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ARTICLE

How renewable energy consumption and natural resource abundance impact environmental degradation? New findings and policy implications from quantile approach

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ABSTRACT
The EKC literature has ignored the importance of natural resources on environmental degradation. Thus, this paper aims to investigate the impact of renewable energy consumption and the abundance of natural resources on CO2 emissions for a panel of 82 countries by using quantile regressions. Empirical results show that renewable energy consumption reduces CO2 emissions and its effect increases in higher quantiles. The impact on carbon emissions of natural resource abundance is negative at lower quantiles but positive at medium and higher quantiles. Also, the validity of the EKC hypothesis is confirmed for all quantiles, and an increase in trade openness and urbanization increases environmental degradation in lower and middle quantile levels; however, these determinants have negative impacts on carbon emissions at higher quantiles. Policy implications related to this outcome are further discussed in the study.

KEYWORDS
Renewable energy;
natural resources;
pollution;
panel quantile approach

1. Introduction

Environmental degradation is widely investigated especially in the context of the environmental Kuznets curve (EKC) hypothesis in the environment-growth literature. Although the focus of early studies on the EKC is economic growth and pollution nexus (for example Grossman and Kreuger 1991; Holtz-Eakin and Selden 1995; Shafik and Bandyopadhyay 1992) new models with many control variables have been developed and applied for a different sample of countries over time (Altintas and Kassouri, 2020; Ang 2007; Inglesi-Lotz and Dogan 2018; Saboori, Sulaiman, and Mohd 2016). As discussed in the literature review in detail, each study has a different focus point to explain the causes of the environmental degradation problem. Admittedly, this interest is related to the fact that the climate change problem reaches terrible levels. Scientists from all over the world have pointed out the importance of the problem such that global warming is likely to exceed 2°C above preindustrial levels by 2060. The proportion of greenhouse gases in the atmosphere started to increase after the industrial revolution that started in the 1750s, and it brought international measures to the agenda as a global problem. These measures especially include topics such as generalizing the use of renewable energy, energy efficiency, and energy-saving. Hence energy, particularly renewable energy, is extremely critical for environmental quality.

Although the relationship between the use of renewable energy and environmental quality has been widely investigated (Jebli, Farhani, and Guesmi 2020), the nexus of pollution with natural resource abundance is a newer perspective (Balsalobre-Lorente et al. 2018; Kwakwa, Alhassan, and Adu 2020). As a result of the low carbon economy policies, the use of renewable energy sources globally is

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increasing day by day. According to the International Energy Agency renewables 2018 Report, the share of renewable energy sources in meeting global energy demand is expected to grow to reach 12.4% in 2023 by one-fifth in the next five years. This prediction is about the tendency of the world to perceive the climate change problem and to move away from fossil fuel consumption to prevent this. However, it is still controversial whether renewable energy consumption is successful in reducing carbon emissions.

Additionally, there is an increasing interest in the nexus between natural resource abundance and pollution. The issue of natural resources has been largely associated with economic development under the "natural resources curse" hypothesis. This hypothesis is based on the view that natural resource abundance causes lower economic growth. Sachs and Warner (1995) and Gylfason (2001) are among the main studies revealing this relationship. Later, Stijns (2005) used separately natural resource as gas, oil, mineral, and coal. Arezki and Ploeg (2011), and Bah (2016) included trade openness and institutions in the model. While investigating the resource curse hypothesis, Zalle (2019) focused on both institutions and human capital. Although the studies on the natural resource curse have developed over time, it is a fact that the relationship between natural resource abundance and environmental degradation has little attention. However, the impact of natural resource abundance on environmental quality is also a critical issue. First of all, natural resource extraction, such as oil, coal, and gas, causes an increase in carbon emissions (Kwakwa et al., 2019). Moreover, the abundance of resources increases emissions when natural resources are described as revenue from natural resource extraction (Bekun, Alola, and Sarkodie 2019). When this process, called mining, is not carried out in an environmentally friendly manner, it results in land degradation, habitat change, water, and air pollution. To put it more precisely, it includes many stages such as mining, exploration, extraction, transportation, processing, and closing, and the environmental costs of each stage are enormous (Gutti, Aji, and Magaji 2012). On the other hand, arguments suggest that natural resource abundance improves environmental quality. Accordingly, natural resource abundance may be a tool to attract foreign direct investments, which used energy-efficient technologies. This is possible with good natural resource management and proper policies (Shahabadi and Feyzi 2016). In summary, natural resource extraction is a serious carbon emissions source, but this problem may be eliminated with the effective management of revenues from these resources.

