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The impact of governance quality and educational level on environmental performance

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Environmental degradation and its impact on sustainable development have sparked the interest of national and international policymakers, specialists, and academia. This paper aims to demonstrate the empirical nexus between environmental performance, measured by carbon dioxide emissions, and education levels together with institutional quality in a society. To achieve this goal, the regression model includes the main variables that reflect the quality of governance (government effectiveness, regulatory quality, control of corruption, and rule of law), together with education dimension, gross domestic product, renewable energy consumption, fossil fuel energy consumption, and industry. The data were collected for the 1995–2020 period, for a set of 43 countries, consisting of all European Union (EU) members and The Group of Twenty (G20) states. The research uses three estimations methods, respectively Pooled ordinary least squares (Pooled OLS), Fixed effects model (FEM) and Random effects model (REM), together with a two-step dynamic GMM model, to address the endogeneity issue as well. The main results show that all the independent variables reflecting institutional quality from a technical point of view, included in the model when considering the PCSE estimation, have a direct and positive link to *CO2 emissions*' level, with control of corruption variable being the only one to influence in a positive manner *CO2 emissions* at a significant level. Education level, together with economic growth, fossil fuel energy consumption and industry, had a negative significant impact as well upon environmental performance, an increase of one unit in these variables contributing to increased carbon dioxide levels in the EU and G20 sample when considering both the panel corrected model as well as the GMM scenario. Renewable energy is the only independent variable to manifest a significant positive and direct link with environmental performance, drawing attention to the need of adapting the primary sources of energy, in line with international organizations' sustainable development policy recommendations. Also, there is a need to improve citizens' perceptions of public services and institutions by building confidence in government's ability to formulate and implement regulations.

KEYWORDS

environmental performance, education, governance quality, panel data regression, green future

1 Introduction

The subjects of ecological sustainability, green economy, circular economy, as well as environmental performance have been intensely analyzed by researchers in recent decades. This is no surprise, as the rapid growth of manufacturing economies poses a major threat upon environmental health and public health. The most notable example in this regard is China, the largest manufacturing economy, and at the same time, the most polluted country in the world in terms of CO2 emissions (Nguyen et al., 2021). Because of these threats, the regulatory institutions around the world have aligned their visions and acted to develop a concrete set of measures and instruments aiming at promoting a sustainable welfare economy, as stated by the EU Parliament's Environment Committee. Thus, governments and public institutions' quality play an important role in ensuring a green and sustainable development.

Besides the institutional perspective, one must not omit the role of education in enhancing environmental performance. It is considered that through increased educational levels, societies will become more aware of the necessity for a green future.

When seeking to reduce pollution levels, decision-makers should forward legislative proposals backed by long-term strategies in the educational sector, otherwise the expected results might fall short of the expected ones. To achieve sustainability goals, a mixture of environmental and educational policies should complement each other. Nevertheless, our current expectations will be tested in the remaining sections of this research.

As the topic of environmental performance has attracted a lot of interest from the general public in recent years, so did the scientific community become more active in tackling the topic. Whether for measuring pollution or highlighting the role and responsibilities of politics in obtaining the common objective of a green society, numerous studies of an undisputable quality have been conducted already.

The existing literature has not put enough emphasis on the link between education, governance quality, and environmental performance. Therefore, this research aims at developing a model to examine the relationships linking environmental performance and relevant macroeconomic variables such as the level of education, the quality of governance (government effectiveness, regulatory quality, control of corruption, and rule of law), together with the education dimension, gross domestic product, renewable energy consumption, fossil fuel energy consumption, and industry.

The paper aims to bridge this specific gap in the literature, generating the following research question: How significant are, amongst other variables, education and the quality of institutions in establishing our green, sustainable future? The underlying assumption of this research is that increased education and improved institutional quality will lead to higher levels of environmental performance. Addresing this issue underlines new key factors for intervention. The novelty and contributions made by this paper are to be found in an extensive database, including 43 countries and a multi-level research design. Furthermore, the current study contributes to enriching the current literature by developing the well-known model of Mavragani et al. (2016) by bringing into focus the importance of education level, technical quality of governance distributed over the four governance indicators, in connection with key macroeconomic variables such as economic growth, industry, and main sources of energy.

The results of this study should be relevant for policy makers as it will assist them prioritizing between the four pillars of governance which we have included. Also, if a significant connection is found between education and CO2 emissions, this will provide justification for a multi-layered approach.

The results can be taken as a reference point, promoting enhanced future research.

The current paper is organized as follows. The next section consists of a short literature review. The third section presents the data used in our model and the methodology. The fourth section reports the empirical results. The fifth section consists of a discussion based upon our findings. The final section presents the main conclusions of the research and policy recommendations.

2 Literature review

The purpose of current section is to develop a better understanding of the literature approaching the intertwined concepts of governance quality, educational attainment and environmental performance.

The environmental performance, measured through CO2 emissions, can be expressed as a function of income, population density, governance, political institutions, and government investment in education, as well as the level of education of the population, as portrayed by the years of schooling and other socio-economic factors (Dutt, 2009).

The constant economic growth observed worldwide throughout the past decades has led to an increased standard of living and a much more substantial energy consumption and demand. Nonetheless, the cost of this economic growth is transposed in growing CO2 emissions levels (Kasperowicz, 2015), which have become a reason for concern and a call for action.

In this regard, the Environmental Kuznets Curve (EKC) underlines that the cost of economic growth, in terms of environmental degradation, can be sustained by the benefits of economic growth, in terms of innovation and development of new technologies that shall reduce pollution in the long run. Furthermore, as income per capita increases, the intrinsic abilities of consumers develop, thus contributing to diminishing levels of degradation (De Bruyn et al., 1998).

The EKC theory has been tested in recent years by several researchers. All of the identified findings confirm the validity of the theory for less industrialized countries (Hamid et al., 2022a), countries heavily dependent on fossil fuels (Alam et al., 2022), and even for the G7 countries (Nathaniel et al., 2021). Also, according to Dutt (2009), higher-income countries are observed to yield lower CO2 emissions as a consequence of better institutions and higher levels of education. The EKC theory was recently tested for Turkey's case (Yunpeng et al., 2021) with two different proxies (carbon emissions and ecological footprint), the results confirming the EKC curve for tourism industry.

Education is an essential tool for promoting a sustainable set of values and for countering environmental degradation. A first channel through which education interferes is of political nature. Educated citizens have the ability to understand the necessity for green policies and will inevitably request them from policy makers. A second channel can be observed through consumption decisions. A household that is aware of environmental issues will seek to choose less harmful products. A third channel in which education indirectly contributes to the fight against environmental degradation is the accumulation of human capital in work places (Lan and Munro, 2013). These green-oriented work places are considered to deliver goods and services that are less harmful to the environment.

