC hypothesis, the fact that EU is the second largest economy in the world makes GDP and ecological footprint meaningful as an environmental indicator in the model. As a requirement of EU policies, common policies need to be developed and implemented in many socio-economic factors. Education is one of the most important socio-economic factors. With the common education policy implemented in EU countries, the share of education expenditures in national income has been standardized. Moreover, a significant economic development has been seen in the EU because of common environmental and educational policies implementation in all EU members. In this context, the education, environment, and economy variables used in the model become even more meaningful. The REC variable used in the model is chosen as the control variable that can affect the ecological footprint the most. According to Eurostat data, the share of REC used in the total energy consumption in many EU countries, especially Sweden, Finland, and Latvia, is around 50%. Looking at the whole EU, it can be said that this share is close to 20%. Therefore, renewable energy consumption should also be included in the model.

In addition, the variable REC, which is known to affect the EF, was also included in the model as a control variable. Moreover, the logarithmic form of GDP was used in the analysis because the variables other than GDP in the model were index values or ratios. The main reason for use of logarithmic forms was to reduce the variables by obtaining the logarithms according to a certain base and to facilitate the interpretation of the analysis results. Logarithmic forms of the series do not cause any loss of information in the data, reduce the autocorrelation problem, and ensure that the series show normal distribution.

In the present study, in which the relationship between environment, education, and economy was examined, the model created in the specified sample and data interval was constructed as in Eq. (1) within the scope of the hypothesis established.

$$EF_t = \beta_0 + \beta_1 EE_{it} + \beta_2 GDP_{it} + \beta_3 REC_{it} + \varepsilon_{it} \tag{1}$$

While i=1, 2, 3,… .N represents the cross-sectional data in the model, t=1, 2, 3, …..T represents the time dimension and ε represents the error term.

Methods and results

In the present study, which analyzed the relationship between environment, education, and economy with the annual data for selected EU countries during the period of 1998–2017, panel data analysis techniques were used, and the applied methodological order was as follows:

- In order to analyze the existence of cross-sectional dependence of the variables, Breush and Pagan (1980) CD_{lm1} test and Pesaran et al.'s (2008) LM_{adj} test were used.
- In order to determine whether the variables included in the model contain a unit root, Pesaran's (2007) CADF test was used.
- In order to determine the homogeneity or heterogeneity of the variables, the homogeneity test developed by Pesaran and Yamagata (2008) was used.
- In order to determine the existence of a cointegration relationship between the variables included in the model, the Durbin-Hausman cointegration test developed by Westerlund (2008) was used.
- Finally, in order to analyze causality, the Dumitrescu and Hurlin (2012) panel causality test was performed.

Cross-sectional dependence test

In the global world, the interdependence of countries has increased. Therefore, a positive or negative change or a shock experienced in the economy of any country may affect other countries due to the dependency relationship. Thus, in econometric studies, it is necessary to determine the cross-sectional dependence of the variables due to the common factor problem.

Looking at the literature, Phillips and Sul (2003), Andrews Donald (2005), and Pesaran (2006), in their studies on cross-sectional dependence, stated that in the absence of cross-section analysis, studies would produce inconsistent and biased results. According to Breush and Pagan (1980) and Pesaran (2004), if cross-sectional dependence is detected in the variables, the analyses should be continued by taking this situation into account.

The tests used in the determination of cross-sectional dependence can be listed as follows:

- When the time dimension is greater than the cross-section dimension ($T>N$), the Breush and Pagan (1980) CD_{lm1} test is used.
- When the time dimension is equal to the cross-section dimension ($T=N$), the Pesaran (2004) CD_{lm2} test is used.
- When the time dimension is less than the cross-section dimension ($T<N$), the Pesaran (2004) CD_{lm} test is used.
- When the time dimension is both less than the cross-section dimension ($T<N$) and greater than the cross-section dimension ($T>N$), Pesaran et al.'s (2008) (LM_{adj}) test is used for the analyses.

While the Breush and Pagan (1980) LM test can be applied when the time dimension is greater than the cross-section dimension ($T>N$), the Pesaran (2004) CD test can be applied in any case.

$$CDLMI = T\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}^2 \sim \chi^2_{\frac{N(N-1)}{2}}$$

These tests give biased results when the group mean is zero and the individual mean is different from zero. This problem was corrected by Pesaran et al. (2008) by including the variance and mean in the test statistic. Therefore, the deviation corrected equation is expressed as LM_{adj}. The final version of the equation is given below.

$$LM_{adj} = \left(\frac{2}{N(N-1)}\right)^{1/2}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}^2\frac{(T-K-1)\hat{\rho}_{ij}^2-\hat{\mu}_{T_{ij}}^2}{v_{T_{ij}}} \sim N(0,1)$$

$\hat{\mu}_{T_{ij}}^2$ = average $v_{T_{ij}}$ = variance

The test statistic obtained from this equation shows a standard normal distribution asymptotically (Pesaran et al. 2008). The hypotheses of the test are as follows:

H_0: There is no cross-section dependency.
H_1: There is a cross-section dependency.

When the probability value to be obtained as a result of the test is less than 0.05, at the 5% significance level, the H_0 hypothesis is rejected and it is concluded that there is a cross-sectional dependency between the units forming the panel (Pesaran et al. 2008).