This paper aims to explore the effect of renewable energy consumption and natural resource abundance on carbon emissions. In this line, this paper presents several contributions to the current literature. First, as far as we are aware, this paper is the first attempt to study the energy-environment-resource nexus for a large panel of countries for the period of 1990–2014. Therefore, results from this study reveal essential policy suggestions at a global level. Second, this study contributes to the thin body of literature that employs the panel quantile regression method. An important feature and advantage of this method are that it produces robust results in the existence of heterogeneity in the sample over the analyzed variables; it is more robust relative to traditional regression if the errors are highly non-normal; the quantile regression produces different effects along with the distribution (quantiles) of the carbon emissions. Third, several control variables including urbanization and trade openness are included in the model for robustness purposes. Overall, attention is drawn to the importance of natural resources and renewable energy, which are considered important tools against global warming. Considering that climate change is not a regional but a global struggle, the global policy suggestions have become more meaningful.

The rest of the study is structured as follows. In the second part, related literature is discussed. In the third section, the model, data set, and methodology are introduced, in the fourth section findings are evaluated and in the fifth section, the conclusion title is included.

2. Literature review

There are many studies in the literature investigating the relationship between renewable energy consumption and CO_2 emissions. These studies provide different results as they are applied for different methods, sample groups, and periods. The results of more recent studies are discussed in this section. Also, a limited number of studies explaining environmental degradation with natural resources are presented.

Bilgili, Kocak, and bulut (2016) employed the FMOLS and the DOLS estimation methods to examine the nexus between renewable energy consumption and CO_2 emissions in 17 OECD countries for the period from 1977 to 2010. Also, their model includes GDP per capita to test the EKC hypothesis. Their results suggested that while renewable energy consumption has a negative impact on CO_2 emissions, GDP per capita positively affects it. A similar model is used by Dogan and Seker (2016), but the effect of nonrenewable energy consumption on CO_2 is also tested in European Union countries covering the period of 1980–2012. The results showed that, while supporting EKC, nonrenewable energy consumption increase emissions and renewable energy consumption decrease it. By developing this model, Bhattacharya, Churchill, and Paramati (2017) included institutional quality as an independent variable. They found that renewable energy consumption harms emissions. However, institutional quality mitigates CO_2 emissions. Alvarez-Herranz et al. (2017) researched the EKC hypothesis, taking into account energy innovation in 17 OECD countries covering the data period 1990–2012, and the results illustrated that innovations are increased pollution, while renewable energy consumption positively affects environmental quality. Also, Khoshnevis Yazdi and Ghorchi Beygi (2018) concluded that renewable energy consumption reduces CO_2 emissions for African countries by focusing on economic growth, total energy consumption, renewable energy consumption, trade openness, and urbanization and pollution nexus. Dong et al. (2017) used natural gas consumption as a proxy of nonrenewable energy consumption. They studied for BRICS countries and revealed that both natural gas and renewable energy consumption have a negative impact on CO_2 emissions. Additionally, the impact of renewable energy consumption is higher than natural gas consumption. Belaid and Zrelli (2019) tested the effect of renewable and nonrenewable electricity consumption on CO_2 emission in the Mediterranean, they reached that nonrenewable electricity consumption contributes to CO_2 emissions, while renewable electricity consumption reduces it. Valadkhani, Nguyen, and Bowden (2019) explained the causes of CO_2 emissions taking into account stages of economic development. In terms of energy consumption, they used fossil (oil, coal, gas) and renewable energy consumption indicators for 79 countries. Threshold regression analysis results suggested that renewable energy sources reduce CO_2 emissions in 79 countries. Focusing on the stock market growth, Paramati, Mo, and Gupta (2017) tested the relationship between two variables and found a negative relationship. Inglesi-Lotz and Dogan (2018) reached the same results in terms of the effect of renewable energy consumption for sub-Saharan African countries. Jebli, Farhani, and Guesmi (2020) reached the same result for lower-income, lower-middle-income, upper-middle-income, and higher-income countries.