Therefore, one can consider that the primary institutions which lead to a substantial increase in environmental performance are educational institutions. The goal of these institutions should be to promote the objective of sustainable development with a clear vision and strategy, through modern teaching techniques such as blended learning (Aleixo et al., 2018; Alam and Agarwal, 2020). Gill et al. (2021) confirm the strategic position held by higher education institutions in the race towards improving environmental performance. Their findings suggest that green human resource management strategies for employees in higher education institutions will have a snowball effect towards their students, thus the entire population. Nevertheless, as we acknowledge educational institutions as responsible for modelling the future of our societies, we must not ignore the effect of external shocks towards attitudes and behaviors. For example, the COVID-19 pandemic has changed our working and transportation habits and indirectly reduced our environmental footprint (Khan et al., 2021).

In terms of available empirical evidence, we refer to Li et al. (2021), which find that a 1% increase in higher education enrolment leads to a 0.19% decrease in CO2 emission levels. In the long run, the effect of higher education is found to be even higher, respectively a decrease of 0.33% (Eyuboglu and Uzar, 2021). Nevertheless, the role of tertiary education should not be neglected as 1 year increase in tertiary education leads to a 50–60% decrease in CO2 emissions (Yao et al., 2020).

In today's societies institutions draw the rules and frameworks within which we live and conduct our activities. In regards to pollution, one can expect that a higher institutional quality will contribute towards a reduction in CO2 emissions (Bhattacharya et al., 2017). Similarly, increased democracy and social participation construct channels through which environmental performance is increased (Laegreid and Povitkina 2018). Furthermore, it is considered that countries which encourage the rule of law along with powerful political rights will, in fact, encourage their citizens to form interest groups, with the common goal of tackling environmental sustainability (Ali et al., 2019; Khan S. A. R. et al., 2020).

Nevertheless, institutional quality can be defined as a broad concept that embodies regulation, public services, control of corruption, political stability and does not benefit of a specific metric (Bruinshoofd 2016). If we were to further expand the concept of institutional quality to a wider "governance" approach, we should include the processes of exerting authority and implementing policies (World Bank, 1994). According to Smith (2007), good governance implies effective public policy and structures, as well as a network of economic cooperation.

The identified scientific literature that covers the impact of institutional quality on CO2 emissions presents similar results. Using GMM estimations, it was found that increased institutional quality leads to sustained environmental performance growth in the long run (Tamazian and Rao, 2010; Usman et al., 2020). In line with previously mentioned studies, using ARDL models, it was found that institutional quality reduces the levels of CO2 emissions (Ahmed et al., 2020; Zhan et al., 2021). Moreover, a meta-analysis of Ahmed et al. (2020) concluded that irrespective of the time frame or geographical area, the effect presented earlier persists and remains valid (Goel et al., 2013; Zakaria and Bibi 2019; Lau et al., 2014; Ibrahim and Law, 2016; Christoforidis and Katrakilidis 2021).

Currently, societies mostly rely upon fossil fuels to support their energy demands. Nevertheless, this dependency has proven itself to be a costly one in terms of CO2 emissions (Lotfalipour, Falahi and Ashena 2010; Ayompe, Davis and Egoh, 2021). In terms of the empiric dimensions of this relation, a study of Pachiyappan et al. (2021), shows that increases of 1% in fossil fuels, GDP and population each contribute to around 1% increase in CO2 emissions. Having acknowledged the constant pressure the current status quo exerts upon the environment, the scientific community has recently pointed out towards nuclear energy as a possible alternative. Even if the process of fully switching to nuclear energy dependency might be a slow one, there is proof of long-term benefits in terms of lowered CO2 emissions (Nathaniel et al., 2021; Rehman et al., 2021).

Besides nuclear energy, there is another possible long-term solution that needs to be accounted for, namely politics. Adding the political dimension to institutions which have assumed an environmental commitment (Lober, 1996; Jahn, 1998; Scruggs, 1999; Gallego-Alvarez et al., 2014), we find an increased presence of green parties (Müller-Rommel, 1989). This augmented political presence can be attributed to a more environmentally aware population that is constantly requesting more green-oriented legislation (Dolezal, 2010; Burchell, 2014; Shan et al., 2021). Finally, another identified tool in the race towards zero CO2 emissions is found in big data applications and improved data collection (Dragomir, 2018; Song et al., 2018).

The identified literature on the main determinants of CO2 emissions is noted to highlight similar effects. Firstly, more education, either through higher enrollment (Li et al., 2021) or additional years of education, leads to diminishing levels of CO2 in the long run (Eyuboglu and Uzar, 2021). Secondly, improved governance quality in conjunction with a green political agenda once more will determine increased environmental performance (Bhattacharya et al., 2017). Thirdly and finally, when the two aforementioned factors are deemed insufficient, returning to nuclear energy (Nathaniel et al., 2021).

Can offer important potential benefits, especially in the context of the Ukraine war.

Even if the available literature is significant in number and quality, a study accounting for institutional performance, educational attainment, fossil fuel and renewable energy altogether, in the case of the G20 countries and EU member states is yet to be found. In this regard, the following sections will contribute towards this identified gap.

3 Materials and methods

This paper aims to demonstrate the empirical nexus between environmental performance, measured by carbon dioxide emissions, and education levels together with institutional quality in a society. To achieve this goal, the regression model includes the main variables that reflect the quality of governance (government effectiveness, regulatory quality, control of corruption, and rule of law), together with the education dimension, gross domestic product, renewable energy consumption, fossil fuel energy consumption, and industry.

The panel data was built for the 1995–2020 period, for a set of 43 countries, consisting of all the European Union (EU) members and the Group of Twenty (G20) states (except for some isolated cases where no information was published by statistical institutions). The analysis includes Australia, Canada, Saudi Arabia, United States, India, Russian Federation, South Africa, Turkey, Argentina, Brazil, Mexico, France, Germany, Italy, United Kingdom, China, Indonesia, Japan, South Korea, Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Greece, Hungary, Ireland, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain and Sweden.

The research design of this paper follows a model proposed by Mavragani et al. (2016) which identifies a positive relation between economic growth and environmental performance. The model was further developed by adding variables capturing the industrial development degree, the population's education level, and the main sources of energy used. Also, instead focusing on the impact of the open market on environmental performance, this model retained the four indicators of the technical quality of governance out of the six proposed in the original analysis. Furthermore, in comparison with the above-mentioned study, the current proposed model does not take into consideration the EPI index as the dependent variable, considering the data limitations for our analysis period. Instead, carbon dioxide emissions were considered as dependent variable to measure environmental performance, with an increase in this dependent variable reflecting the decrease in environmental performance.