The number of countries included in the analysis in the study was 8. Therefore, N=8, which represents the cross-sectional dimension. The time dimension, on the other hand, is T=20 since the study includes annual data for the 1998–2017 period. Since $T>N$, the Breusch-Pagan CD_{lm1} test and Pesaran et al.'s (2008) LM_{adj} test were used in the analyses.

Considering the countries included in the model and the time dimension, the decision can be made according to the CD_{lm1} and LM_{adj} results, since $T>N$. Since the CD_{lm1} test usually gives conflicting results in cross-sectional dependence tests, the results of the LM_{adj} test are taken into account. When Table 4, which shows the cross-sectional dependence test results, was examined, it was seen that the probability values of all variables were statistically significant at the 1% level. Accordingly, the main hypothesis for all variables, "*there is no cross-section dependence*," is rejected, and the hypothesis in the panel data that says "*there is a cross-sectional dependence between countries*" is accepted. This situation is consistent with today's global world, and it was concluded that a shock that may occur in one of the selected EU countries will also affect others. Therefore, the leaders and policymakers of the countries

Table 4 Cross-sectional dependence tests results

Variables	CD tests	CD_{lm1} (BP 1980)	CD_{lm2} (Pesaran 2004)	CD (Pesaran 2004)	LM_{adj} (Pesaran et al. 2008)
GDP	T-statistics	531.7334*	67.31421*	23.05541*	67.10369*
	Prob. Value	0.0000	0.0000	0.0000	0.0000
EF	T-statistics	128.8385*	13.47511*	8.625865*	13.26458*
	Prob. Value	0.0000	0.0000	0.0000	0.0000
EE	T-statistics	67.27514*	5.248361*	0.951662*	5.037835*
	Prob. Value	0.0000	0.0000	0.3413	0.0000
REC	T-statistics	353.7878*	43.53522*	15.12310*	43.32469*
	Prob. Value	0.0000	0.0000	0.0000	0.0000

*, **, and *** indicate cross-section dependency at 1%, 5%, and 10% significance levels, respectively

included in the analysis should make decisions and plans considering this situation.

Panel unit root test

In econometric analysis, stationarity tests are required to solve the spurious regression problem. Granger and Newbold (1974) stated that in the case of a unit root in the series of variables included in the model, the results obtained from the analyses will not be real findings. The determination of the stationarity of the series can be measured as follows: A series is stationary if the variance and mean do not change over time and the covariance between two periods depends only on the distance between two periods, not on the period of this covariance.

The main point to be considered in the stationarity tests of panel data analyses is whether the countries in the sample included in the model are independent of each other. In this context, unit root tests of panel data analyses consist of first- and second-generation tests. First-generation unit root tests are divided into two according to the homogeneity and heterogeneity characteristics of the countries included in the model. Among these tests, Levin et al. (2002), Hadri (2000), and Breitung (2005), which are the most widely used in the literature, are tested according to the homogeneity assumption, while Im et al. (2003), Maddala and Wu (1999), and Choi (2001) are tested according to the heterogeneity assumption.

While the first-generation unit root tests do not take into account the cross-sectional dependence, the second-generation tests perform their analyses according to the cross-sectional dependence. In today's global world, it is more realistic that a shock that occurs in one of the countries in the panel also affects other countries. Therefore, in the literature therefore, the use of second-generation tests is interpreted as a more accurate approach. In the present study, in which the relationship between environment, education, and economy was analyzed, it was thought that second-generation unit root tests should be used since there is a cross-sectional dependence between the variables included in the model. Therefore, the CADF unit root test, which was developed by Pesaran (2007) and is the most preferred second-generation unit root test in the literature, was used in the study. CADF test statistics estimation is given below:

$$T_{it} = \left(1 - \varnothing_i\right)\mu_i + \varnothing_i y_{i,t-1} + u_{i,t} \quad i = 1, 2, \ldots \ldots, N \; ve \; t = 1, 2 \ldots \ldots T$$
$$u_{i,t} = \gamma_i f_t + \varepsilon_{it}$$

f_t unobserved common effects of each country

ε_{it} Individual-specific error

The equations are given above, and their hypotheses are given as follows:

$$\Delta y_{it} = \alpha_i + \beta_i y_{i,t-1} + \gamma_i f_t + \varepsilon_{it} \quad i = 1, 2, \ldots \ldots, N \; ve \; t = 1, 2 \ldots \ldots T$$

H0: If β_i=0, the series are not stationary
H1: If β_i<0, Series are stationary

Finally, the unit root test statistics for the entire panel are calculated by taking the average of the unit root test statistics for each country. The statistical value expressed by CIPS is calculated with the following equation (Pesaran 2007):

$$CIPS = N^{-1} \sum_{i=1}^{N} CADF_i$$

The main differences between the CADF unit root test and other stationarity tests can be expressed as follows:

– Considering the countries included in the model and the time dimension, it gives consistent results for cases where $T>N$. In our study, N=18, which represents the cross-sectional dimension. The time dimension, on the other hand, is T=20 since it had annual data for the 1998–2017 period. Since $T>N$, the most preferred CADF unit root test in the literature will be used.

