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RESEARCH ARTICLE

Globalization, renewable energy consumption, and agricultural production impacts on ecological footprint in emerging countries: using quantile regression approach

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Abstract
Nowadays, paying attention to globalization and the consumption of renewable energy on the ecological footprint is one of the most important issues in the world. In the age of globalization, all countries are trying to prevent the spread of ecological degradation by enacting laws and regulations at the national level and regulating international agreements. This study investigates the effect of explanatory variables of globalization, renewable energy consumption, and agricultural production on the ecological footprint in emerging countries using fixed-effect panel quantile regression of 10th, 25th, 50th, 75th, and 90th in the period 2002 to 2016. The results showed that the consumption of renewable energy at all levels except the 25th quantile has a positive and significant effect on the ecological footprint; this effect is more in higher quantiles. Globalization in all quantiles has a negative and significant impact on the ecological footprint and has had the most excellent effect among other explanatory variables. Agricultural production variable at the 25th and 50th quantile levels had the most significant and positive effect on the ecological footprint. Therefore, it can be concluded that the increase in agricultural production, income, renewable energy consumption, population, and trade openness can lead to increased environmental degradation. However, the effects of globalization have had the most negligible negative impact on the ecological footprint.

Keywords Renewable energy · Environmental degradation · Agriculture · Quantile regression · Responsible Editor: Nicholas Apergis

Introduction

Globalization is a complex and multidimensional process that encompasses economics, ideology, politics, culture, and the environment (Mesino Rivero 2009; Victoria Flores 2016). Globalization emerged with rapid industrialization, increased energy demand, transfer of knowledge and technology, increased flow of trade and economic investment, and agricultural production (Etokakpan et al. 2020; Ibrahiem and Hanafy 2020). Studies show that with the increase in world trade, environmental resources are changing, and substantial changes have occurred (Xu and Lin 2018). As a result, ecosystem change has faced detrimental effects such as over-exploitation of energy resources, scarcity of natural resources (agricultural and freshwater), and biodiversity loss (Dogan and Seker 2016; Ibrahiem and Hanafy 2020). In recent years, environmental degradation has been a concern among economists (Enfedaque and Martínez 2014; Hynes and Wang 2012), social scientists (Curutchet et al. 2012; Robert and Castañeda 2014), academics (Kattumuri 2018), environmental thinkers (Abid 2016; Daigle and Vasseur 2019), policymakers (Wang et al. 2019), governments, and other stakeholders (Sarkodie and Strezov 2019). Since the beginning of globalization, a 2.7% increase in greenhouse gas (GHG) emissions has been reported in 3 years following Paris Agreement (Wang et al. 2019). According to Musibau et al. (2020), CO_2 emissions have increased by almost 20% in the last 5 years.

Globalization can be harmful to the environment and beneficial if sufficient regulations are used (Sarkodie and Adams 2018). Thus, globalization, energy, and environment

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encompass various dimensions and can be classified into three categories: (A) Scale effect shows that globalization encourages economic growth, and its energy consumption increases environmental pollution (Cole 2006; Dedeoğlu and Kaya 2013). (B) The combined effect shows that globalization in the production process using technology reduces CO2 emissions (Stern 2007). (C) The technical effect occurs when globalization, due to its use of advanced technology, technical knowledge, and research and development, helps enhance a country's economic growth and reducing energy consumption and environmental degradation (Antweiler et al. 2001; Dollar and Kraay 2004).

In globalization, competition between developed and developing countries in energy consumption and agricultural production has increased and has affected the global economy (Danish 2019). Emerging countries invested $ 131 billion in the energy sector in 2014 (Kozlova et al. 2015). Therefore, the desire to expand economic activities to attract investment in energy, trade development, and agricultural production is one of the goals of emerging countries (Danish 2019). These activities have increased investment in industry and agricultural products, increased energy demand and consumption, and led to increased carbon dioxide (CO2) emissions and a threat to human health and sustainable development to achieve economic growth. (Asongu and Odhiambo 2019a). Thus, the decisions and actions of emerging countries have a significant impact on global energy systems and environmental degradation.

In most studies, the ordinary least squares (OLS) method has been used to analyze environmental pollution factors. The OLS method can only determine the average effect of influencing factors on the dependent variable and fails to show the heterogeneous effect of different quantiles (Bouhajeb et al. 2018). One of the methods that can overcome the shortcomings of the OLS method is panel quantile regression methods (Meraya et al. 2018).

Very few studies have been conducted on the effects of globalization and agricultural production on ecological footprint; these studies have examined farm production and renewable energy consumption as environmental indicators. But the ecological footprint is a more comprehensive indicator of the agricultural output in this study. Therefore, this research is one of the few studies that has examined the ecological footprint on a large scale. A list of emerging countries in terms of indicators (globalization, renewable energy consumption, and agricultural production) that in the future can be economically strong and have important effects on the world's ecological footprint has been studied and been considered as the first contribution of this study.

The rest of the article is as follows. In Sect. 2, a review of the literature is provided; in Sect. 3, emerging countries are introduced, and the importance of these countries in the world is stated; Sect. 4 discusses the methodology and model specifications, in Sect. 5, the results are presented, In Sect. 6; The results and discussion are reviewed, and finally the conclusions are presented in Section 7.

Literature reviews

In recent decades, globalization has changed the world and has led to the interaction of countries economically, socially, institutionally, and politically. These economic, social, and political factors affect the environment (Kirikkaleli et al. 2020). For example, in resource-rich countries such as Australia, Brazil, Canada, China, India, and the USA, investments in this country have a measurable contribution to the development of the financial system, and their impact on GDP includes globalization and human and natural capital (Ma et al. 2021). Globalization is predicted to accelerate internal and external migration, increase poverty, and change climate (Leal et al. 2020). Therefore, a greater understanding of globalization and changes in energy consumption and increased production has caused environmental concerns and paved the way for the coordination of foreign initiatives, including the Kyoto Protocol and the Paris Agreement, by intergovernmental institutions (Kirikkaleli et al. 2020). For example, Dreher et al. (2008) state a significant relationship between the effects of globalization and climate pollution. The development of globalization has led to an increase in the consumption of wood products and a wide range of sulfur dioxide and biochemical consumption. Also, the conversion of half of the world's land to crops and pastures has contributed to humanity's environmental challenges for three important reasons: (1) Agriculture is a quarter of the human greenhouse gas emissions in vegetation and soil. (2) Agriculture is a major cause of habitat loss, which is the biggest threat to global biodiversity. (3) Agriculture sector has used more than 70% of freshwater (Beyer et al. 2018). Besides, experts examining the ecological footprint of developed and emerging countries stated factors such as trade openness, investment and financial development, overuse of energy, increased agricultural production, and institutional and political factors affect the ecological footprint (Irfan and Faisal 2021). Thus, in the age of globalization, the world's countries have turned to the use of renewable energy and have put it at the forefront of their development plans (Majeed 2018). International Energy Agency considers the use of renewable energy to reduce pollution and to have energy security and sustainable economic growth.