In addition to the view that renewable energy consumption reduces carbon emissions, there are also studies concluding that there is no relationship or there is a positive relationship between them. Cherni and Jouni (2017) studied Tunisia and revealed that there is no statistically significant relationship between CO_2 and renewable energy consumption. A similar result was obtained from Pata (2018). This paper analyzed the relationship between CO_2 emissions, GDP, urbanization, financial development, and renewable energy consumption in Turkey. Charfeddine and Kahia (2019) confirmed that renewable energy consumption has a slight impact on CO_2 emissions in MENA countries for the period from 1980 to 2015. However, Jebli and Youssef (2017) analyzed the effect of agriculture on emissions as well as renewable energy in North Africa countries. Empirical findings indicated that renewable energy consumption increases CO_2 emissions, whereas an increase in agricultural value-added reduces it. Destek and Aslan (2020) separately investigated the impact of different types of renewable energy consumption on carbon emissions in G7 countries. Results implied that hydroelectricity, biomass, and wind energy consumption reduces CO_2 emissions, but the effect of solar energy consumption is statistically insignificant.

The study focused on the natural resource abundance as well as renewable energy consumption to explain pollution. Nevertheless, the results of the literature research revealed that the natural resource factor is not emphasized as much as renewable energy consumption. Balsalobre-Lorente et al. (2018) analyzed the effect of economic growth, renewable electricity, and natural resources on CO_2 emissions in European Union 5 countries (Germany, France, Italy, Spain, and the United Kingdom). Their results demonstrated that renewable electricity consumption, natural resource abundance, and energy innovation contribute to the improvement of environmental quality. Bekun, Alola, and Sarkodie (2019) studied for European Union 16 countries and reached that overdependence on natural resources rents affects environmental sustainability. Also, while renewable energy consumption has a negative impact on carbon emissions, fossil fuels damage environmental sustainability. Another study was conducted by Danish et al. (2019) for BRICS countries. Their findings suggested that natural resource abundance has a negative impact on CO_2 emissions in Russia, but contributes to emissions in South Africa. On the other hand, Shahabadi and Feyzi (2016) explored the relationship between natural resource abundance, foreign direct investment, and environmental quality in developed countries for the period from 1996 to 2013. Results implied that good governance and natural resources contribute to environmental quality through FDI. Regarding the existing studies related to non-linear causal examinations in renewable energy literature, Apergis and Payne (2014) demonstrated by recognizing the regime shift in 2002 show that the impact of renewable energy consumption upon real coal and oil prices strengthened for the post-2002 period relative to the pre-2002 period as well as a greater sensitivity of real GDP per capita to carbon emissions per capita.

3. Model, data, and methodology

This study builds on a strong theoretical model the Environmental Kuznets Curve (EKC) to test the nexus of real income and environmental degradation in Model I as originally stated by Grossman and Kruger (1995).

$$ModelI : ENVR_{it} = f(GDP_{it},\ GDP^2{}_{it}) \tag{1}$$

Studies in the existing EKC literature have added several control variables into Model I. In detail, renewable energy consumption, trade, urbanization, and natural resource abundance have been included in the original model (Dogan and Turkeul 2016; Balsalobre-Lorente et al. 2018; Alola et al., 2019; Danish et al., 2020). Inspired by the mentioned works, this study uses the following model II:

$$ModelII : ENVR_{it} = f(GDP_{it},\ GDP^2{}_{it}, REN_{it},\ NRA_{it},\ OPEN_{it},\ URB_{it}) \tag{2}$$

where ENVR stands for environmental degradation measured by CO_2 emissions per capita; GDP is economic growth measured by the real gross domestic product per capita in constant 2010 $; REN denotes renewable energy consumption measured by the share of renewable energy in total final energy consumption; NRA stands for natural resource abundance measured by total natural resources rents, which is equal to the sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents; OPEN is trade openness: the sum of exports and imports of goods and services measured as a share of the gross domestic product; URB denotes the number of people living in urban areas. The expected sign of coefficients on GDP and GDP^2 will be positive and negative if the EKC hypothesis is valid for countries. The annual data from 1990–2014 are withdrawn for 82 countries from the World Development Indicators to analyze the impact of economic growth, renewable energy consumption, natural resource, openness, and urbanization on the environment (WDI, 2020). The list of countries is presented in the Appendix. It should hereby worth noting that this study covers the maximum available group of countries and the largest period for the analyzed variables. The data are in the level and converted into a natural logarithm.