– In the analysis, a test statistic value is calculated for all units that make up the panel, and then the arithmetic average of these tests is taken to calculate the cross-sectionally augmented IPS (CIPS) test statistic for the panel as a whole. Thus, stationarity analyses can be performed for all countries as well as the panel in general.
– In the CADF test, the extended version of the ADF regression with delayed cross-sectional means is used. Thus, the regression model established with CADF will be reduced to estimating the regression specified in equation 1 with OLS (Pesaran 2007: 269).

$$\Delta y_{it} = a_i + b_i y_{i,t-1} + c_i \overline{y}_{t-1} + d_i \Delta \overline{y}_t + e_{it}$$

The CADF and CIPS test statistics values obtained after the CADF unit root tests are compared with the critical table values created by Pesaran (2007) with Monte Carlo simulations, and the hypotheses for stationarity are tested. Here, if the calculated CADF and CIPS test statistics values are greater than the critical table values in absolute value, the basic hypothesis (there is a unit root in the series) is rejected and the alternative hypothesis (there is no unit root in the series) is accepted for the relevant unit-panel in general (Pesaran 2007: 265-312). In the study, the stationarity of the variables included in the model for the selected EU countries, the overall panel, and the CADF unit root test for the cross-section units that make up the panel were analyzed with the fixed model and the results are presented in Table 5 with the critical table values given by Pesaran (2007).

When Table 5 is examined, it is seen that there is a unit root in the level values of the series across the countries that make up the panel, according to the CADF test results for the variables included in the model. On the basis of countries, the EE variable in Austria and the EF variable in Italy were stationary at the level of 5%. It was concluded that the CIPS statistical results, which express the overall panel, had unit roots in the level value of the overall panel, since all variables were smaller than the table critical values in absolute value.

In econometric analysis, the series must be stationary to the same extent in order to examine the medium- and long-run cointegration relationship between the variables. The most common method used in the stationarization of unit rooted series in empirical studies is to take the difference. Therefore, when unit root tests are performed again by taking the first order difference of all series, it is seen that the series become stationary because the CIPS statistical results expressing the panel in general are larger than the table critical values in absolute value. In this context, after taking the first order difference, when the variables were evaluated on a country basis:

- While the LGDP variable was unit rooted in all countries, it became stationary at 10% level in the panel according to CIPS statistics.
- While the EE variable is stationary at 10% in Portugal and Slovakia, it is unit rooted in other countries. According to the CIPS statistics, the panel stabilized at the level of 5%.
- While the REC variable was stationary at the level of 1% in Italy and Slovakia and 5% in Romania, it was unit rooted in the other countries. According to the CIPS statistics, it was stationary at the 5% level in the panel.

Table 5 CADF unit root test results

Country	LGDP	ΔLGDP	EE	ΔEE	REC	ΔREC	EF	ΔEF
Austria	0.246	−2.14	−4.140**	−2.01	−2.875	−2.590	−1.66	−1.461
Italy	−1.424	−2.00	−0.015	−1.56	−2.553	−4.843*	−3.35**	−4.404*
Netherlands	2.671	−2.81	−2.327	−2.15	−2.509	−2.886	−0.845	−1.721
Norway	−2.957	−2.14	−0.285	−2.16	−1.405	−1.608	−1.64	−4.596*
Poland	−1.318	−2.35	−1.107	−2.57	−2.383	−1.524	−0.875	−0.794
Portugal	−1.812	−2.06	−2.457	−3.12***	−0.38	−1.829	−1.66	−3.482**
Romania	−1.367	−2.18	−1.645	−2.57	−4.231	−3.539**	−1.01	−2.604
Slovak Republic	−1.691	−2.22	−1.806	−3.27***	−3.039	−5.567*	−0.614	−1.734
CIPS statistics	−1.624	−2.24***	−1.723	−2.42**	−1.795	−3.48**	−1.24	−2.600*

(1)CADF table critical values for Fixed Model: 1%: −4.35 5%: −3.43 10%: −3.00. CIPS table critical values: 1%: −2.60 5%: −2.34 10%: −2.21

(2) (*), (**), and (***) signs indicate that they are statistically stationary at 1%, 5%, and 10% significance levels, respectively

(3) The lag lengths were chosen according to the Schwarz information criterion

- While the EF variable was stationary at the level of 1% in Italy and Norway and 5% in Portugal, it was unit rooted in the other countries. According to the CIPS statistics, it became stationary at the level of 1% in the panel.

In the present study, in which the relationship between environment, education, and economy was analyzed, it can be inferred that after taking the first-order difference of the variables included in the model, all the variables become stationary at the same level, that is, at the I(I) level, and then the necessary prerequisite for the long-run cointegration analysis between the variables is met.

Homogeneity test

In panel data analysis methods, it is necessary to decide whether the coefficients of the variables assumed to have a long-run cointegration relationship are homogeneous. The homogeneity test determines whether the change in one of the countries is affected at the same level by the other countries. In this context, in the models created for countries with different economic structures, the coefficients are expected to be heterogeneous. In the models created for groups of countries with similar economic structures, the coefficients are expected to be homogeneous. In the present study, the slope homogeneity test (delta test) developed by Pesaran and Yamagata (2008) was used to test homogeneity.