Meanwhile, the reduction of pollution due to the importance of the issue for the planet attracts a lot of attention; for example, the International Energy Agency (IEA) places the environment at the center of ET (Hasanov et al. 2021). In 2015, about 146 countries worldwide introduced renewable energy policies to improve the environment in four significant sources of electricity generation, transportation, air/water cooling/heating, and rural and urban energy services (Ren et al. 2010). The use of renewable energy potentials is widespread, as it can, in principle, be a lever to meet global energy demand while reducing environmental degradation (Martínez et al. 2009; Owusu and Asumadu-Sarkodie 2016; Pehnt 2006). In this regard, Asongu and Odhiambo (2019b) believe that small hydropower plants and wind, solar, biomass, and geothermal power plants can provide significant energy services for indigenous people.

In recent years, researchers and environmental activists (e.g., Abid 2016; Apergis and Payne 2009; Destek and Ozsoy 2015; Pao and Tsai 2010; Shahbaz et al. 2015; Shahbaz et al. 2014) have shown interest in the relationship among globalization, renewable energy, agricultural production, and the environment. They examined the indicators of economic growth, energy consumption, globalization, urbanization, and environmental degradation and reported that energy consumption and economic growth lead to environmental degradation, but the globalization and economic growth index reduce CO_2 emissions. Dogan and Seker (2016) surveyed the relationship among renewable energy consumption, environmental degradation, and commercial production growth and reported that renewable energy is inversely related to environmental degradation but has a positive effect on production growth. Apergis and Payne (2009) reported that reforming regulatory policies on production costs and economic growth reduces ecological degradation. Research has shown that environmental degradation is caused by greenhouse gas emissions (GHG) caused by the overuse of non-renewable resources (Daigle and Vasseur 2019). Zafar et al. (2019) reported that the use of renewable energy leads to improved environmental quality and reduced CO_2 emissions. Renewable energy, economic development, actual production, and globalization have been reported to be positively associated with ecological footprint. There is a two-way causal relationship between agricultural production, globalization, and financial development (Usman et al. 2020b). Moreover, by examining the relationship between natural resources and globalization with energy consumption in Asian countries, they reported that natural resources and globalization significantly impact energy efficiency in these countries (Hussain et al. 2020). Increased real incomes and fossil fuel consumption have a negative impact on ecology. The existence of a two-way causal relationship between real incomes and globalization and ecological footprint has been proved (Ibrahiem and Hanafy 2020; Ike et al. 2020). G20 countries' research found that renewable energy prices have a negative effect on CO_2 emissions. Still, increased trade has a strong positive effect on CO_2 emissions. A summary of this research is given in Table 1.

Emerging countries

The beginning of the twenty-first century was marked by the emergence of a range of new economic powers, the emergence of new players, and the issue of global power shifts. These new economic powers are called "emerging powers." The most important emerging powers are Brazil, Russia, India, China, and South Africa. These countries have accounted for almost twice the growth of world GDP and more than half of new consumption in the last 15 years (Shaw et al. 2009). Within this large group of countries, economic performance is very different. Some of these countries have achieved sustained economic growth over a long period, enabling them to narrow their gap with developed, high-income countries. These countries account for the bulk of the world's population and territory, GDP, and world trade. The emergence of these countries has introduced shifting political-economic power in the world (Lopes Jr 2015). The selection and classification of emerging countries in this study were based on the EM bond index method and access to data from these countries. Table 2 refers to emerging countries.

Methodology and model specifications

Panel quantile regression

Panel quantile regression model was introduced by Koenker and Bassett Jr (1978) and became a comprehensive method for statistical analysis of linear and nonlinear models in various fields (economic, social, and environmental) (Andrews and Phillips 1987; Koenker and Hallock 2001). This model provides a more robust and more efficient coefficient estimate than OLS (Marasinghe 2014; Xu and Lin 2018). Panel quantile regression method has been used by researchers in the field of climate (Paltasingh and Goyari 2018), agriculture (Balducci et al. 2018), soil resource improvement (Steers et al. 2011), economics (Zhu et al. 2016), and the environment (Xu et al. 2017). Therefore, panel quantile regression method has been used in this study to evaluate the effects of globalization, renewable energy consumption, and agricultural production on the ecological footprint in emerging countries.

The mathematical Eq.1 of the quantile regression model is as follows:

$$\begin{aligned} y_i &= x_i b_{\theta i} + \mu_{\theta i}. 0 < \theta < 1 \\ Quant_{i\theta}(y_i/x_i) &= x_i \beta_\theta \end{aligned} \quad (1)$$

where x is the vector of explanatory variables and y represents the dependent variable. μ is a random error whose conditional

Table 1 Summary of studies on the effects of globalization, renewable energy consumption, and agricultural production on ecological footprint

Researcher	Indicator	Summary of results
Pao and Tsai (2010);Shahbaz et al. (2014);Shahbaz et al. (2015)	Economic growth, energy consumption, globalization, agricultural production, and environmental degradation	The results showed that energy consumption and economic growth indices lead to ecological degradation, but globalization and economic growth indices reduce CO_2 emissions
Destek and Ozsoy (2015);Dogan and Seker (2016)	Free trade, renewable energy consumption, and environmental degradation	The results showed that renewable energy is inversely related to environmental degradation but positively affects production growth
Apergis and Payne (2009)	Institutional-political, economic growth, and ecological footprint	The results showed that the reform of regulatory policies on production costs and economic growth reduces environmental degradation
Daigle and Vasseur (2019)	Carbon dioxide emissions, renewable energy, environmental degradation	This study showed that the cause of environmental degradation is the emission of greenhouse gases (GHGs) that excessive use of non-renewable resources causes large volumes of waste
Zafar et al. (2019)	Renewable energy, CO_2 emissions; agricultural production, globalization, ecology	The results of this study showed that on the one hand, the use of renewable energy leads to improved environmental quality and reduced CO_2 emissions. On the other hand, renewable energy, economic development, actual production, and globalization are positively related to the ecological footprint. There is a two-way relationship between agricultural production, globalization, and financial growth
Usman et al. (2020a)	Globalization, agricultural production, energy consumption, environmental degradation	The results showed that natural resources and globalization have an essential causal effect on energy efficiency in these countries
Hussain et al. (2020)	Income, energy consumption, ecological	The results showed that the increase in real income and fossil fuel consumption are severe ecological factors
Ibrahiem and Hanafy (2020)	Globalization, rising incomes, ecological footprint	The results showed that there is a two-way causal relationship between real income and globalization and ecological footprint
Ike et al. (2020);Yilanci and Gorus (2020)	Renewable energy, free trade, CO_2 emissions	The results showed that renewable energy at energy prices has a negative effect on CO_2 emissions, but increased trade has strong and positive effects on CO_2 emissions

quantile distribution is zero. $Quant_{i\theta}(y_i/x_i)$ is the quantile value of the described variable. The β_θ estimate shows the quantile regression θth and solves Eq. 2.

$$min\sum_{yi\geq x_i'\beta}\theta|y_t-x_i'\beta| + \sum_{yi<x_i'\beta}(1-\theta)|y_t-x_i'\beta| \quad (2)$$

Table 2 List of emerging countries

Argentina	Mexico
Colombia	Morocco
Brazil	Pakistan
Chile	Peru
China	Philippines
Czech Republic	Poland
Egypt	Russia
Greece	South Africa
Hungary	South Korea
India	Thailand
Indonesia	Turkey
Malaysia	

When θ is equal to different values, estimates of other parameters are obtained. Mean regression is a particular case of quantile regression under conditions where $\theta = 0.5$ (Xu and Lin 2018).