Firstly, the stationarity of the series is tested. Cross-sectionally augmented Im-Pesaran-Shin (CIPS) and cross-sectionally augmented Dickey-Fuller (CADF) second-generation panel unit root tests developed by Pesaran (2007) are employed to determine the degree of integration of the respective variables. Secondly, Pedroni and Westerlund cointegration tests (Pedroni 1999; Westerlund 2005) are applied in the case that the series are found to be stationary at first-differences. Last, the coefficients are estimated by the quantile regression model. The quantile regression models make it possible to account for heterogeneity and non-Gaussian distributions. Another feature of this method is that the quantile regression estimators are robust to outliers and skewed distributions. Also, allowing for unobserved heterogeneity, this approach enables the exploration of differences in the dependent variable among low, medium, and high changes. The Ordinary Least Squares (OLS) methods provide estimates that represent the effect from an independent variable on the "average country", and so, these estimates are not supposed to represent the entire distribution and provide an incomplete picture of the impact observed by the determinants under study. The panel quantile regression model is useful because it provides the stated advantages and overcomes the disadvantages of the OLS methods.

The panel linear regression Equation (1) is written in matrix notation and a quantile regression form as follows:

$$y_{it} = \alpha_i + \beta(q)xit + u_{it} \tag{3}$$

where i denotes the number of countries and t is the time dimension. The dependent variable y is a dependent variable, while the vector x includes all independent variables. q denotes the quantile $(0 < q < 1)$ of the conditional distribution, and α shows the presence of fixed effects. The impact of the x drivers is allowed to depend upon the quantile q, but the fixed effects α_i do not. Following Koenker (2004), the estimation of Equation (1) for several quantiles simultaneously is obtained by solving the following minimization problem:

$$min_{\alpha\beta} \sum_{k=1}^{\tau} \sum_{j=1}^{n} \sum_{i=1}^{m} w_k \rho_{qk} \left(y_{ij} - \alpha_i - \beta(q_k) xij \right) \tag{4}$$

where $\rho_{qk} = u(q - I(u < 0))$ is the piecewise linear quantile loss function provided by Koenker and Bassette (1978). The weights w_k control the relative influence of the τ quantiles $(q_1, \ldots, q_\tau)$ on the estimation of the α_i parameters. In the case where potentially the number of cross-sections n is large relative to the time dimension m (as in our case), then the estimates show a large number of fixed effects which can significantly inflate the variability of the other coefficient estimates. To this end, Koenker (2004) suggests a regularization or shrinkage of these individual effects toward a common value by considering a penalty. This method, called penalized quantile regression, takes the following form:

$$min_{\alpha\beta} \sum_{k=1}^{\tau} \sum_{j=1}^{n} \sum_{i=1}^{m} w_k \rho_{qk} \left(y_{ij} - \alpha_i - \beta(q_k) xij \right) + \lambda P(\alpha) \tag{5}$$

where $p(\alpha) = \sum_{i=1}^{n} |\alpha_i|$ is the penalty considered.

4. Empirical results and discussions

This section begins with displaying descriptive statistics of CO_2 emissions, real GDP, renewable energy consumption, natural resource abundance, openness, and urbanization. Table 1a shows that the number of observations (82 countries * period of 25 years), mean, median, minimum, and maximum values of data, and skewness and kurtosis statistics. It can be claimed that the analyzed variables are not symmetric and normally distributed because values of skewness statistics are different from zero. Besides, values have heavier tails than a normal distribution because kurtosis statistics are greater than +3 in most cases. Finally, descriptive statistics demonstrate the heterogeneity of data, which suggests the use of the panel quantile regression method for reliable empirical results.

Table 1a. Descriptive statistics.

Var.	Obs#	Mean	Min	Median	Max	Std. Dev.	Skewness	Kurtosis
ENVR	2,050	0,36	−1.47	0,43	1,43	0,57	−0,45	2,37
GDP	2,050	3.77	2,54	3,71	5,04	0,63	0,12	1,86
REN	2,050	1,25	−2,22	1,42	1,97	0.64	−2,02	9,76
NRA	2,050	−0.01	−3,50	0,22	1,77	1,01	−0,96	3,72
OPEN	2,050	1,80	1,04	1,80	2,64	0,23	0,24	3,84
URB	2,050	1,75	0,94	1,79	2,01	0,18	−1,15	4,26

Table 1b. Correlation matrix.