Pesaran and Yamagata (2008) developed two homogeneity tests that can analyze the homogeneity assumption without considering the magnitudes of N and T. For example, in the cointegration model given below, whether the β_i coefficients are homogeneous between cross-section units is tested with the delta test.

$$y_{it} = \alpha + \beta_i X_{it} + \varepsilon_{it}$$

On the other hand, the equation given below was developed by Pesaran and Yamagata (2008) for large samples. They developed 2 delta statistics that are valid for small samples.

$$\hat{\Delta} = \sqrt{N\left(N - 1\tilde{S} - k\ 2k\right)} \sim Xk2$$

The equation that is used for small samples developed by the same authors and is given below.

$$\hat{\Delta}_{adj} = \sqrt{N\left(N - 1\tilde{S}\ k\ v\left(T, k\right)\right)} \sim N(0, 1)$$

In the equations, the N value represents the number of cross sections, the S value represents the Swamy test statistic, the k value represents the number of explanatory variables, and the $\nu(T, k)$ value represents the standard error.

The delta test is valid for large samples and the delta adj test is valid for small samples. In the homogeneity test, it is interpreted as "the slope coefficients are homogeneous" in the null hypothesis (H_0) and as heterogeneous in the alternative hypothesis (H_1).

In the present study, in which the relationship between EF, EE, and GDP was analyzed, the homogeneity test results of the variables included in the model are given in Table 6.

According to the test results, since the probability value of both test statistics was greater than 0.05, it was concluded that the slope coefficients did not change between the units in the long term, and therefore the variables were homogeneous. Since the variables were homogeneous, it was necessary to use panel statistics instead of group statistics in the analysis of relationships between variables.

Panel cointegration test

After the degree of stationarity of the variables is determined, the cointegration relationship can be examined for the existence of a long-run relationship. In the literature, the existence of a long-run relationship in panel data analyses is most frequently carried out by the methods used in the studies by Pedroni (1999), Pedroni (2007), Westerlund and Edgerton (2007), and Westerlund (2008). However, in cointegration analyses, as in unit root tests, cross-sectional dependence must be taken into account. Otherwise, problems such as accepting the hypothesis that there is a relationship even though there is no cointegration relationship may be encountered. Due to this problem, the Durbin-Hausman analysis developed by Westerlund (2008), which takes into account the cross-sectional dependence, was used in the present study.

There are many reasons for using the Durbin-Hausman test developed by Westerlund (2008) in our study. The most important advantage of the test is that it is a second-generation panel cointegration test that considering cross-sectional dependence. It also allows independent variables to be I(0) or I(I), while the dependent variable has to be I(I) (Westerlund 2008: 205). In addition, the Durbin–Hausman cointegration test allows both the parameters in the panel to be the same (homogeneous) among the units and the differentiation (heterogeneous) of the parameters between the units. If the

Table 6 Homogeneity test results

Test statistics	T statistics	Prob. value
Delta_tilde	−1035	0.850
Delta_tilde_adj	−1186	0.882

*, **, and *** indicate that the coefficients of the panel are heterogeneous at the 1%, 5%, and 10% significance levels, respectively

parameters are homogeneous among the units, *DH Panel* test statistics are used and if heterogeneous, *DH Group*. In the present study in which the relationship between environment, education, and economy was analyzed, it was concluded that the coefficients were homogeneous according to the results of the delta test developed by Pesaran and Yamagata (2008). Thus, it can be stated that the DH Panel test statistical results will give more reliable results in the cointegration test.

The hypotheses of the Durbin-Hausman panel cointegration test are listed as follows:

H_0 $\varnothing_i = 1$, There is no cointegration relationship. (i=1,2,….n)
H_1 $\varnothing_i < 1$, There is a cointegration relationship. (i=1,2,….n)

In the Durbin-Hausman method, the cointegration relationship allows one to test separately in the panel dimension and in the group dimension. In the Durbin-Hausman group test, the autoregressive parameter is allowed to differ between sections. The rejection of the H_0 hypothesis according to this test indicates the existence of a cointegration relationship in some sections. According to this test, it is accepted that the autoregressive parameter is the same in all sections. According to this assumption, if the H_0 hypothesis is rejected, it is accepted that there is a cointegration relationship for all cross-sections (Di Iorio and Fachin 2007).

The Durbin-Hausman panel data model is expressed by the following equation:

$$y_{it} = \alpha_i + \beta_i x_{it} + z_{it}$$
$$x_{it} = \delta X_{it-1} + w_{it}$$

The distribution of z_{ti} is assumed to be consistent with the set of equations specified below, which allows cross-section dependence through the use of common factors.

$$z_{it} = \lambda_i' F_t + e_{it}$$
$$F_{jt} = p_j F_{jt-1} + u_{it}$$
$$\mathrm{e}_{\mathrm{it}} = \phi_{\mathrm{i}} \mathrm{e}_{\mathrm{it-1}} + \mathrm{v}_{\mathrm{it}} \ (\text{For every j;}\mathrm{p_j} < 1)$$

$\mathrm{F_t}$ $\mathrm{F_{jt}}$ k-dimensional common factor vector

λ_i consistent vector of factor loads

Finally, the core estimator required for the Durbin-Hausman test is expressed by the following equation:

$$\hat{\omega} = \frac{1}{T-1} \sum_{j=M_i}^{M_i} \left(1 - \frac{j}{M_i + 1}\right) \sum_{t=j+1}^{T} \hat{v}_{it} \hat{v}_{it-j}$$

Where;

$\hat{v}_{it}$ OLS remains,

M_{ii} bandwidth parameter

The value of $\hat{\omega}_i^2$ is consistent with the estimate of ω_i^2 which is the long-run variance of $\hat{v}_{it}$. The corresponding simultaneous variance estimation can be specified with $\hat{\sigma}_i^2$. Given these estimates.