Model specifications

The STIRPAT model is a classical model for determining environmental pollution factors (Ge et al. 2018). Equation 3 is as follows:

$$I_t = aP_t^bA_t^cT_t^de_t \quad (3)$$

I indicates pollution, P indicates population size, A indicates financial ability, and T indicates technical factors. The pressure on the environment is not only through the population, economic development, and technology. It is affected by many other factors. Therefore, many researchers have used the extended STIRPAT model (Eq. 4) to investigate the effects of different environmental factors (Xu and Lin 2018).

$$EFP_t = aPOP_t^bNIC_t^cEF_t^dREC_t^\alpha ARG_t^\beta GI_t^\gamma TO_t^Z e_t \quad (4)$$

EFP represents ecological footprint measured in global hectares; REC is renewable energy consumption, which includes wind, solar, hydropower, and biomass and is calculated in million tons oil equivalent; AGR is total value of agricultural products; GI is globalization index used as a variable to measure the economic, social, and political dimensions of globalization; EF is energy efficiency, which is calculated through dividing GDP by energy consumption and is considered as a technology variable; the NIC is the adjusted net per capita income that is used as a proxy for economic viability; POP refers to total population; and TO is trade openness that measures the sum of exports and imports in GDP.

Econometric theory points out that the model variables must be logarithmic to eliminate possible heterogeneity phenomena. Therefore, Eq. 5 is as follows:

$$LEFP_{it} = La + \beta_1 LREC_{it} + \beta_2 LAGR_{it} + \beta_3 LGI_{it} + \beta_4 LEF_{IT} + \beta_5 LNIC_{it} + \beta_6 LPOP_{it} + \beta_7 LTO_{it} + \delta_{it} \quad (5)$$

This study used quantile regression to measure ecological footprints in emerging countries. For this purpose, Eq. 6 is converted to the following form:

$$Q_\tau(LEFP_{it}) = (La)_\tau + \beta_{1\tau} LREC_{i\tau} + \beta_{2\tau} LAGR_{i\tau} + \beta_{3\tau} LGI_{i\tau} + \beta_{4\tau} EF_{i\tau} + \beta_{5\tau} LNIC_{i\tau} + \beta_{6\tau} LPOP_{i\tau} + \beta_{7\tau} LTO_{i\tau} + \delta_{i\tau} \quad (6)$$

In this regard, Q_r means the estimation of the quantile regression τth in the ecological footprint and $(la)_r$ is a constant component. The coefficients $\beta_{1\tau}.\ \beta_{2\tau}.\ \beta_{3\tau}.\ \beta_{4\tau}.\ \beta_{5\tau}.\ \beta_{6\tau}.\ \beta_{7\tau}$ are the quantile regression parameters and show the influencing factors.

Data source and data description

The data used in this study are in the form of panels for 21 emerging countries in 2002–2016. The data obtained for ecological variables in terms of global hectares are taken from the Global Footprint Network (GFN); the total value of agricultural products in (constant = 2010 US $) is obtained from the Food and Agriculture Organization (FAO); globalization index data is received from KOF Swiss Economic Institute; REC is renewable energy consumption data (wind, solar, hydropower, biomass); EF is energy efficiency; NIC Adjusted Net Per capita Income (constant = 2010 US $); POP total population; TO (trade openness), calculated from total imports and exports as a percentage of GDP, is obtained from the World Development Indicators (WDI). Table 3 provides definitions of all variables.

WDI World Development Indicator, *GFN* Global Footprint Network, *FAO* Food and Agriculture Organization

Table 4 shows the descriptive characteristics of the indicators used in terms of mean, standard deviation, maxim, and the minimum of variables.

Figure 1 shows the relationship between ecological footprint and agricultural production (a), globalization (b), and renewable energy consumption (c) in emerging countries (Fig. 1a). This figure shows that the relationship between ecological footprint and agricultural production is positive; Fig. 1b shows that the relationship between the globalization index and the ecological footprint is negative, meaning that the lower the globalization index in these countries, the greater the ecological footprint. Figure 1c shows the positive relationship between renewable energy consumption and ecological footprint among emerging countries.

Results

Multicollinearity test

Multicollinearity is a condition that indicates that an independent variable is a linear function of other independent variables. Suppose the multicollinearity in a regression equation is high. In that case, there is a high correlation between the independent variables, and the model may not have high validity despite the high R2. Therefore, multicollinearity test

Table 3 Variable definitions

Abbreviation	Variables	Sources
EFP	Ecological footprint (In global hectares)	GFN
REC	Renewable consumption = million tonnes oil equivalent	WDI
AGR	Agriculture Total (gross production value (constant=2010 US$))	FAO
GI	Globalization index (KOF Index)	KOF Index
EF	Energy efficiency = calculated by dividing GDP to total energy consumption	WDI
NIC	Adjusted net national income per capita (constant 2010 US$)	WDI
POP	Total population	WDI
TO	Total openness= (import+export)/GDP	WDI

Table 4 Summary of descriptive statistics

Variable	Mean	Std. dev.	Min	Max	Obs
EFP	4.19e+08	8.89e+08	2.93e+07	5.26e+09	345
REC	16.98662	38.14958	0.0534009	275.0157	345
AGR	78195.07	180020.4	4009.033	1219569	345
GI	68.51565	8.642986	47.8	86.8	345
EF	174.2381	220.7617	1.52606	924.5416	345
NIC	7045.473	5309.623	-1955.68	24896.9	345
POP	1.85e+08	3.44e+08	9814023	1.39e+09	345
TO	69.79017	39.38225	22.10598	210.3743	345

methods including stepwise regression, comprehensive testing, and Klein's criterion methods can be used (Klein and Marquez 1985).

In this research, Klein's method has been used to test the multicollinearity. To perform this method, a comparison is made between the correlation coefficient (r) of the explanatory variables and the coefficient of R^2 determination obtained from estimating the fixed effect panel model. If $|r_{x_i,x_j}| > R^2$, then the multicollinearity between the variables x_i and x_j is harmful. Otherwise, the multicollinearity between the variables can be ignored. As shown in Table 5, the absolute value of all correlation coefficients between the explanatory variables is less than R^2 = 0.9807. This means that there is no multicollinearity problem.

Unit root test

One of the important characteristics of variables is their stationary status. In the panel model, the stationary status of the data must be tested before performing regression (Wang et al. 2015). Using non-stationary data leads to spurious regression, and the regression result is not reliable. In this study, to assess the stationary status of variables, three panel unit root tests, namely, Levin-Lin-Chu (LLC) test (Levine and Kendall 2006), Fisher-ADF test and Fisher's test (Maddala and Wu 1999), and PP, have been used.