The paper uses a regression that combines macroeconomic and institutional variables, presented in Table 1. The data used were collected from different sources, specified below.

The impact of education level on environmental performance of a society was investigated using the linear model shown below.

$$CO2\_EM_{it} = \alpha + \beta_1 EDU_{it} + \beta_2 GDP\_GR_{it} + \beta_3 RNEC_{it} + \beta_4 FFEC_{it} + \beta_5 IND_{it} + \beta_6 GOVEFF_{it} + \beta_7 REGQ_{it} + \beta_8 CCORR_{it} + \beta_9 RLAW_{it} + \mu_i + \varepsilon i_t$$

The regression equation presents CO2_EM it as a dependent variable, followed by the independent variables EDU_{it}, GDP_GR_{it}, $RNEC_{it}$, $FFEC_{it}$, IND_{it}, $GOVEFF_{it}$, $REGQ_{it}$, $CCORR_{it}$ and $RLAW_{it}$ *and* μ_i, which captures the constant effect and particularity of each G20 and EU member i = 1, 2...43, at the time t = 1,2, . . .,T, where T is the observed time in the model and εit is the error term that is correlated with the independent variables. The β_1, β_2, β_3, β_4, β_5, β_6, β_7, β_8 and β_9 are the parameter coefficients and α is the constant.

First of all, in this model, the main independent variable is represented by the *EDU* (the education index), which is an average of mean years of schooling (of adults) and expected years of schooling (of children), both expressed as an index obtained by scaling with the corresponding maxima. *EDU* measures the quality of life and economic development for every country included in our database. Numerous studies have documented the effect of education on environmental performance, according to which countries associated with higher levels of education tend to have lower levels of carbon dioxide emissions (Dutt, 2009). Also, countries with superior levels of education enjoy high-quality government institutions, which in turn positively affects economic growth. Tran et al. (2019) found that human development helps to improve environmental quality.

Secondly, *GDP_GR* (gross domestic product per capita growth) is calculated as the percentage change in the real GDP per capita between two consecutive years. An upper level of *GDP_GR* can be closely related to growth in the

TABLE 1 The variables.

Dependent variable	Abbreviation	Unit	Source
Carbon dioxide emissions	CO2_EM	Metric tons per capita	World Development Indicators (WDI)
Independent variables	Abbreviation	Unit	Source
Education index	*EDU*	Score (0–1)	United Nations Development Programme
Gross domestic product per capita growth	*GDP_GR*	Annual %	World Development Indicators (WDI)
Renewable energy consumption	*RNEC*	% of total final energy consumption	International Energy Agency (IEA)
Fossil fuel energy consumption	*FFEC*	% of total final energy consumption	International Energy Agency (IEA)
Industry (including construction)	*IND*	% of GDP	World Development Indicators (WDI)
Government effectiveness	*GOVEFF*	Score (-2,5;2,5)	World Bank Governance Indicators Database
Regulatory Quality	*REGQ*	Score (-2,5;2,5)	World Bank Governance Indicators Database
Control of corruption	*CCORR*	Score (-2,5;2,5)	World Bank Governance Indicators Database
Rule of law	*RLAW*	Score (-2,5;2,5)	World Bank Governance Indicators Database

modern sectors and industry, motorized transport, and urban areas. This growth is usually based on a higher level of fossil fuel energy consumption, which is the largest driver of global climate change because of the CO2 emissions resulted from burning fossil fuel.

Next, renewable energy consumption (*RNE*) represents the share of renewable energy in total final energy consumption, while *FFE* shows the used energy produced from burning fossil fuels like coal, oil, petroleum, and natural gas products.

IND is another independent variable used here (industry, including construction), which incorporates additional value generated in sectors such as mining, manufacturing, construction, electricity, water, and gas. Additional value is obtained as the net output of a sector, which includes all the outputs excepting the value of the intermediate inputs. The origin of value added is determined by the International Standard Industrial Classification (ISIC) (Metadata Glossary, World Bank).

The model takes into account four more indicators of governance quality, namely: *GOV_EFF* (government effectiveness), *REGQ* (regulatory quality), *CCORR* (control of corruption), and *RLAW* (rule of law).

Government effectiveness (*GOV_EFF*) variable sums up considerations about the quality of public services, the autonomy of civil service regardless of political constraints, and the way in which the government manages to formulate and implement its policies at a high-quality level.

The variable *REGQ* (regulatory quality) refers to laws that fall within the government's capacity to formulate and implement them so as to promote public sector development.

World Bank methodology defines control of corruption (*CCORR*) as perceptions of the extent to which politicians exercise power for their private interest and the public institutions are managed by financially potent people, guided by the increase of their personal gains.

TABLE 2 Descriptive Statistics for the set of 43 members of G20 and EU.

Variable	Obs	Mean	Std. Dev	Min	Max
CO2_EM	1,032	7.982938	4.448722	0.768838	25.6687
EDU	1,075	0.762647	0.116307	0.344	0.943
GDP_GR	1,110	2.207022	3.881688	−14.4643	23.99909
RNE	1,032	15.37741	12.91369	0	54.48412
FFE	886	77.88262	16.53382	13.05622	100
IND	1,109	26.70636	7.879628	9.984704	66.75666
GOVEFF	946	0.914968	0.733177	−0.72703	2.353998
REGQ	946	0.912205	0.696154	−1.07426	2.098008
CCORR	946	0.76552	0.923741	−1.17636	2.469991
RLAW	946	0.832173	0.826222	−1.09756	2.129668

The rule of law (*RLAW*) indicator shows the extent to which both citizens and social players comply with the law in terms of possession rights, courts, the quality of contract enforcement together with the possibility of crime and violence issues.

The institutional variables mentioned above range between -2.5 and 2.5 points. The value of -2.5 points expresses a weak governance, while the value of 2.5 shows a strong governance. Thus, the influences that these independent variables have on the dependent variable after model processing can be found in the section of empirical results.

4 Results

Table 2 summarizes the most important descriptive coefficients of the variables included in the research. Central tendency, dispersion and standard deviation are measured.

Descriptive statistics show that fossil fuel energy consumption (*FFEC*), which holds 16.53382% of total energy consumption, is the variable with the most significant deviation from the average, This shows that the level of non-renewable energy consumption in the selected countries is the furthest away from their average value. Malta stands out in the top of the countries with significant levels of fossil fuel energy consumption, as no. 1 in 1995, 1996, 1997 and 1999, with 100% of total energy consumption among all the countries in the sample. Saudi Arabia (99.9% of total), Cyprus (97.8% of total) and Poland (96.3% of total energy consumption) follow Malta as countries where fossil fuels had and continue to have an important role in global energy systems. A high level of fossil fuel energy consumption generates a high level of CO2 emissions, that leads to global climate change. At the opposite pole, Sweden, Finland and France, presented the lowest levels of fossil fuel consumption, with Estonia being the country that in 2016 registered the minimum value of 13.05622% of total energy consumption.