Two different variance ratios can be written as follow

$$\hat{S}_i = \frac{\hat{\omega}_i^2}{\hat{\sigma}_i^4} \text{ and } \hat{S}_i = \frac{\hat{\omega}_n^2}{(\hat{\omega}_n^2)^2}$$

After all necessary calculations are made, Durbin-Hausman group and panel (DH_g, DH_p) statistics can be estimated by the equations given below:

$$DH_g = \sum_{i=1}^{n} \hat{S}\left(\hat{\phi}_i - \hat{\phi}_i\right)^2 \sum_{t=2}^{T} \hat{e}_{it-1}^2$$
$$DH_p \hat{S}\left(\hat{\phi}_i - \hat{\phi}_i\right)^2 \sum_{i=1}^{n} \sum_{t=2}^{T} \hat{e}_{it-1}^2$$

In the present study, in which the relationship between environment, education, and economy was analyzed, it was concluded that there was a long-run relationship between the variables included in the model, according to the Durbin-Hausman cointegration test results and both group and panel statistical results seen in Table 7. According to results, a long-run relationship between the variables was determined at the level of 1%. Considering the delta test results, it can be said that the panel statistics results will give more reliable results. This shows that all kinds of decisions to be taken regarding environment, education, and economic policies, which are known to have a widespread impact on the socio-economy on both micro and macro scales, must be taken sensitively and carefully.

Panel causality test

Following the cointegration analyses among the variables included in the model, it is necessary to test the causality relationship and its direction. The cointegration relationship

Table 7 Durbin-Hausman cointegration test results

Test statistics	T statistics	Prob. value
Durbin-H Group Statistics	4.681*	0.000
Durbin-H Panel Statistics	16.048*	0.000

*, **, and *** show statistical significance levels of 1%, 5%, and 10% in the series, respectively. The maximum number of common factors was taken as 1

does not provide information about the causality relationship and its direction between the variables. In the present study, the causality relationship between environment, education, and economy was analyzed in the long run with the causality test developed by Dumitrescu and Hurlin (2012), and in the short run with the Granger causality test based on the VEC model developed by Engle and Granger (1987).

The main reason for choosing the Dumitrescu and Hurlin causality test was that it can be performed even in the absence of a cointegration relationship. At the same time, this test is a causality test that gives effective results when there is cross-sectional dependence or independence. In this method, constant slope coefficients are calculated separately for each country and cross-sectional dependence is also taken into account (Dumitrescu and Hurlin 2012:1457). The Dumitrescu and Hurlin (2012) panel causality test also gives results in $T>N$ and $T<N$ cases. Another important advantage is that, considering the cross-section dependence, it can give more accurate results in cases with unbalanced panel data.

Dumitrescu and Hurlin (2012) use the assumption that there is no homogeneous causality relationship since the panel causality test considers the regression model and the causality relationship. The hypothesis is defined as follows:

$$H_0 : \beta_i = 0, \forall_i = 1, 2, \dots, N$$

According to this equality, the β_i value continues as $\beta_i = \beta_i^{(1)}, \beta_i^{(2)}, \dots, \beta_i^{(k)}$ and it can differ between groups. The test also operates on the assumption that individual vectors (β_i) are equal to "0." There is also an individual process in which there is no causal relationship from $N_1 < N$ number of x to y in the null hypothesis. The alternative hypothesis is described as follows:

$$H_1 : \beta_i = 0, \forall_i = 1, 2, \dots, N_1$$
$$\beta_i \neq 0, \forall_i = N_1 + 1, \dots, N$$

In this equation, the value of N_1 is unknown and it meets the $0 \leq N_1/N < 1$ condition. The N_1/N ratio must be less than 1. The main reason for this is that there is no causal relationship between the variables used in the analysis, in the case $N_1 = N$. On the other hand, $N_1 = 0$ indicates the existence of a causal relationship between all the variables in the analysis.

In testing the null hypothesis, first, the Wald statistic ($W_{i,T}$) is calculated for all cross-sections, and the average of each is taken to calculate the panel Wald statistic ($W_{N,T}^{HNC}$). Finally, Dumitrescu and Hurlin (2012) has to use $Z_{N,T}^{HNC}$ in the case of $T>N$, and has to use Z_N^{HNC} the test statistic in the other case.

In the present study, in which the relationship between environment, education, and economy was analyzed, the Dumitrescu-Hurlin causality test was used to determine the long-run causality relationship between the variables, and the results of the findings are given in Table 8. An examination of the table revealed the following:

- A unidirectional causality relationship from EE to EF at the level of 5%,
- A unidirectional causality relationship from EF to REC at the level of 1%,
- A bidirectional causality relationship at the level of 1% between EF and GDP.