Var.	ENVR	GDP	REN	NRA	OPEN	URB
ENVR	1,0000					
GDP	0.8898	1,0000				
REN	−0.6836	−0.5242	1,0000			
NRA	−0.3459	−0.4432	0.2820	1,0000		
OPEN	0.2302	0.2268	−0.2171	−0.1250	1,0000	
URB	0.7623	0.7691	−0.5021	−0.2385	0.1963	1,0000

Note: Values are in natural logarithm.

In addition to that, Table 1b presents the correlation matrix for the analyzed variables. While some indicators are positively correlated, some other variables are negatively correlated. Furthermore, the IPS and CIPS panel unit root tests reveal that ENVR, GDP, REN, NRA, OPEN, and URB are stationary (no unit root) at their first differences at 5% level of significance. Besides, Westerlund and Pedroni cointegration tests suggest that the analyzed variables are cointegrated at 5% level of significance; thus, a long-run relationship is confirmed. It should be noted that these results are not provided in the study since they are not of fundamental interest but available upon request.

Table 2 reports the estimate of Model II for the OLS and quantiles (i.e., lower-pollution, 10% and 25%; medium-pollution, 50%; and higher-pollution, 75% and 90%). In Table 2, column 2 denotes the OLS estimation results while other columns illustrate the results of the panel quantile regression. The results of the OLS suggest that natural resource abundance and renewable energy consumption have a negative and statistically significant effect on CO_2 emissions but the effect of renewable energy consumption is higher than the effect of natural resource abundance. Also, both trade openness and urbanization positively affect CO_2 emissions but urbanization is more disruptive to air quality. Although the findings from the OLS provide some clues, the findings obtained with the quantile regression method are more critical in terms of policy-making because the panel quantile regression approach is up-to-date and reveals the effect of each independent variable on the environment for

Table 2. Quantile regression results (dependent variable: CO_2).

		QUANTILE REGRESSION				
	OLS (FE)	0.10q	0.25q	0.5q	0.75q	0.90q
GDP	1.61**	2.39**	2.32**	2.06**	1.82**	1.85**
	(0.132)	(0.164)	(0.156)	(0.137)	(0.194)	(0.197)
GDP^2	−0.15**	−0.21**	−0.21**	−0.18**	−0.14**	−0.14**
	(0.017)	0.020)	(0.019)	(0.017)	(0.024)	(0.024)
REN	−0.21**	−0.22**	−0.23**	−0.31**	−0.40**	−0.46**
	(0.011)	(0.012)	(0.012)	(0.010)	(0.015)	(0.015)
NRA	−0.01*	−0.02	−0.002	0.05**	0.08**	0.09**
	(0.004)	(0.007)	(0.007)	(0.006)	0.035)	(0.009)
OPEN	0.07**	0.06*	0.13**	0.07**	−0.09*	−0.23**
	0.019)	(0.069)	(0.028)	(0.025)	(0.035)	(0.035)
URB	0.56**	0.07	0.20**	0.06	−0.25**	−0.36**
	(0.056)	(0.066)	(0.063)	(0.055)	(0.078)	(0.079)
CONS	−4.29**	−5.69**	−5.64**	−4.61**	−3.10**	−2.60**
	(0.230)	(0.278)	(0.264)	(0.232)	(0.328)	(0.333)

Note: ** and *represents 1% and 5% level of significance. Numbers in parenthesis are standard errors.

various quantiles over carbon emissions. Therefore, the focus is on the results from the quantile regression since the most important contribution of the study is the use of the quantile method, which considers heterogeneity depending on the pollution rather than the OLS estimation method which estimates average effects.

According to the quantile regression results in Table 2 and Figure 1; firstly, the EKC hypothesis is valid at all quantile levels. This outcome implies that economic development contributes positively to environmental pollution in the early stages, but after a threshold, it has a decreasing effect on pollution (Bilgili, Kocak, and bulut 2016; Dogan and Seker 2016; Dong et al., 2017; Pata 2018; Danish et al. 2019; Ajmi and Inglesi-Lotz 2020); however, the validity of EKC hypothesis is not in line with Mikayilov et al. (2020) Accordingly, it can be said that the GDP in countries with lower, medium and higher pollution levels cause scale, technique and composition effect respectively (Grossman and Kreuger 1991). Accordingly, it can be observed that the sample countries adopt environmentally friendly transformations along with economic growth.