The second variable which has a significant standard deviation value is renewable energy consumption (12.91369% of total). A high level of this variable indicates that future decarbonization of energy systems in the next decades will be beneficial. As we can see, the maximum value (of 54.48412%) was reached by India in 1995, yet in the next years, the level of its renewable energy decreased along with the growth of fossil fuel energy levels, which led to ensuing technological, social, economic, and development progress. The same path can be noticed in Indonesia. A better example can be observed in Sweden, which has one of the highest levels of renewable energy consumption (52.8577% of total) that has increased over the years, illustrating lower levels of pollution from 1995 to 2018. Finland is another good example of a country that followed the same path as Sweden. Countries with the lowest levels of renewable energy consumption include Malta (0.0000% of total), Saudi Arabia (0.0066% of total), and the United Kingdom (0.6083% of total), where fossil fuel is the primary source of energy.

Another relevant standard deviation is distinguished in the situation of industry variable (value is 7.879628% of GDP). A high weight of the industrial sector leads to high environmental degradation, according to the studies of Rai and Rawat (2022), Opoku and Aluko (2021), Patnaick (2018), Sunny et al. (2012). Countries like Saudi Arabia (with 66.76% of GDP in 2008), Indonesia (with 48.06% of GDP in 2006) and China (47.56% of GDP) have a significant industry compared with their gross domestic product. At the opposite pole, states with a low industrial weight, such as Cyprus (9.98% of GDP in 2014), Luxembourg (with 10.72% of GDP in 2020) and Malta (with 12.06% of GDP in 2017) are likely to generate lower environmental degradation levels.

The value of standard deviation of carbon dioxide emissions (4.448722 metric tons per capita), suggests a spread influenced by fossil fuel consumption to the detriment of renewable energy. India, Brazil, China and Indonesia recorded in the first years of this analysis low levels of CO2 emissions, yet they were increasingly affected in the last years by the development of industry based on fossil fuel consumption. Over time, this fact leads to environmental degradation. The United States and Luxembourg, known as developed economies, report the maximum values of CO2 emissions during the analyzed period of time.

The lowest levels of standard deviation are found in case of institutional variables and of education index, with the sampled countries showing more homogeneity. The highest levels of these variables were recorded in Finland, Australia, the Netherlands, and Sweden, illustrating strong governance. Saudi Arabia, Indonesia, China and the Russian Federation registered the lowest levels of governance, which might explain their high environmental degradation in the analyzed period.

Lastly, the education index displays the lowest value of standard deviation (0.116307). From 1995 to 2019, all countries followed an upward trend for this measure. In 1995, countries such as India, Indonesia, China, and Turkey displayed a reduced level of education, whereas, in 2019, Germany, United Kingdom, Finland, and Australia reached the maximum value of the education index variable. From year to year, people from these states increased their education level, which led to a superior quality of life that can negatively impact the environment. However, a higher level of education can lead to an improvement in institutional quality, which in turn contributes to a better protection of the environment.

The nature and level of correlation among the variables are presented in Table 3 below.

Table 3 illustrates that the education index, fossil fuel consumption and all institutional variables are positively correlated with the lack of environmental performance, as measured by the levels of CO2 emissions. Nevertheless, there is a negative relationship between GDP growth, renewable energy consumption, industry, and CO2 emissions, thus influencing in a favorable way environmental performance. Overall, we can confirm the absence of multicollinearity, as there is not a strong (larger than 0.7) correlation between variables, except for independent variables capturing governmental quality.

This paper considers the application of panel data regressions in the light of the advantages it has over classic cross-section or time-series data, especially its capacity to capture the complexity of a certain phenomenon, as presented by Hsiao (2006). Further, in view of our database, when applying the Breusch-Pagan Lagrange multiplier (LM) test, the presence of differences across entities was highlighted, therefore the data presents panel characteristics.

When testing the stationarity of the considered variables, both the first and the second generation of unit root tests have been used for analysis, in line with the study of Sini et al. (2022). The results of the panel unit root test are presented in Table 4. The variables rejecting the null hypothesis of non-stationarity at

TABLE 3 Correlation matrix with significance levels.

Variables	*CO2_EM*	*EDU*	*GDP_GR*	*RNE*	*FFE*	*IND*	*GOVEFF*	*REGO*	*CCORR*	*RLAW*
CO2_EM	1.000	—	—	—	—	—	—	—	—	—
EDU	0.456***	1.000	—	—	—	—	—	—	—	—
GDP GR	−0.104***	−0.157***	1.000	—	—	—	—	—	—	—
RNE	−0.483***	−0.237***	0.053*	1.000	—	—	—	—	—	—
FFE	0.229***	−0.102***	−0.056*	−0.665***	1.000	—	—	—	—	—
IND	−0.055*	−0.377***	0.223***	−0.009	0.092***	1.000	—	—	—	—
GOVEFF	0.499***	−0.652***	−0.152***	−0.120***	−0.114***	−0.430***	1.000	—	—	—
REGO	0.497***	−0.687***	−0.123***	−0.142***	−0.115	−0.453***	0.910***	1.000	—	—
CCORR	0.512***	−0.626***	−0.160***	−0.074**	−0.129***	−0.413***	0.956***	0.908***	1.000	—
RLAW	0.497***	−0.653***	−0.161***	−0.088***	−0.116***	−0.434***	0.951***	0.934***	0.957***	1.000

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

TABLE 4 The results of first and second generation unit root tests.

	Fisher ADF—First generation unit root test		Pesaran CADF—Second generation unit root test	
Variable	**Level**	**First difference**	**Level**	**First difference**
CO2_EM	4.4558	−25.2445***	4.771	−17.117***
EDU	−3.7543***	−17.5205***	−0.941	−14.339***
GDP_GR	−10.6047***	−28.9599***	−9.336***	−22.860***
RNEC	7.2640	−23.3200***	0.350	−19.673***
FFEC	5.5805	-19.9008***	3.841	−15.119***
IND	0.8711	−24.0145***	0.092	−17.876***
GOVEFF	−1.4098*	−23.7128***	−0.670	−16.494***
REGQ	−3.1760***	−23.9484***	−2.502***	−16.388***
CCORR	0.5558	−21.4037***	−1.265	−13.734***
RLAW	−1.5564*	−23.9497***	−0.130	−16.813***

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

1% significance levels are the variables that capture education level, economic growth, and regulatory quality when considering the Fisher type unit root test for panel data with augmented Dickey-Fuller unit root tests on each panel with zero lags. Governance efficiency together with rule of law variable reject the null hypothesis of non-stationarity at the significance threshold of 10%. Using the second generation Pesaran test for unit roots accounting for heterogenous panels with cross-section dependence, only economic growth and regulatory quality variables are stationary at first level.