The results that were obtained showed that changes in EE can affect the EF. It can be concluded that environmental awareness can also improve when EE are used efficiently at the optimum level. This result, which is consistent with the theory, shows that the sensitivity of educated societies to environmental problems is high, especially through production and consumption. Apart from production and consumption, it can be said that societies with a high level of education may be more sensitive to environmental issues such as environmental pollution, protecting green, and the importance of recycling. In addition, the development in the EF can affect renewable energy. This situation is congruent with the theory and the solution of environmental problems affects renewable energy resources positively and can increase the use of these resources. Ecological footprint chosen as an environmental indicator in the study covers all environmental indicators with many sub-titles. It is expected that the improvements in environmental indicators will also encourage the consumption of renewable energy sources because the CO_2 emission created by fossil fuels can lead to environmental disasters as seen in many studies. Therefore, the causality relationship obtained once again

Table 8 Dumitrescu-Hurlin causality test results

Direction of causality	Test	Test statistics	Prob. value (%5)
EF≠>EE	Z-bar	0.1453	0.9000
	Z-bar tilde	−0.1248	0.8750
EE ≠> EF	Z-bar	4.7386**	0.0250
	Z-bar tilde	2.0618**	0.0250
EF ≠> REC	Z-bar	3.4372*	0.0000
	Z-bar tilde	2.4041*	0.0000
REC ≠> EF	Z-bar	0.6484	0.5750
	Z-bar tilde	0.2617	0.8250
EF ≠> LGDP	Z-bar	1550.8008*	0.0000
	Z-bar tilde	516.2669*	0.0000
LGDP ≠> EF	Z-bar	64.9678*	0.0000
	Z-bar tilde	20.9893*	0.0000

*, **, and *** show statistical significance levels of 1%, 5%, and 10% in the series, respectively

reveals the importance of renewable energy sources such as sun and wind. Finally, it was concluded that there was a mutual causality relationship between GDP and EF. This is also in line with the theory and is within the expectations. Improvements in GDP and welfare will affect environmental awareness, environmental investments, and environmental policies. Likewise, it is known that solving environmental problems, increasing environmental awareness, and reducing environmental disasters will have an impact on GDP. It is seen that many studies in the literature have obtained similar results (see Table 1). Especially, reducing environmental pollution will decrease the expenditures to be made in this area and increase the production; thus, the national income will be positively affected. Thus, with the increase in the national income and the welfare level, environmental awareness will also rise, and it will ensure that the necessary actions are taken by investing in the areas that affect the environmental pollution.

In the study, in which the relationship between environment, education, and economy was analyzed, the Granger causality test based on the VEC model was used to determine the short-run causality relationship between the variables, and the results of the findings are given in Table 9. An examination of the table revealed the following:

- A unidirectional causality relationship from EF to EE at the level of 5%
- A bidirectional causality relationship between EF and REC (from EF to REC at the level of 10%; from REC to EF at the level of 1%)

This relationship is 10% from EF to REC and 1% from REC to EF.

Table 9 VEC Modeline Dayalı Granger Nedensellik Testi

Direction of causality	Test statistics	Prob. value (%5)
EF≠>EE	10.3773	0.0056**
	2.8214	0.2440
EE ≠> EF	4.8730	0.0875***
	10.1639	0.0006*
EF ≠> REC	1.6977	0.4279
	1.2159	0.5444
REC ≠> EF	10.3773	0.0056**
	2.8214	0.2440
EF ≠> LGDP	4.8730	0.0875***
	10.1639	0.0006*
LGDP ≠> EF	1.6977	0.4279
	1.2159	0.5444

*, **, and *** show statistical significance levels of 1%, 5%, and 10% in the series, respectively

The obtained results are partially compatible with long-run causality analysis. However, the effects of changes that may take place in the short run may not have a direct response in the long run. For example, while there is no causality relationship between the EF and the GDP in the short run, the relationship has emerged strongly in the long run. In addition, while there is no causality relationship from EE to EF in the short run, it is seen that there is a causality relationship between education and the environment in the long run. As a result, it can be said that these results are compatible with the theory. When the results obtained in the short term are examined, causality is seen from EE to EF in the long run, while the opposite result is seen in the short run. Improvements in the EF, which is in environmental indicators, can also be interpreted as an indicator of social welfare. This situation can also affect many variables such as education and health in the global world. Therefore, the obtained results can be interpreted as the improvements in environmental indicators may affect education policies in the short term. The second causality relationship obtained is bidirectional causality from EF to REC. In the long run, a causality relationship was only seen from EF to REC. In the short run, it is seen that the effect of REC on environmental indicators is clearer. In other words, the EF and REC are important variables that mutually affect each other. All in all, it can be said that all these results are consistent with the theory.

Discussion

The core of the study is to investigate the relationship between education policies, economy, and environmental indicators, and their effects on the environment are investigated. The main contribution of the study to the literature can be interpreted as the development of environmental policies and proposals through education policies. In addition, it is thought that the use of education, economy, and environment variables together in the model over selected EU countries will bring an important novelty to the literature.