Second, renewable energy consumption reduces CO_2 emissions at all quantile levels. The result is compatible with that of Bilgili, Kocak, and bulut (2016), Dogan and Seker (2016), Bhattacharya, Churchill, and Paramati (2017), Dong et al. (2017), Paramati, Mo, and Gupta (2017), Inglesi-Lotz and Dogan (2018), and Jebli, Farhani, and Guesmi (2020). Moreover, the emission-reducing effect of renewable energy increases with the quantile level. Overall, from a statistical perspective, the impact of REN is statistically significant and negative at lower (0.10; 0.25), middle (0.50), and higher (0.75; 0.90) quantiles, with the coefficient increasing from around 0.20 at the 10th and 25th quantile to 0.40 at the 75th to 0.46 at the 90th quantile. That said, the contribution of renewable energy consumption to environmental quality increases with the quantile level. This result suggests that the tendency to renewable energy sources leads to a lower emissions reduction in countries with lower pollution while it has a very strong emission-reducing effect in countries with a higher pollution level. The main reason for this, renewable energy consumption in countries with high pollution levels is almost an imperative rather than an alternative policy proposal, and even a small increase in the use of such resources is critical to environmental quality. Therefore, when countries increase the share of renewable energy sources in their energy composition instead of turning directly toward fossil energy sources against increasing energy demand, significant improvements occur in environmental quality.

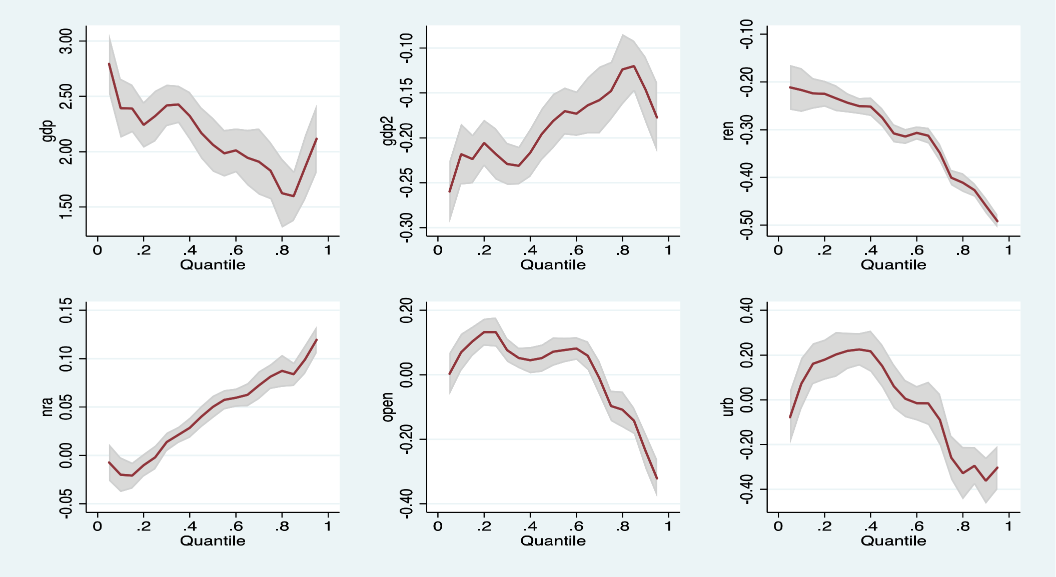

Figure 1. Results from quantile regression.

According to Alvarez-Herranz et al. (2017), the most critical advantage of such policies is also controlling the scale effect that exposes economies to increasing levels.