When the first difference of the considered variables is taken into account, they all become stationary at a 1% significance level, also confirmed by the second generation Pesaran stationarity test.

Furthermore, the Kao panel cointegration test is used to examine the long-run equilibrium between variables. The Kao test proved a long-run relationship between variables, considering the Kao ADF (Augmented Dickey Fuller) statistic of 6.5521, significant at 1% level, with a p-value of 0.0000.

This research uses for the estimations the following three methods with this panel data regression model: Pooled ordinary least squares (Pooled OLS), Fixed effects model (FEM) and Random effects model (REM), together with a two-step dynamic GMM model to address the endogeneity issue as well. Those techniques mentioned before are the most frequently used techniques, also found in the other similar relevant research papers. Each of them has advantages as well as limitations.

Pooled OLS, which considers all the countries homogeneous, has also one important shortcoming. Individual characteristics of the countries are represented by the constant and the error term that are

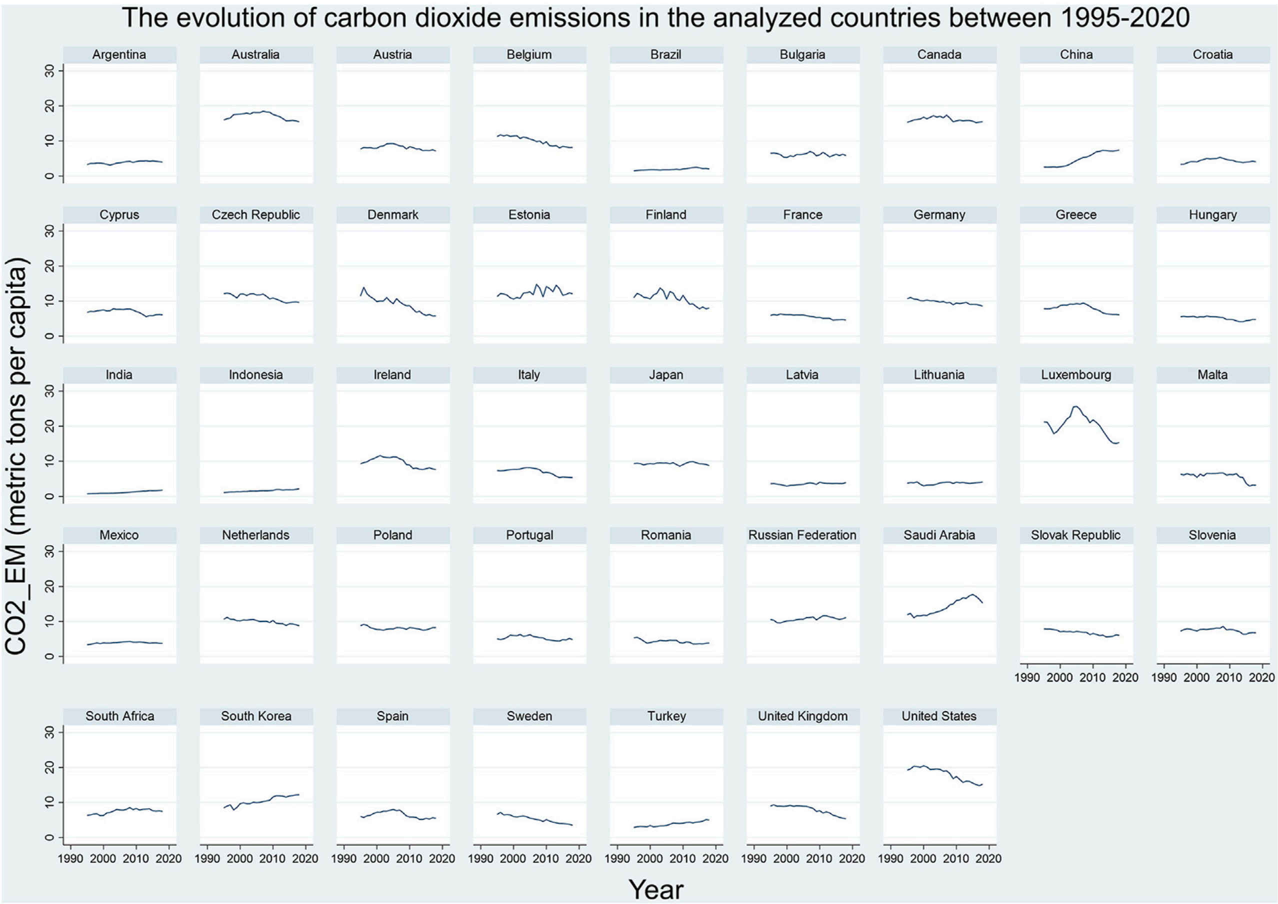

FIGURE 1
Representation of panel data- CO2 emissions by countries for the period 1995-2020.

not correlated with the others. It is already known that this particular method can lead to erroneous estimates when correlations between individual elements and independent variables are not controlled.

The fixed effects model differs from the random effects model in that the former investigates the explanatory variables as non-random. FEM is often used to illustrate the type of impact variables which changes from year to year, and it is considered necessary to check if individual characteristics can affect the variables. The net effect of the independent variables may be evaluated using FEM, whose primary function is to eliminate the influence of these time-independent factors from the independent variables.

According to Greene (2008), the fundamental difference between FEM and REM is the link between individual effects and the regressors in the model. When these effects are random with the independent variable, REM is more appropriate to be used, but if there is a correlation between them, FEM is best suited.

There are some tests that can be used when it is time to choose between these three methods. F test (based on Lagrange Multiplier) is used for the decision to select pooled OLS or FEM and Hausman test is used to choose between REM or FEM. Next, to illustrate how the variance of the FEM model is not homogeneous, the Breusch- Pagan test was applied.

Figure 1 below summarizes these considerations for the sampled countries.

As we can see in Figure 1 There is a sign of heterogeneity between countries because the confidence interval for each country has different widths and the graph has significant oscillations.

Table 5 below presents the regression results.