Education policy and quality in a country can create significant benefits that cannot be measured over the citizens of the country. The most important of these benefits emerge on the consumption, production, and investment decisions of educated individuals and environmental awareness. In addition, the increase in the level of education in the country will also solve the problem of the shortage of qualified personnel and positively affect the employment policies in the country. As can be seen, education policies can provide many improvements in social and economic fields in a country. When education policies are evaluated through social improvements, it is known that in recent years, main social problems have arisen from environmental problems. Generally, economic measures play an important role in the solution of environmental problems. However, since the developments in education policies will lead to an increase in educated individuals and a rise in social sensitivity, it should be evaluated in a different dimension in the fight against environmental problems because environmental problems cannot be solved by laws alone in today's global world. Environmental problems can be solved more easily with conscious societies and the high technology developed by educated individuals in these societies.

It is stated that the key to being strong and surviving in global competition is economic growth. When the dynamics of economic growth is examined, it is seen that the power of human capital is at the forefront. Human capital is fully powered by the education policies implemented in the country. As the share allocated to education from the budget is increased, more qualified people are trained, human capital is strengthened, and these circumstances can have positive effects on economic growth. So, the economic dimension of education is the increase in national income as a result of the increase in the quality of the workforce and then the economic growth. For this reason, EE should be considered as a national investment, and this investment should be assessed while bearing the socioeconomic problems of the country in mind.

The fundamental driving force of economic growth is increased production. Unless the increase in production is achieved by the right methods, significant environmental problems may occur. In addition, the consumption dimension of economic growth other than production should be analyzed correctly. With economic growth, the consumption habits of individuals whose income level rises are changing while increasing. This increase in production and consumption can cause significant environmental problems in societies that have not developed environmental awareness. As long as these environmental problems that may arise from economic growth are managed correctly with education policies, they will be kept at an optimum level and remedies can be developed. Because as the income level of both the consumers who have received quality education and the producers who make conscious production increases, their demand for environmental quality and their sensitivity to environmental problems will also increase.

The theory that best explains relationship between the environment and economic growth in the literature is the EKC hypothesis, which argues that the relationship between environmental pollution and economic growth is in an inverted U shape. When the studies investigating the EKC hypothesis in the literature were examined, it was seen that CO_2 emissions were the most frequently used environmental indicator. In the present study, the EF variable was used as an environmental indicator because it is the most widely used indicator of environmental degradation in the literature recently, it has many sub-components (grazing land footprint, fishing grounds footprint, cropland footprint, forest land footprint, built-up land footprint, and carbon footprint) and so it is more inclusive. In addition, the fact that the EF is not used at a sufficient level compared to CO_2 emissions as a variable in the whole literature shows the contribution of the present study to the literature in terms of the selected variable.

According to the EKC hypothesis, while environmental pollution increases in the early stages of economic growth, environmental problems decrease with the increase in national income. In other words, economic growth promotes environmental improvements. In the studies examining the relationship between economic growth and the environment in the literature, it is argued that the level of economic growth may have a share in ecological destruction. It is known that production and consumption policies affecting economic growth play an important role in ecological destruction. These results require the development of policies that will reduce environmental problems and ensure economic growth.

As conveyed in the theoretical framework of the present study, important disasters such as the climate crisis and global warming can be encountered in cases where the production process is not carried out with environmental awareness while economic growth is achieved. Since such environmental problems have become global in recent years, many institutions and organizations have implemented various types of cooperation and agreements to reduce environmental pollution. As the number of these deals increases and their applicability improves, it is expected that environmental quality will increase with economic growth. In addition, especially in developing countries, the energy needed in production for economic growth is mostly provided from fossil fuels. The negative effects of fossil fuels on the environment were explained in the theoretical framework of the study. Instead, access to proposed renewable energy sources and necessary investments require high investment costs. On the other hand, with the economic growth reaching a certain level, environmental awareness increases in educated societies. This situation puts pressure on governors of country to produce policies on renewable energy sources.

Improvements in environmental policies are related to education policies and economic growth. In order for countries to survive in global competition, they need to correctly manage all the variables that affect economic growth. In today's world, environmental awareness has increased considerably, especially in developed countries. The reasons for this are thought to be the developments in the economy and the increase in educated individuals. With this motivation, in the study, the relationship between education and economy variables and the environment was investigated through the EU countries, which are at the top as economic power, and policy proposals were developed based on the findings.

Conclusions

In the present study, in which the relationship between environment, education, and economy was analyzed, EU countries were chosen as the country sample group in the analyses carried out with the annual data for the 1998–2017 period. Austria, Italy, the Netherlands, Norway, Poland, Portugal, Romania, and Slovakia were included in the analysis due to the data constraint of the variables included in the model and the problem of creating common data.