Table 6 shows the results of the panel unit root test. The variables REC, AGR, and EF for all three tests are the root of the panel unit, and reject the null hypothesis of non-stationary of data at the 1% significance level. The variables EFP and NIC for LLC and PP test are at the stationary level, and reject the null hypothesis that the data are non-stationary at the level of less than 1%. The variables EF and TO are stationary only for the LCC test at the significance level of 10% and 1%, and POP with the PP test is stationary at the level of 1%. However, when the first-order difference is taken into account by the relevant tests, all variables are stationary at the significance level of 1%. Therefore, since all variables are stationary in the first-order difference, the relationship between the ecological footprint and other variables can be determined by the co-integration test.

Panel cointegration test

Cointegration panel tests can examine the long-run balance between variables. Cointegration theory states as long as there is cointegration between the dependent and independent variables, these variables can be used to make a model. The results of Table 6 shows the stationary status of all variables at the first-order difference. To examine the correlation between ecological footprint (EFP) and its variables, the Kao test (1999) was used. The results in Table 7 show that ADF = −3.5645, P value = 0.0002, and a long-run balance relationship between ecological footprint (EFP) and the factors affecting it can be used to estimate the model. The results obtained from the significance of the cointegration test are the basic assumptions for estimating quantile regression.

Normal distribution test

When the sample data are not normally distributed, the estimation results from quantile regression are more robust than the OLS estimation. If the ordinary least squares (OLS) method is used to estimate regression, the skewed distribution of economic variables is ignored. This will have negative consequences such as increased variance and low robustness of the model (Koenker and Xiao 2002). Therefore, before performing regression analysis, the normality of all available variables must be tested. Two methods have been used to normalize the data: graphic (Fig. 2) and numerical method (Table 8). As shown in Table 7, the skewness coefficients of LEFP, LREC, LAGR, LGI, LEF, LNIC, LPOP, and LTO are significantly non-zero, indicating that these variables are not normally distributed. Moreover, the results of the kurtosis coefficients are not equal to 3 in any of the variables, which means the variables are not normally distributed.

Table 8 shows that the probability values of the Shapiro-Wilk and Shapiro-France tests for all variables are less than 1%. This means that these variables can reject the null hypothesis that the variable is distributed normally. In other words, the above variables are not normally distributed.

Sig. represents the significance level. Obs. indicates the number of observations

In this study, the most common normal data distribution test (Q-Q test plot) is used (Fig. 2). The Q-Q diagram is a probability graph that can graphically show whether the data follow a normal distribution. If the Q-Q diagram overlaps the straight blue line in Fig. 2, it means that the data is normally distributed. Otherwise, it indicates that the data distribution is skewed. The results in Fig. 2 show that the Q-Q diagrams of all variables deviate from the straight line, which indicates that the distribution of these variables is not normal.

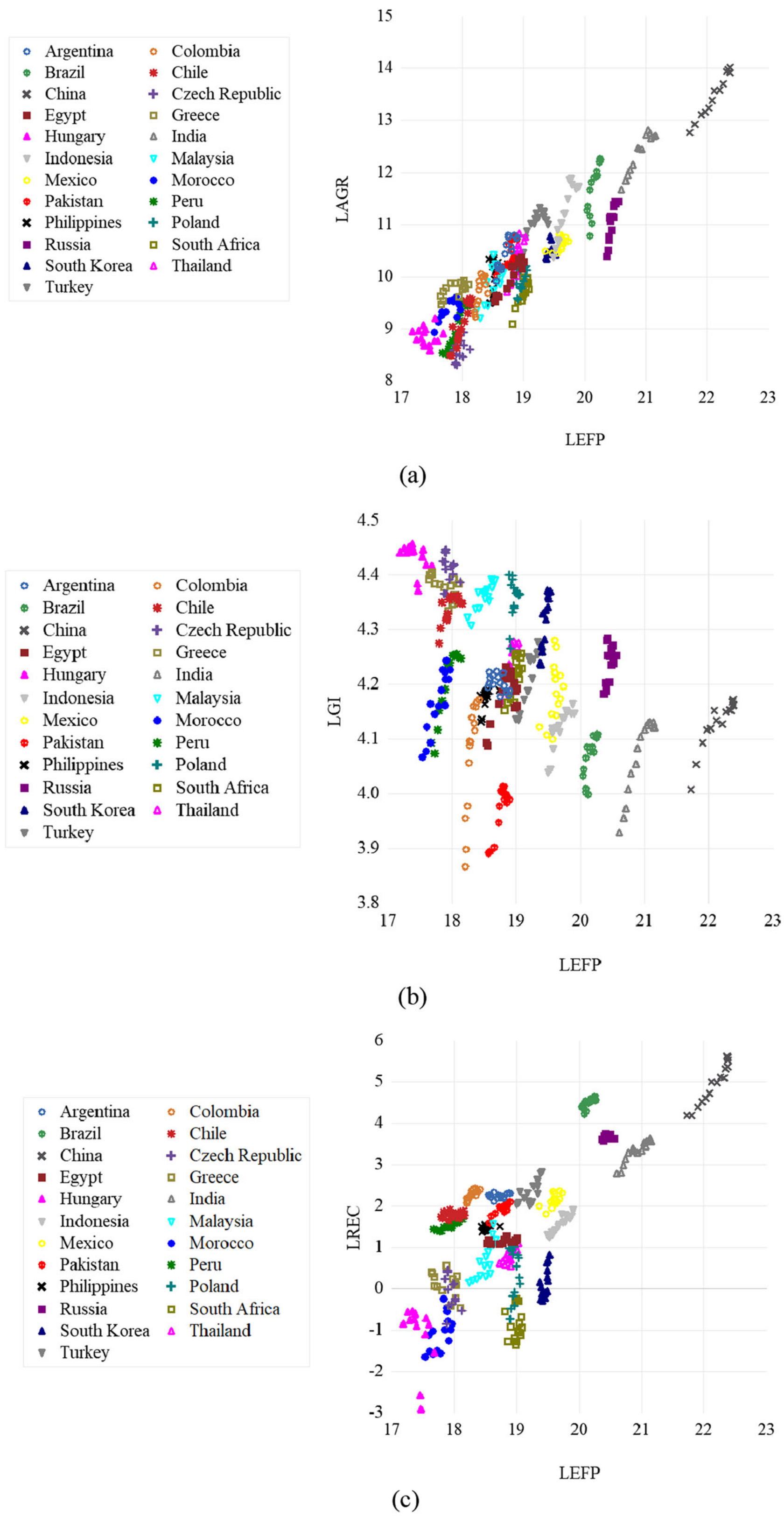


Fig. 1 Relationship between **a** ecological footprint and agriculture, **b** globalization, and **c** renewable energy for emerging countries

According to the results in Table 8 and Fig. 2, it can be seen that these variables are not normally distributed. The tail of data distribution reveals essential information that cannot be demonstrated by OLS regression. This proves that the use of the quantile regression model for experimental analysis is more appropriate and reasonable.