Third, natural resource abundance which is the other main explanatory variable hurts emissions at a lower quantile level (this result is compatible with Balsalobre-Lorente et al. 2018; Danish et al. 2019; and Shahabadi and Feyzi 2020) while this effect turns out positive at medium and higher quantile levels (as seen in Bekun, Alola, and Sarkodie 2019). Besides, the relationship between natural resources and environmental quality is weak in lower pollution countries since the related coefficient is too small. The positive effect of natural resource abundance on emissions emerges at the medium quantile level. Moreover, the impact of NRA is statistically significant and positive at medium and higher quantiles, with the coefficient increasing from 0.05 at the 50th quantile to 0.09 at the 90th quantile. Accordingly, the abundance of natural resource in countries with medium and especially high pollution levels evokes the prevalence of primary resource usage. An industrialization process that increases the fossil fuel dependency of these countries and as a result of this, the acceleration of natural resources extraction activities is one of the reasons for the unsustainability of the natural resources abundance (Danish et al. 2019). Also, considering the view that natural resources cause pollution through the economic growth channel (Bekun, Alola, and Sarkodie 2019), it is understood that natural resources do not make a positive contribution to growth in countries with both medium and higher pollution levels. Because the EKC hypothesis is valid in these countries and this case, there are two options. Either the contribution of resources to the GDP is up to the threshold value of the inverted-U curve mentioned in the EKC hypothesis or the natural resource curse hypothesis is valid (as seen in Sachs and Warner 1995).

Fourth, an increase in trade openness arouses CO_2 emissions in lower and middle quantile levels but openness has a negative impact on carbon emissions at higher quantile levels. Results for trade openness demonstrate that the effect of OPEN is statistically and positive at lower and medium quantiles and negative at higher quantiles, with the coefficient decreasing from 0.13 at the 25th quantile to 0.07 at the medium quantile. Also, an increase in trade openness mitigates CO_2 emissions at higher quantiles. This result means that countries with high pollution levels place more emphasis on environmental measures in their trade policies. This result can be evaluated based on three different effects of the income discussed by Grossman and Kreuger (1991). If there is a positive relationship between pollution and trade openness, this indicates that trade openness in the country is not yet optimal. Pollution emerges in the early stages of trade liberalization, but the conditions for the environment improve in countries after a certain threshold level is exceeded. Within the scope of this explanation, it is understood that trade openness is not yet at the optimal level in countries with lower and medium pollution levels, while the effect of technical scale has started to be observed in higher pollution countries. The negative relationship between trade openness and pollution is similar to the findings of Dogan and Seker (2016), and Inglesi-Lotz and Dogan (2018); and in such a case implies the validity of the view that the technical and composition effect overrides the scale effect. At the same time, the effort to achieve sustainable competition in international trade and compliance with international environmental standards increase in proportion to trade liberalization.

Fifth, similar results are obtained for urbanization. While urbanization leads to an increase in emissions in lower pollution countries, it has the opposite effect at a higher pollution level. For countries with a medium pollution level, the coefficient value is calculated as 0.06, but statistically insignificant. Also, the positive effect, which is 0.20 at the 25th quantile level, turns into a 0.25 negative effect at the 75th quantile level. Consequently, the increasing energy demand and intensive natural resource usage together with urbanization in countries with lower pollution levels significantly increase CO_2 emissions (Pata 2018). Environmental awareness is increasing because environmental destruction is felt more in countries with higher pollution levels, and it is possible to follow policies such as widespread horizontal structure and taking heavy traffic mitigation measures in these countries.

The robustness check is carried out by splitting the whole sample into three sub-samples: low-emissions countries, middle-emissions countries, and high-emissions countries. Results from Table 3

Table 3. Robustness check with OLS results from sub-samples.

	Low-emissions countries		Middle-emissions countries		High-emissions countries	
Dependent variable: CO_2	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
GDP	0.97**	0.206	2.15**	0.165	1,69**	0.173
GDP^2	−0.08**	0.027	−0.21**	0.022	−0.16**	0.022
REN	−0.20**	0.016	−0.25**	0.016	−0.17**	0.014
NRA	−0.03**	0.008	−0.01	0.005	−0.04**	0.006
OPEN	0.09**	0.029	0.06*	0.024	0.06*	0.025
URB	0.71**	0.089	0.49**	0.068	0.61**	0.069
CONS	−3.25**	0.350	−5.22**	0.293	−4.67**	0.311

Note: ** and *represents 1% and 5% level of significance.

present that the outcomes of the overall panel are the same as those of sub-samples. In detail, the EKC hypothesis is supported in the three groups, and renewable energy and resource abundance reduce the volume of air pollution while openness and urbanization increase CO_2 emissions.