In the analysis part of this study, first of all, the cross-sectional dependence of the variables included in the model created in accordance with the determined hypothesis and the literature was determined by Breush and Pagan (1980) CD_{lm1} test and Pesaran et al.'s (2008) LM_{adj} test. According to the results obtained, cross-sectional dependence was observed between the countries included in the analysis. Since there was cross-sectional dependence between the variables included in the model, the CADF unit root test devised by Pesaran (2007), a second-generation unit root test, was used in the stationarity analysis. While the variables included in the model according to the unit root test results were unit rooted in level values, all variables became stationary when their differences were taken. The homogeneity test developed by Pesaran and Yamagata (2008) was performed to determine whether the coefficients of the variables thought to have a long-term relationship in the panel data analysis were homogeneous. According to the results obtained from the homogeneity test, it was concluded that the variables were homogeneous, since the slope coefficients did not change between the units in the long term. In order to determine the existence of a cointegration relationship between the variables included in the model, the Durbin-Hausman cointegration test developed by Westerlund (2008) was used. It was concluded that there was a long-run relationship between the variables included in the model, when both group and panel statistical results were examined according to the panel cointegration test results. Finally, in the analysis part of the study, the causality relationship and direction between the variables in which the long-run relationship was seen were examined. In this context, analyses were carried out using the Dumitrescu-Hurlin (2012) panel causality test. According to the results of the panel causality test, a unidirectional causality relationship was determined from EE to EF at the level of 5%, a unidirectional causality relationship from EF to REC at the level of 1%, and a bidirectional causality relationship at the level of 1% between EF and GDP. According to the results of Granger causality test based on the VEC model, a unidirectional causality relationship from to ecological footprint to educational expenditures at the level of 5%, and bidirectional causality relationship between ecological footprint and renewable energy (from ecological footprint to renewable energy at the level of 10%; from renewable energy to ecological footprint at the level of 1%) were determined.

Considering the literature comparison of the analysis findings of the study, a direct comparison cannot be made since there is no study examining the environment-education-economy relationship in terms of EF, EE, and GDP. When the results of the research were compared with the literature, it was seen that while the results were compatible with those of many studies, they differed from those of some. The reason for this is thought to be the method used, the selected country group, the selected variables in the model, or the date range of the variables. Since the studies in which the variables used in the present study were used together were not sufficient in the literature, the literature comparison was made by binary grouping of the variables as seen in Tables 1 and 2. As can be seen in the literature comparison, this study differs from other studies due to the variables used, because it is seen that the studies that include socioeconomic analyses and propositions based on the solution of environmental problems with education policies have not reached certain maturity level yet.

Based on the empirical findings of this work, it can be concluded that economic and educational policy makers should be aware that they have important consequences on environment. The following policy implications are extracted: (i) Policy makers in the country's administration should first create solutions through education policies and expenditures. If the education budget is used efficiently and all kinds of investments in education can be managed correctly, it will be seen that the goals can be reached through economic growth, environmental awareness can be raised, and environmental problems can be prevented. Therefore, countries' administrators should develop new policies to produce individuals who are more sensitive to environmental problems with the education policies they will implement or the education mobilization that they can spread throughout the country. Especially among the country sample included in the analysis, countries that later joined the EU, such as Poland, Romania, and Slovakia, need to develop their education policies and manage their expenditures from the budget for education in order to reach EU standards because these countries are behind the other countries in the union, especially in terms of socioeconomic factors. (ii) It is necessary to develop policies in order to eliminate the risks posed by the ecological deficit. In this context, it is of great importance to reduce fossil fuel–based energy consumption in the production needed to ensure economic growth. In this context, the use of renewable energy sources should be encouraged and supported. It is very important that Italy, which is a major exporter of products such as machinery, medicine, furniture, textiles and ranks after Germany in terms of production power among EU countries, develops the specified policies regarding production. In this respect, it is essential for the development of the EU and the country that Italy provides the energy it needs in production from renewable sources. Depending on the level of development, countries should use nonrenewable energy resources with limited reserves in a planned manner and benefit more from renewable energy resources in order to increase the welfare level of societies and meet the increasing energy needs due to population and technological developments. In the EU in terms of population, Italy, which is the 3rd largest country, and Poland, which is the 5th country, should attach more importance to these policies. (iii) Consequently, it can be suggested that countries' administrators implement structural reforms that increase per capita income because, as can be seen from the EKC hypothesis, environmental problems are constantly increasing in countries that have not yet achieved economic prosperity. Therefore, it is necessary to give priority to policies that will increase GDP and welfare by increasing production, especially of value-added goods, and to develop sustainable and stable growth policies. Policy makers should consider the environmental costs in all kinds of economic and social decisions they take in governing of the country, because, after a certain economic growth performance, the environmental awareness of households increases. iv) The trend of deepening environmental awareness has revealed the necessity of establishing a strong environmental policy demanding reduction of environmental problems and transition to cleaner technology. In response to these requirements, it is not enough for the industry to redefine its roles in the social and economic context in relation to the natural environment, but also to develop and adopt eco-innovation that improves economic performance and minimizes environmental impacts. Companies operating in countries such as the Netherlands, Norway, and Austria, which are known to be ahead in terms of environmental policies, renewable energy resources production, and welfare level, are expected to take a leading role in such corporations.

Important policy proposals can be formulated from the findings of the analysis carried out in the present study and the results obtained in general. Suggestions will be made separately for new researchers, markets operating in the relevant sectors, and decision-makers in the country's administration. In this context, first of all, new researchers can conduct research on similar variables with different countries and country groups. Especially among the EU countries, the countries with the largest economy and/or education expenditures can be selected and analyses can be made using time series techniques. In addition, the relationship can be tested with different variables representing the basic headings of environment, education, and economy or to test the relationship between same variables using different tests.

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Data availability The data will be provided upon a reasonable request to the corresponding author.

Declarations

Ethics approval The manuscript does not report on or involve the use of any animal or human data etc.

Consent to participate The authors have agreed to authorship, read and approved the manuscript, and given consent to submit the manuscript.

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