Table 5 The correlation coefficient matrix

	LREC	LAGR	LGI	LEF	LNIC	LPOP	LTO
LREC	1.0000						
LAGR	0.7663	1.0000					
LGI	−0.5083	−0.4479	1.0000				
LEF	−0.6479	−0.8448	0.6232	1.0000			
LNIC	−0.2225	−0.2734	0.7417	0.6284	1.0000		
LPOP	0.7595	0.8199	−0.6110	−0.8888	−0.5594	1.0000	
LTO	−0.5911	−0.4478	0.7291	0.3789	0.2962	−0.4784	1.0000

Panel quantile regression results

The results of normality tests show that all variables used in this study are distributed normally. In such cases, it is more appropriate to use panel quantile regression to estimate the model. This regression can obtain independent variables on the dependent variable in different quantiles between 0 and 1. However, due to data fluctuations, it is impossible to estimate each of the quantile values effectively. According to most researchers, quantile values of 10, 25, 50, 75, and 90 are used as representative values for experimental analysis. In this study, based on the ecological footprint scale, emerging countries are classified into six groups shown in Table 9.

According to the level of ecological footprint, we divided 23 countries into six grades

Furthermore, ordinary least squares regression (OLS) was used in this study to estimate the results of the fixed effects of the panel data model, which can only estimate the average impact of explanatory variables on the dependent variable. The results of quantile regression are graphically shown in Fig. 3.

Discussion

Different quantiles (10th, 25th, 50th, 75th, and 90th) have been used to estimate in this study. The results of these estimates are given in Table 10 and Fig. 3. To facilitate comparative analysis, the results of the OLS estimation are shown in Table 10. This table shows that the impact of influential factors on ecological footprint is different in different quantiles. These other effects need to be analyzed to support countries to adopt policies to reduce the ecological footprint.

Effects of renewable energy consumption on ecological footprint

As shown in Table 10, renewable energy consumption on the ecological footprint in all quantiles of countries is positive and significant. This variable has the most negligible effect on ecological footprint. The results show that this effect is more significant in quantiles higher than 75th and 90th. It can be concluded that renewable energy consumption positively affects ecological footprint (Bilgili et al. 2016). Nathaniel

Table 6 Results of unit root tests for panel data

Series	Level data			First-order difference data		
	LLC	Fisher-ADF	PP	LLC	Fisher-ADF	PP
EFP	-4.702***	45.649	65.473**	-6.457***	130.559***	285.993***
REC	-5.401***	91.350***	106.683***	-9.445***	165.451***	326.585***
AGR	-5.672***	63.946**	81.566***	-6.465***	91.483***	139.061***
GI	-9.2081***	107.941***	164.672***	-6.297***	100.450***	153.318***
EF	-1.5453*	49.177	47.605	-6.261***	101.153***	187.106***
NIC	-4.591***	42.785	94.702***	-7.229***	91.397***	146.291***
POP	-0.681	54.019	166.891***	-7.513***	115.445***	115.365***
TO	-2.377***	49.885	58.386	-7.417***	114.753***	227.081***

Note: Level indicates the logarithmic variable value, PP represents Phillips-Perron test, LLC denotes Levin-Lin-Chu test. *, ** and *** indicates that the tested variable sequence passed the significance test at significance levels of 10%, 5%, and 1%, respectively

Table 7 Kao cointegration test

	t statistic	Prob.
ADF	−3.5645	0.0002
Residual variance	0.00279	
HAC variance	0.00230	

(2020) also reported that renewable energy consumption reduces environmental degradation. Therefore, he proposed policies to reduce greenhouse gas emissions, reduce urban anomalies, and maintain a sustainable environment. Therefore, while renewable energies improve the quality of the environment, non-renewable energy consumption and urbanization are the leading cause of environmental degradation in CIVETS countries.

Effects of agricultural products on ecological footprint

Agricultural production also has a positive and significant effect on ecological footprint in all quantiles, but their coefficients are different. Since the greatest impact of agricultural production on the ecological footprint is in the quintile of the 25th countries, and with higher deciles, this effect decreases, it can be concluded that the increase in agricultural production has a positive effect on the ecological footprint and has created the ground for environmental degradation and the increase in CO_2 emissions (Lustigová and Kuskova 2006). Agricultural production is a major cause of biodiversity loss, a quarter of greenhouse gas emissions, and the consumption of 70% of freshwater (Beyer et al. 2018). In recent decades, global trade in agricultural products has grown significantly and has experienced annual growth of 6% from 2000 to 2016 (Balogh and Jámbor 2020). Agricultural products show 36% growth from 2008 to 2018; the top 10 exporters of agricultural products (EU, USA, Brazil, China, Canada, Indonesia, Thailand, India, Australia, Mexico) account for 72% of total world exports in 2018 (WTO 2018). The most significant increase in agricultural exports in the top 10 exporters was recorded by China (9%), Brazil (6%), and Mexico (6%) in 2018 (WTO 2018). Emerging economies such as Brazil, China, India, and Indonesia were the main drivers of this growth as they accounted for 14.5% of the value of global exports in 2016, compared to 8.5% in 2000, which paved the way for environmental and ecological degradation (Balogh and Jámbor 2020).

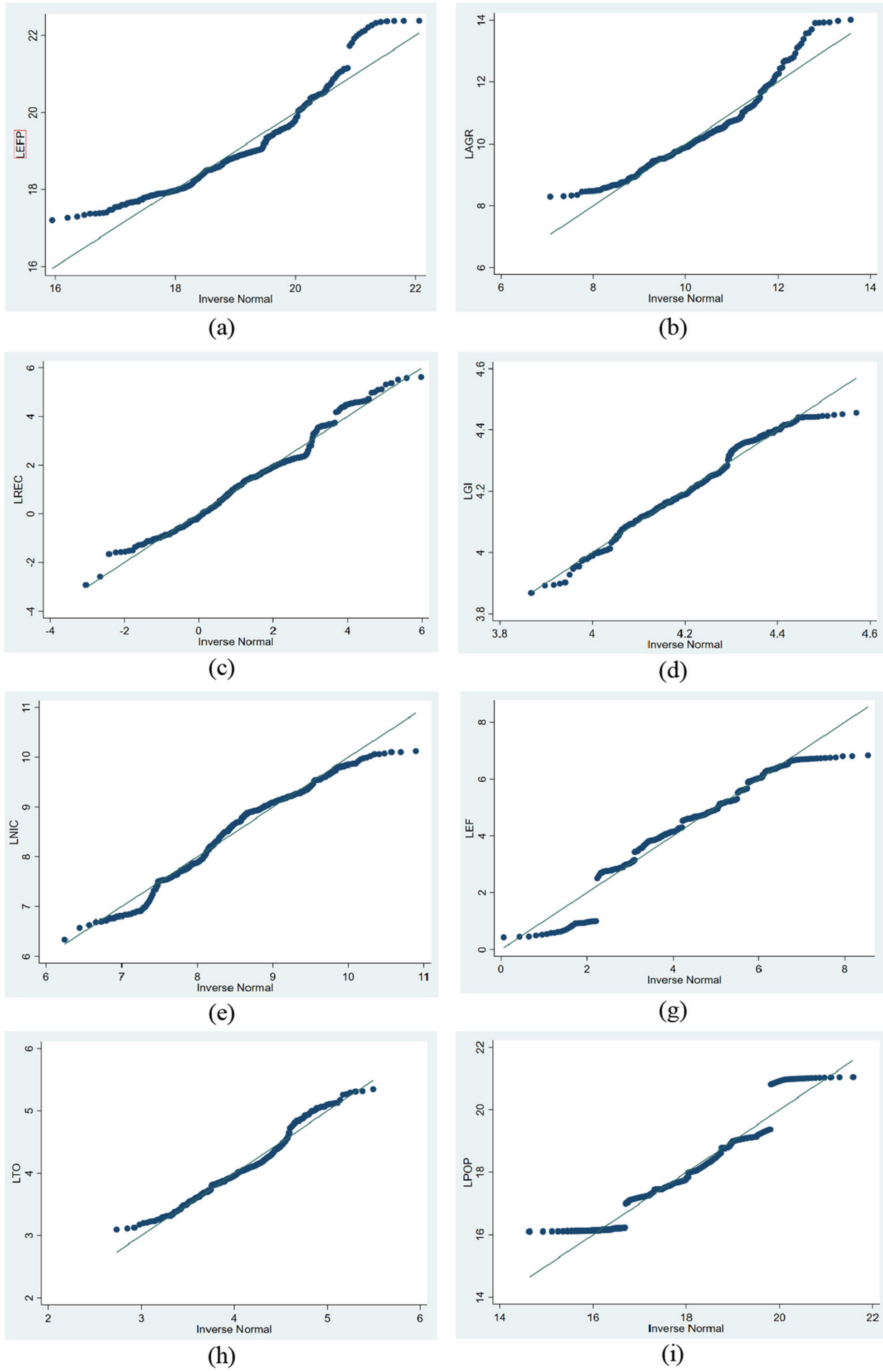
The effects of globalization on the ecological footprint