5. Conclusion and policy implications

The aim of the paper is to study the nexus between renewable energy consumption, natural resource abundance, and carbon dioxide emission in a panel of 82 countries for 1990–2014. Besides, the GDP, the squared of GDP, trade openness, and urbanization are included in the econometric model as control variables. As another contribution to the literature, the panel quantile regression method is used to obtain the empirical results. They suggest that renewable energy consumption reduces carbon emissions and its magnitude increases as the level of quantiles increases. However, an increase in natural resource abundance increases CO_2 emissions. Besides, while trade openness and urbanization increase CO_2 emissions at lower and middle quantiles, they decrease emissions at higher quantiles. Finally, the validity of the EKC hypothesis is confirmed. The findings discussed above motivated us for a range of policy recommendations.

(I) First of all, countries should turn to renewable energy sources to meet increasing energy demand. Although this is accepted as a general truth today, the share of renewable energy consumption in emissions reduction almost doubles at the higher quantile levels compared to the lower quantile levels. This means that any increase in renewable energy consumption at high pollution levels has a serious positive impact on environmental quality. This is a detail that should not be ignored due to the significant increase in emissions at the global level today. Although the policy proposal certainly has a generally valid accuracy, dependence on fossil energy sources is a barrier in terms of applicability. Therefore, the main critical point is to eliminate these obstacles. This is possible with environmentally friendly technologic investments in the long term. Especially in the industrial sector, keeping this priority at every stage of production should be created both consciously and made attractive with some incentives (such as tax exemption).

(II) Second, natural resources causing an increase in emissions may seem insignificant compared to the emission-reducing effect of renewable. However, the point the world has reached in global warming makes this positive impact important. Because the atmosphere no longer tolerates even a small increase in temperature. For this reason, technologies that minimize the damage to the environment to a minimum during the extraction of natural resources should be encouraged. A legal and institutional infrastructure should be established that allows mining companies to be careful in this regard. Transfer of the abundance of natural resources obtained to environmentally friendly technologies should also be ensured.

(III) Third, an increase in trade openness arouses CO_2 emissions in lower and middle quantile levels, but openness harms carbon emissions at higher quantile levels. Today, both trade and environmental problems cover a wide area on a global scale. It is known that trade liberalization has accelerated in addition to the increase in environmental regulations since the 1970s. Therefore, it can be said that international trade concerns eliminate environmental sensitivity. On the other hand, sustainability competitiveness is linked to environmental quality. For this reason, instead of environmental taxes and fees that harm the competitiveness by causing an increase in firm costs (especially in pollution-intensive sectors), subsidies should be adopted. However, heavier sanctions are inevitable in countries with a high level of pollution. This creates pressure on firms, resulting in an environmentally good image by causing initiatives such as environmentally friendly technology and good waste management, so emission reduction power is high in the long run.

(IV) Fourth, while urbanization is the reason for the increase in emissions at lower quantile levels, this effect decreases in the medium quantile and has an emissions-reducing effect at higher quantiles. Hence, with the increase in the pollution level, policies related to urbanization become more effective. Primarily, urban areas are known to consume intensive energy and natural resources. Therefore, the energy consumption composition especially in transportation, industrial establishments, households, should be geared toward renewable resources. Besides, an environmental transformation of local authorities should be ensured and waste management policies should be developed. Another suggestion is to prevent excessive natural resource consumption and to strengthen the emission-reducing effect of urbanization. This can be provided by local authorities with some local taxes or sanctions.

Article highlight

- Energy-environment-resources nexus is studied for a panel of 82 countries.
- Quantile regression is used for empirical purpose.
- The validity of the EKC is confirmed for all quantiles.
- Renewable energy decreases carbon emissions.

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Appendix The list of sample countries

ALB
ARG
AUS
AUT
BEL
BEN
BGD
BGR
BOL
BRA
BWA
CAN
CHE
CHL
CHN
CIV
CMR
COG
COL
CRI
CUB
CYP
DNK
DOM
ECU
EGY
ESP
FIN
FRA
GAB
GBR
GHA
GRC
GTM
HND
HTI
IDN
IND
IRL
ISR
ITA
JAM
JOR
JPN
KEN
KOR
LBN
LKA
LUX
MAR
MEX
MIC
MNG
MUS
MYS
NGA
NIC
NLD
NOR
NPL
NZL
PAK
PAN
PER
PHL
PRT
PRY
ROU
SAS
SAU
SDN
SEN
SLV
SWE
TGO
THA
TUN
TUR
TZA
URY
USA
ZAF

Note: The three-letter country codes are presented.