Evaluation of the pooled OLS regression model

From the Pooled OLS regression in Table 5 it results that education has a negative impact on environmental performance during the analyzed period, impacting in a positive manner *CO2 emissions*. Moreover, looking at the probabilities, variables such as education index, renewable energy consumption, industry, and control of corruption are significant for this model. The value of R-squared shows the amount of variance of environmental

TABLE 5 Regression results.

Dependent variable	(1)	(2)	(3)	(4)	(5)	(6)
CO2_EM	OLS	REM	FEM	LSDV	PCSE	TWO-STEP GMM
EDU	4.754**	4.140***	4.141***	4.141***	5.951***	12.53**
	(1.605)	(0.683)	(0.684)	(0.684)	(1.431)	(4.211)
GDP_GR	−0.0135	−0.0126	−0.0131	−0.0131	0.0218*	0.0394**
	(0.0333)	(0.00860)	(0.00856)	(0.00856)	(0.00846)	(0.0121)
RNEC	−0.130***	−0.115***	−0.110***	−0.110***	−0.104***	−0.353***
	(0.0149)	(0.0117)	(0.0119)	(0.0119)	(0.0140)	(0.0970)
FFEC	0.0105	0.0702***	0.0776***	0.0776***	0.0283	0.155*
	(0.0109)	(0.0113)	(0.0116)	(0.0116)	(0.0150)	(0.0683)
IND	0.112***	0.107***	0.111***	0.111***	0.0575***	-0.0739
	(0.0176)	(0.0143)	(0.0145)	(0.0145)	(0.0165)	(0.0639)
GOVEFF	−1.253	0.720***	0.692**	0.692**	0.237	−3.839
	(0.641)	(0.212)	(0.211)	(0.211)	(0.259)	(2.215)
REGQ	0.610	0.495*	0.500*	0.500*	0.257	1.416
	(0.527)	(0.202)	(0.202)	(0.202)	(0.281)	(1.466)
CCORR	2.690***	0.0142	−0.121	−0.121	1.155***	2.275
	(0.540)	(0.221)	(0.222)	(0.222)	(0.286)	(1.893)
RLAW	0.363	−0.224	−0.351	−0.351	0.401	−0.586
	(0.602)	(0.278)	(0.280)	(0.280)	(0.328)	(0.672)
L.CO2_EM	—	—	—	—	—	−0.148
	—	—	—	—	—	(0.101)
_cons	0.832	−2.585	−3.078*	3.340*	−0.349	−4.789
	(1.907)	(1.381)	(1.294)	(1.473)	(2.031)	(9.705)
N (Obs.)	713	713	713	713	713	713
R^2	0.497		0.507	0.976	0.748	—

Standard errors in parentheses.
* $p < 0.05$,
** $p < 0.01$,
*** $p < 0.001$

performance explained by the independent variables, and as such exogenous variables explain 49.70% of carbon dioxide emissions' variance. Furthermore, an increase of a unit of education index will lead to an increase of *CO2 emissions* by 4.754 metric tons per capita and also, a change of one unit of industry variable or control of corruption will determine an increase of carbon dioxide emissions by 0.112 metric tons per capita and 2.690 metric tons per capita respectively. The negative impact on the *CO2 emissions* is led by renewable energy consumption whose growth with a unit will decrease *CO2 emissions* by 0.130 metric tons per capita.

Evaluation of the random effects model (REM)

Table 5 (column 2) presents the results of the evaluation random effects method and also illustrates the positive impact of education on *CO2 emissions*, and the variables *EDU, RNEC, FFEC, IND, GOVEFF* and *REGQ* as statistically significant in the model (*p-value<0.001*). Withal, the table illustrates how variables significantly affect the environmental performance. The value of *Wald chi2* reveals the model explains 50.54% of the dependent variable, respectively the variance of CO2 emissions.

Evaluation of the fixed effects model (FEM)

In light of using the Fixed Effects method for the 43 set of countries, (all European Union members and Group of Twenty - G20 states), it is easily noted that education has a positive impact on CO2 emissions and that all the variables (except *GDP_GR, CCORR* and *RLAW*) have some significant impact on environmental performance. The value of *R-squared* reveals that the estimated model explains 50.70% of the variance of the *CO2 emissions*. Because the *p-value* of the education index is 0.0000, education is statistically significant, thus a change of one unit of the education

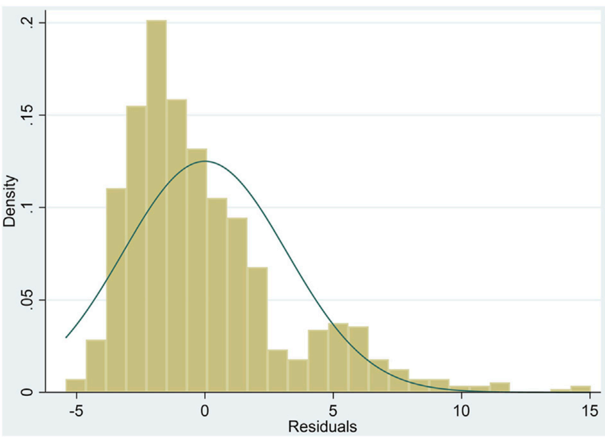

FIGURE 2
Residual control for the FEM

index will increase carbon dioxide emissions by 4.141 metric tons per capita. A growth of fossil fuel energy consumption, industry, government effectiveness or regulatory quality with a unit increases CO2 emissions by 0.077 metric tons per capita, 0.111 metric tons per capita, 0.692 metric tons per capita and 0.5 metric tons per capita. Meanwhile, one unit modification of renewable energy consumption contributes to a decrease in carbon dioxide emissions by 0.11 metric tons per capita.

All three evaluations present alpha test *F value* equal to zero (<0.05) allowing us to reject the hypothesis that the estimated model is significantly invalid, and accept the validity of the model.

Evaluation of residuals

Skewness Kurtosis is a normality test that helps determine the probability that a random variable underlying the data set is normally distributed. The probability of skewness is 0.0000 implying that skewness is not asymptotically normally distributed (*p-value of skewness < 0.05*). Similarly, Pr (Kurtosis) points out that kurtosis is not also asymptotically distributed (*p-value of kurtosis 0.0000 < 0.05*). Finally, *chi* (2) is 0.0000 which is lower than 0.05 implying its significance at a 5% level. Consequently, the null hypothesis can be rejected. Therefore, according to the Skewness test for normality, residuals are not normally-distributed as it is illustrated by Figure 2.

Evaluation of the best model

The results of the statistical tests show that the use of FEM together with a panel corrected standard error regression would be the most appropriate methods of analysis for selected data.