Globalization has the greatest effect on ecological footprint. The globalization index in all quantiles has a negative and significant effect on the ecological footprint. This effect is greater in the 10th and 50th countries. This index considers the economic, social, and political dimensions of globalization. It can be said that the development of countries and their global relationship lead to environmental protection and ecological sustainability. These results can be seen in research conducted by Sarkodie and Adams (2018) They stated that the effects of globalization on the ecological footprint can be both positive and negative. The study by Saud et al. (2020) showed that globalization has led to significant investments in new production methods, technology, and operational productivity in green industries and has reduced environmental and ecological degradation. That is, 1% growth in global indicators reduces ecological footprint in the long run by 0.0038% (gha), and this indicates an inverse relationship. However, in some countries, due to old technologies and high consumption of fossil fuels, we are witnessing more environmental degradation. In other studies, globalization criteria such as FDI, trade openness, and KOF index positively and significantly affect ecological footprint. Yet, improvement in technological changes has little effect on the quality of the environment. The study reported that globalization and

Table 8 Tests of normal distribution

Variable	Skewness	Kurtosis	Shapiro-Wilk test		Shapiro-France test		Obs
			Statistic	Sig.	Statistic	Sig.	
LEFP	1.044541	3.987408	0.92419	0.0000	0.92567	0.0000	345
LREC	0.248910	2.811579	0.98299	0.0004	0.98400	0.0011	345
LAGR	0.927923	3.968911	0.94163	0.0000	0.94294	0.0002	345
LGI	−0.164740	2.570924	0.97888	0.0000	0.98076	0.0000	345
LEF	−0.684082	3.263253	0.94326	0.0000	0.94557	0.0000	345
LNIC	−0.451363	2.495522	0.96702	0.0000	0.96906	0.0000	345
LPOP	0.574589	3.209068	0.93455	0.0000	0.93716	0.0000	345
LTO	0.430368	2.689647	0.96877	0.0000	0.97075	0.0000	345

Fig. 2 The normal Q-Q plot of **a** LEFP, **b** LAGR, **c** LREC, **d** LGI, **e** LNIC, **f** LEF, **g** LTO, **h** LPOP



unsustainable economic development have increased environmental degradation in South Asian countries (Sabir and Gorus 2019). Also, globalization can have a negative impact on the environment due to industrial production (Herrmann and Hauschild 2009).

Effects of energy efficiency on ecological footprint

As shown in Table 10, this factor negatively affects the ecological footprint in different quantiles. Increasing energy efficiency will lead to an improvement in energy consumption

Table 9 Country distribution in terms of ecological footprint

Quantile	Country
The lower 10th quantile group	Hungary, South Africa
The 10th and 25th quantile group	Czech Republic, Greece, Morocco, Peru
The 25th and 50th quantile group	Argentina, Colombia, Chile, Pakistan, Philippines
The 50th and 75th quantile group	Egypt, Mexico, Poland, South Korea, Thailand, Turkey
The 75th and 90th quantile group	Russia, Indonesia, Brazil
The upper 90th quantile group	China, India, Malaysia

relative to GDP, which will reduce the emission of pollutants and, consequently, a reduction in ecological footprint. The effect of this factor is greater in the 10th and 90th quantiles of countries than in other levels. These results were obtained by researchers such as Rosen (2002) who reported that increasing energy efficiency leads to reduced environmental pollution and increased competition. Monitoring environmentally friendly energy efficiency policies is very important for countries' economic development, and progress development based on energy efficiency should be the basis for countries' energy policies. Suppose governments balance economic growth with energy consumption. In that case, their energy efficiency will increase, and as environmental performance improves, countries will have to increase their economic activities and reach a good level of energy efficiency. Therefore, energy efficiency is important to ensure sustainable development to reduce CO_2 emissions and the effects of climate change in countries around the world. Levine and Kendall (2006) showed that efficiency and energy saving are the best and most cost-effective ways to solve the ecological crisis.

Effects of net income on ecological footprint

As shown in Table 10, net income is one of the most important and influential variables. The effect of this variable at all levels on the ecological footprint is positive and significant. The results show that the greatest effect of this variable is in the

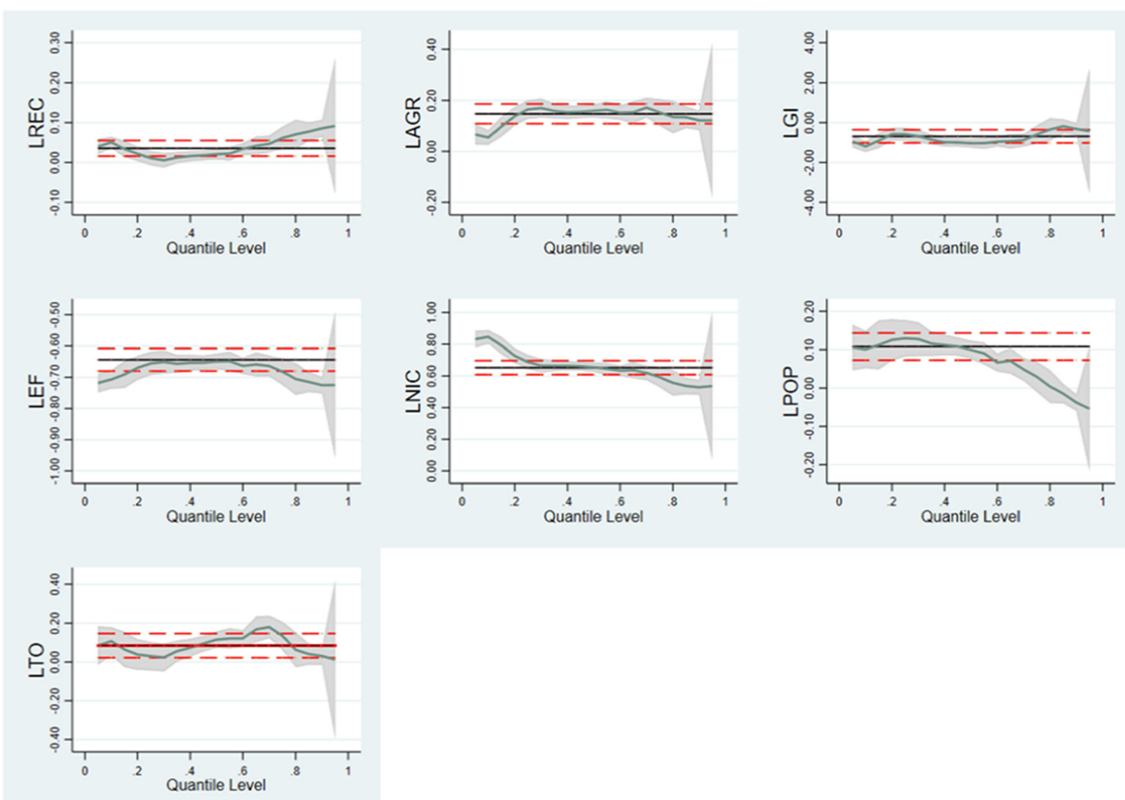


Fig. 3 Quantile estimate: Shaded areas represent 95% confidence band for the quantile regression estimates. The vertical axis indicates the elasticities of the explanatory variables. The red horizontal lines depict the conventional 95% confidence intervals for the OLS coefficient.

Table 10 Panel quantile regression model and linear fixed effects during the period 2002–2016

Variable	Quantiles					
	10th	25th	50th	75th	90th	OLS fixed
LREC	0.0504***	0.0109	0.0208**	0.0614***	0.0855***	0.0356***
LAGR	0.0548**	0.1647***	0.1591***	0.1531***	0.1216***	0.1454***
LGI	−1.1950***	−0.5813***	−1.0320***	−0.5952**	−0.3165*	−0.6887***
LEF	−0.7067***	−0.6554***	−0.6494***	−0.6818***	−0.7251***	−0.6439***
LNIC	0.8466***	0.6879***	0.6551***	0.5927***	0.5287***	0.6527***
LPOP	0.1006***	0.1297***	0.0996***	0.0296	−0.0375	0.1082***
LTO	0.1074***	0.0304	0.1154***	0.1354***	0.0309	0.0845***
Constant	6.7368***	4.0973***	6.5915***	6.7048***	8.2947***	5.2116***
Pseudo	0.8351	0.8455	0.8639	0.8837	0.9039	0.9807

***, **, and * indicate statistical significance at 1%, 5%, and 10%

lower quantiles, and as quantile levels increase, this coefficient decreases. It can be concluded that the impact of GDP per capita on environmental footprint varies at different income levels. NIC coefficients are significant and have a positive sign in other quantiles. This finding is similar to the results (e.g., Wang et al. 2015; Xu et al. 2017; Zhu et al. 2016). Besides, the effects of income on the ecological footprint are steadily declining from low-quantile to high-quantile countries (Fig. 3). This shows that economic growth will have less impact as the ecological footprint increases because as the economy grows, the contradiction between environmental pollution and economic growth gradually intensifies. As a result, rapid economic growth has led to a rapid increase in the ecological footprint. Although the ecological footprint has steadily increased in countries with high ecological footprints, its intensity has decreased. China, for example, is one of the largest countries in the world in terms of ecological impact. Changes in China's economic growth have led to a steady increase in per capita net income from $ 1536.19757 (fixed dollar 2010) in 2002 to $ 5157.712177 in 2016, but the growth rate of the ecological footprint has fallen from 0.11 in 2004 to −0.006 in 2016. As developing countries pursue economic growth, they leave their impact on the environment. Therefore, the analysis of panel data and revenue classification on the effect of exports on the environment is essential (Chen and Chang 2016).

Effects of population on ecological footprint

Population in the quantiles of 10th, 25th, and 50th countries has a positive and significant effect on ecological foot print, and this effect is greater in the 25th quantile than in other levels. It can be said that population growth causes more destruction of the environment. This result can be compared with the results of studies conducted by York et al. (2003) and Mostafa (2010). They reported that the ages 15 to 63 had the most effect on the ecological footprint and its positive correlation. Reports show that from 1961 to 2010, the demand for renewable energy resources and environmental services increased by approximately 14% (from 7.6 to 18.1 billion hectares worldwide) and the earth's bio-production level increased from 9.9 to 12 billion hectares worldwide (Galli et al. 2015). On a large scale, Li et al. (2019) conducted a study on the ecological footprint of 52 countries comprising 85% of the world population and 95% of the world economy and found that 35 countries are at risk in this regard. In South Africa which has rapid economic development and population expansion, the effects of human activities on the ecological footprint are increasing. In 2003, the World Wildlife Fund reported that for Africa, the ecological footprint is 1.1 hectares per capita, slightly less than the global footprint of 2.23 hectares per capita, 6.4 hectares per capita (Musibau et al. 2020). However, there is no reason for satisfaction in this regard in Africa because the data collected often ignore local problems. There seems to be little specific information about the environmental footprint of African cities (Clancy 2008).

Effects of trade openness on ecological footprint

Trade openness in the quantile of 10th, 50th, and 75th countries is positive and significant on the ecological footprint. This effect is greater in the quantile of 75th countries than in other levels. It can be concluded that there is a two-way causal relationship between the effects of trade openness, bio-capacity, human capital, and environmental degradation (Saleem and Shujah-ur-Rahman 2019). Also, trade openness and industrial development increase environmental damage, while political stability can reduce the damage to the environment in the long run (Al-Mulali and Ozturk 2015).

Based on the analysis of this study, it can be said that due to the trend of economic growth in emerging countries and issues such as globalization, consumption of renewable energy, and increasing agricultural production, we are witnessing the uncontrolled expansion of ecological footprint. Table 10 shows that the study of the effects of renewable energy consumption, increasing agricultural production, increasing net income, population, and trade openness has had positive and significant effects among emerging countries. On the one hand, a study of the effects of renewable energy consumption in these countries shows that it is a good indicator for its use in economic and environmental issues. This result by Destek and Ozsoy (2015); Dogan and Seker (2016) Approved. So, the use of renewable energy can have positive and balanced effects on the ecological footprint in the long run. On the other hand, the effects of agricultural production indices in countries (Czech Republic, Greece, Morocco, Peru), increase in net income in countries (Hungary, South Africa), the effects of population in countries (Czech Republic, Greece, Morocco, Peru; Argentina , Colombia, Chile, Pakistan, Philippines), and the effects of trade openness in countries (Czech Republic, Greece, Morocco, Peru, Argentina, Colombia, Chile, Pakistan, Philippines, Egypt, Mexico, Poland, South Korea, Thailand, Turkey) are positive and they are meaningful. This result is confirmed by researchers such as Ike et al. (2020) and Yilanci and Gorus (2020). The findings of this study also showed that the effects of globalization indicators in countries (Czech Republic, Greece, Morocco, Peru; Argentina, Colombia, Chile, Pakistan, Philippines) and energy efficiency in countries (Czech Republic, Greece, Morocco, Peru and Russia, Indonesia, Brazil) are negative and significant. So the results of this research by Kirikkaleli et al. (2020) and Shahbaz et al. (2015) were examined.