To choose the most appropriate estimation technique, the analysis begins by testing the OLS model, applying the Breusch-Pagan/Cook-Weisberg test for heteroskedasticity (*p = 0.0000 < 0.05*) and the White test for heteroskedasticity (*p = 0.0000 < 0.05*), as well as the testparm command (*p = 0.0000 < 0.05*). The obtained results reject the null hypothesis of homoscedasticity, further indicating that OLS would not be the most significant estimation technique for this sample.

Moreover, performing the Breusch and Pagan Lagrangian multiplier test for random effects to choose between panel data regressions and the classical OLS, it results that the probability (0.0000) is less than 5% also highlighting the fact that heteroskedasticity is present in the data set, rejecting the null hypothesis (residuals are homoscedastic) and proving that there is a panel effect in the considered dataset.

Both the Hausman and Sargan Hansen tests allow selecting between FEM or REM, and the null hypothesis (H0) reveals the random effects model is more efficient as compared to the alternative fixed effects (see Greene, 2008, chapter 9). In light of the *Chi-square* statistics of the Hausman test (17.27) and of the probability value (*p value =0.0447 < 0.05*) the null hypothesis is rejected and thereby the fixed effects model is more efficient than the random effects model for this analysis.

The fixed effects model with dummy variables (LSDV) was also performed, which included a dummy variable that absorbed the specific influence of each country. This allowed for estimating the pure impacts of each independent variable on the *CO2_emmissions* variable, while simultaneously correcting for unobserved variation between nations. When applying the LSDV model, the significant independent variables affecting environmental performance are education, industry, fossil fuel energy, and renewable energy at a significance threshold of 0.1%, while regulatory quality is significant for the upper threshold of 5%, and governmental efficiency for the 1% threshold.

However, to correct the limitations of the FEM model (groupwise heteroskedasticity, autocorrelation in panel data and cross-sectional independence) emphasized by the modified Wald test, Wooldridge test, as well as Pesaran's test, with all three *p values < 0.05* threshold, a panel-corrected standard errors regression (PCSE) was applied.

In the PCSE scenario, the estimates indicate that education, industry, control of corruption and economic growth, have a positive impact on carbon emissions (at a significance level of 0.1 and 5% respectively), deterring the environmental performance of the considered sample, while a change of one unit in renewable energy, impacts negatively *CO2 emissions* with a significance threshold of 0.1%, increasing environmental performance (Supplementary Appendix S1).

Furthermore, to control for endogeneity in the considered panel, the generalized method of moments technique (GMM) is applied. The two-step difference GMM is utilized, considering that it is more efficient and robust to the issues of heteroscedasticity and autocorrelation in the panel (Roodman, 2009). The results emphasize that education, together with economic growth positively impacts CO2 emissions, at a 1% significance level, while the use of fossil fuels increases air pollution at a 5% significance level. However, one unit increase in the consumption of renewable energy decreases CO2 emissions by 0.353 metric tons per capita in the 43 considered states, at a 0.1%. Significance level The Arellano and Bond autocorrelation test AR (2) indicates the absence of second-order serial correlation in the residuals of the model. Moreover, the Sargan-Hansen tests for over identifying restrictions emphasize the validity of the model and used instruments.

5 Discussions

The results obtained emphasize that education, economic growth, and industry, together with the control of corruption variable, manifest a positive significant impact upon the *CO2 emissions*, thus affecting environmental sustainability in the PCSE scenario of the analysis. Other institutional quality variables such as governmental efficiency, regulatory quality, and the rule of law also exert a positive impact upon *CO2 emissions*, although not significant in statistical terms. In the PCSE hypothesis, renewable energy consumption is the only independent variable sustaining environmental performance at a significant level, considering the selected sample. In light of FEM methodology, besides renewable energy consumption, variables such as economic growth, control of corruption, and rule of law are the determinants of environmental performance. When accounting for endogeneity, education, economic growth and fossil fuel energy consumptions are the main significant determinants of CO2 emissions, whereas renewable energy consumption has a significant positive impact on environmental performance.

In all three scenarios (LSDV, PCSE, and GMM), considered the most relevant from a statistical point of view, as argued in the results section, higher education seems to be one of the causes of increasing *CO2 emissions*. The results are in line with those of Eyuboglu and Uzar (2021), who, through a vector error correction model (VECM) applied to Turkey, proved that education is positively associated with *CO2 emissions* and stress that education policies can be employed to address environmental issues, considering that their study confirmed the long-term effect of higher education on *CO2 emissions*. The authors argue that *CO2 emissions* and environmental damage may grow throughout the development of educational capacity, particularly with increasing energy consumption, highlighting the need for an integrated education policy leading to an improved human capital quality, which can prevent environmental degradation by enhancing environmental innovations and boosting environmental awareness.

Furthermore, the aforementioned authors point out the long-term and short-term positive influences on *CO2 emissions* of both economic expansion and energy consumption for Turkey, as also demonstrated in the current study for the 43 countries of the G20 group.

Moreover, Gangadharan and Valenzuela (2001) and Hill and Magnani (2002), found that higher levels of education drive to an increasement of using polluting technologies, which utilize non-renewable resources and, in the end, can lead to a degradation of the environment. Improving the level of education can influence the increase of the population's income, which in turn facilitates the use of polluting technologies and negatively impacts the environment.

The positive impact of economic performance on environmental degradation was also confirmed by numerous studies in the literature (Azomahou et al., 2006; Aye and Edoja, 2017; Paramati et al., 2017; Dauda et al., 2019; Anwar et al., 2020). This study reinforced this assumption by centering around a more recent database and a wide range of countries. The results of these studies have had real implications for economic and environmental policymaking among the world's countries. The paradigm shift in what was first referred to as sustainable economic growth, which put at the center of the concept the efficient use of economic resources to ensure performance in key economic sectors, is now transformed into a post growth, green growth, or degrowth policy, focusing on economic growth through the use of renewables and the implementation of more efficient and sustainable manufacturing methods, abandoning the use of only the GDP indicator as a metric of economic performance. On the other hand, Lee and Thiel (2017) demonstrate in their study that an increase in GDP does not have any significant impact on the Environmental Performance Index when applying the latent growth curve model.

Renewable energy consumption significantly improves environmental performance in the considered G20 sample, in accordance with the findings of York and McGee (2017), proving that countries that use a higher share of renewable energy resources have lower *CO2 emissions*, in comparison with the countries that still rely on classic energy sources. The study of Silva et al. (2012) through a structural autoregressive methodology proved that, even though it imposes significant costs on GDP, renewable energy significantly increases environmental performance. Moreover, Khan Z. et al. (2020) argue the use of renewable energy in logistics improves environmental sustainability and also provides greater export chances in environmentally friendly nations, promoting long-term green economic growth.

Furthermore, the study of Dauda et al. (2019) proves that energy consumption is one of the major causes of *CO2 emissions*. The paper of Gani (2021) concludes the urgent need for the "world's fossil fuel energy-dependent countries" to adapt to the development and use of renewable energy sources to prevent environmental damage. Our study is in line with the aforementioned papers, pointing out the significant negative influence of the fossil fuel energy consumption on environmental performance. The study of Zhang and Lin (2012) indicates the direct link between urbanization and increased energy consumption in the case of China, manifesting a positive impact on *CO2 emissions*. In the current context of a continuously growing and developing society, policymakers should prioritize urban planning and the use of renewable energy consumption to make significant contributions to both the use of classic energy sources while also fighting against climate change, as stated by Shafiei, and Salim (2014), which also conclude that the use of green energy decreases carbon footprint, while classic, non-renewable energy consumption increases air pollution and environmental performance.

The results of the panel regression methodology indicate that a one-unit growth in industrialization determines the increase in *CO2 emissions* at a significant level when considering the PCSE approach. The results are in line with the estimation presented in the paper of Li and Lin (2015), who proved through a Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) framework that industrialization reduces energy consumption, but increases *CO2 emissions*, in comparison with urbanization, which raises energy consumption as well as the carbon footprint drastically, when analyzing the middle low-income and high-income groups of countries. The same hypothesis is sustained by Shabaz et al. (2014), who studied the link between industrialization and emissions in Bangladesh, Raheem and Ogebe (2017) who studied the effects of industry and urbanization on CO2 emissions for a sample of twenty African countries in the last decades, and the paper of Liu and Bae (2018), who studied the implications of industrialization in China through a autoregressive distributed lag approach. However, the study of Lin et al. (2015), in which the authors analyzed the impact of industrialization on air pollution in the case of Nigeria, emphasized that industry has an inverse relationship with *CO2 emissions* for the considered sample. Moreover, analyzing the issue from the perspective of the ICT industry, Zhang and Liu (2015), conclude that this particular industry significantly reduces China's carbon footprints.

The independent variables capturing institutional quality manifest a positive, however not significant impact on *CO2 emissions* in the PCSE model of our analysis, except for the control of corruption variable, which is significantly correlated with *CO2 emissions* at a 0.1% level of significance. In the FEM, control of corruption manifests a negative impact on the G20's carbon footprint, increasing environmental performance even though not statistically significant, but even in this scenario, the results are inconclusive regarding the link between institutional quality and environmental performance, in line with the findings of Ahmed et al. (2020). However, the positive coefficients of these variables are in contrast with the results obtained by Mavragani et al. (2016), who concluded that good and effective governance increases a country's environmental performance. Moreover, the findings of Musa et al. (2021) emphasize that to mitigate the possible detrimental effects of economic expansion and also tourism on environmental performance, institutional quality might be investigated and strengthened. Furthermore, an important point to consider when addressing this issue was highlighted by Tamazian and Rao (2010), who demonstrated that if it were not for a solid institutional and governmental structure and governance, financial liberalization may be detrimental to environmental quality.

6 Conclusions and policy recommendations

The present research has started from the following question: How significant are, amongst other variables, education together with the quality of institutions in establishing our sustainable green future?

After applying the research methodology, the main results show that all the independent variables that capture institutional quality from a technical point of view, included in the model, have a direct and positive link to the level of *CO2 emissions*, with control of corruption variable being the only one influencing in a positive manner *CO2 emissions* at a significant level, in the PCSE scenario. In the FEM scenario, government effectiveness, together with regulatory quality are the institutional quality variables that impact carbon emissions at a significant level. Education level, together with economic growth, fossil fuel energy consumption and industry, also resulted in having a negative significant impact upon environmental performance, an increase of one unit in these variables contributing to increased carbon dioxide levels in the EU and G20 sample when considering both the panel corrected model as well as the GMM scenario. Renewable energy is the only independent variable manifesting a significant positive and direct link with environmental performance, drawing attention to the need of adapting the primary sources of energy, in line with the sustainable development policy recommendations of international organizations. The current study's primary limitation might be referred to as its methodology approach, considering that it does not account for a quantile approach, which might be suitable for analyzing the impact of the independent variables on environmental performance at different levels of registered *CO2 emissions*. A future study that accounts for these particular aspects is being taken into consideration. Moreover, there is a need to deepen the empirical link between education level, institutional quality, and their impact on environmental performance, however, we hope that our analysis can be taken as a reference point in the elaboration of the following studies and will promote enhanced future research.

Another limitation that can be viewed as a good starting point for an additional analysis refers to the period of time used, which can be considered slightly short. This fact may be a barrier to the generalization of obtained results.

The main results of this study, namely that economic growth, education, energy consumption, and industry impact in a negative manner environmental performance, and that renewable energy consumption have a positive impact on this performance, are important points to consider for policymakers. Therefore, a sustainable solution to the environmental problems would be to raise the level of renewable energy consumption in all countries by promoting it.

The idea of using as many natural renewable resources as possible would contribute to improving eco-friendly transportation facilities and even the use of fuel-efficient production technologies without ruining forests or contaminating water and air. This approach to green growth and development is the solution to reduce the poverty level in analyzed countries without affecting the environment.

Through a well-defined legislative framework, economic policies should aim at achieving high levels of economic performance, without referring only to long-term economic growth and financial gain, strictly observing already imposed environmental policy measures and further highlighting the need to transition to a renewable energy society, which can only be achieved through coherent and well-defined government and education policies.

Furthermore, a growth built on a higher quality of institutions and of human capital is worth exploring by countries to preserve the environment, because only improvements to these factors can promise less volatile and more sustainable growth.

This can lead to higher per capita incomes, better quality of life based on a balanced natural ecosphere. With the aim of achieving both green environment and economic growth, to the levels of governments there is a need of devoting enough resources to sustain regulatory quality and corruption control, enforce the rule of law, and assist governance effectiveness.

Changes and policies to adapt the economy to an eco-friendlier and greener economic environment are being felt among countries, however, the pace of environmental degradation is rapid and needs direct and concrete action, which cannot be delayed.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Author contributions

Conceptualization, GD, MB, CN; methodology, GD, MB and CN; software, MB and CN; validation, GD and DD; formal analysis, GD, MB, CN and DD; investigation, MB, CN, DD, and LM; resources, GD, MB, CN, DD, and LM; data curation, MB, CN, and DD; writing—original draft preparation, GD, MB, CN, DD, and LM; writing—review and editing, GD, DD, CN, and MB; visualization, CN and MB; supervision, GD, MB, and CN; project administration, GD and MB All authors have read and agreed to the published version of the manuscript.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2022.950683/full#supplementary-material

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