Conclusions

Using quantile regression, this study examines the effects of globalization, renewable energy consumption, and agricultural production on ecological footprint in emerging countries. The study framework for panel data was in 21 emerging countries from 2002 to 2016. Klein's method was used for multicollinearity test, and the absolute value of all correlation coefficients between variables was less than R^2 = 0.9807. Kao (1999) test was used to investigate the cointegration between ecological footprint (EFP) and its variables. The results of this test showed that ADF = −3.5645 (P value = 0.0002) and there is a long-term equilibrium relationship between ecological footprint (EFP) and the factors affecting it. As Fig. 1 shows, in emerging countries, the relationship between ecological footprint and agricultural production is positive (Fig. 1a); the relationship between globalization index and ecological footprint is negative (Fig. 1), and there is positive relationship between renewable energy consumption and ecological footprints (Fig. 1c). This study showed that as agricultural production, income, renewable energy consumption, population, and trade openness increase, environmental degradation increases. Population, renewable energy consumption, agriculture, and trade openness have the most negative effect on the environment in the selected sample. However, globalization reduces the ecological footprint and does not harm the environment. Globalization plays a key role in economic development by introducing foreign investment, new methods of production, and the use of technology. Globalization encourages countries to attract foreign investment and use new production methods, advanced industrial technology, and knowledge and skills. Renewable energy consumption has positively affected the ecological footprint, but this effect has been weak. Given that the consumption of non-renewable energy is one of the most important sources of environmental degradation, planning to develop renewable energy infrastructure for further use in the future can reduce environmental degradation.

Availability of data and materials No availability of data

Author contribution T.E.S., A.R., and E.K. drafted the manuscript. All authors read and approved the final manuscript

Declarations

Consent to participate This paper does not contain any studies with human participants or animals performed by any of the authors.

Consent for publication The authors affirm the informed consent for publication of the article.

Competing interests The authors declare no competing interests.

References

Abid M (2016) Impact of economic, financial, and institutional factors on CO2 emissions: evidence from sub-Saharan Africa economies. Util Policy 41:85–94. https://doi.org/10.1016/j.jup.2016.06.009

Al-Mulali U, Ozturk I (2015) The effect of energy consumption, urbanization, trade openness, industrial output, and the political stability on the environmental degradation in the MENA (Middle East and North African) region. Energy 84:382–389. https://doi.org/10.1016/j.energy.2015.03.004

Andrews DW, Phillips PC (1987) Best median-unbiased estimation in linear regression with bounded asymmetric loss functions. J Am Stat Assoc 82:886–893 http://cowles.yale.edu/sites/default/files/files/pub/d07/d0786

Antweiler W, Copeland BR, Taylor MS (2001) Is free trade good for the environment? Am Econ Rev 91:877–908. https://doi.org/10.1257/aer.91.4.877

Apergis N, Payne JE (2009) CO2 emissions, energy usage, and output in Central America. Energy Policy 37:3282–3286 http://www.sciencedirect.com/science/article/pii/S0301-4215(09)00221-3

Asongu SA, Odhiambo NM (2019a) Environmental degradation and inclusive human development in sub-Saharan Africa. Sustain Dev 27:25–34. https://doi.org/10.1002/sd.1858

Asongu SA, Odhiambo NM (2019b) Basic formal education quality, information technology, and inclusive human development in sub-Saharan Africa. Sustain Dev 27:419–428. https://doi.org/10.2139/ssrn.3278442

Balducci F, Impedovo D, Pirlo G (2018) Machine learning applications on agricultural datasets for smart farm enhancement. Machines 6:38. https://doi.org/10.3390/machines6030038

Balogh JM, Jámbor A (2020) The environmental impacts of agricultural trade: a systematic literature review. Sustainability 12:1152. https://doi.org/10.3390/su12031152

Beyer RM, Manica A, Rademacher TT (2018) Relocating agriculture could drastically reduce humanity's ecological footprint. BioRxiv 488841. https://doi.org/10.1101/488841

Bilgili F, Koçak E, Bulut Ü (2016) The dynamic impact of renewable energy consumption on CO2 emissions: a revisited environmental Kuznets curve approach. Renew Sust Energ Rev 54:838–845. https://doi.org/10.1016/j.rser.2015.10.080

Bouhajeb M, Mefteh H, Ben Ammar R (2018) Higher education and economic growth: the importance of innovation. Atlantic RevEconomics (ARoEc) 1

Chen S-T, Chang H-T (2016) Factors that affect the ecological footprint depending on the different income levels. AIMS Energy 4:557–573. https://doi.org/10.3934/energy.2016.4.557

Clancy JS (2008) Urban ecological footprints in Africa. Afr J Ecol 46:463–470. https://doi.org/10.1111/j.1365-2028.2008.01041.x

Cole MA (2006) Does trade liberalization increase national energy use? Econ Lett 92:108–112

Curutchet G, Grinberg S, Gutiérrez RA (2012) Degradación ambiental y periferia urbana: un estudio transdiciplinario sobre la contaminación en la región metropolitana de Buenos Aires. Ambiente & sociedade 15:173–194. https://doi.org/10.1590/S1414-753X2012000200010

Daigle C, Vasseur L (2019) Is it time to shift our environmental thinking? A perspective on barriers and opportunities to change. Sustainability 11:5010. https://doi.org/10.3390/su11185010

Danish (2019) Moving toward sustainable development: the relationship between water productivity, natural resource rent, international trade, and carbon dioxide emissions. Sustain Dev 28:540–549. https://doi.org/10.1002/sd.2007

Dedeoğlu D, Kaya H (2013) Energy use, exports, imports and GDP: new evidence from the OECD countries. Energy Policy 57:469–476. https://doi.org/10.1016/j.enpol.2013.02.016

Destek MA, Ozsoy FN (2015) Relationships between economic growth, energy consumption, globalization, urbanization and environmental degradation in Turkey. International Journal of Energy and Statistics 3:1550017. https://doi.org/10.1142/S2335680415500179

Dogan E, Seker F (2016) The influence of real output, renewable and non-renewable energy, trade and financial development on carbon emissions in the top renewable energy countries. Renew Sust Energ Rev 60:1074–1085. https://doi.org/10.1016/j.rser.2016.02.006

Dollar D, Kraay A (2004) Trade, growth, and poverty. Econ J 114:F22–F49. https://doi.org/10.1111/j.0013-0133.2004.00186.x

Dreher A, Gaston N, Martens P (2008): Measuring globalisation. Gauging its consequences Springer, New York.

Enfedaque ND, Martínez JMD (2014) El impacto económico de los desastres naturales. eXtoikos:99–101

Etokakpan MU, Adedoyin F, Vedat Y, Bekun FV (2020) Does globalization in Turkey induce increased energy consumption: insights into its environmental pros and cons. Environ Sci Pollut Res 27:26125–26140. https://doi.org/10.1007/s11356-020-08714-3

Galli A, Lin D, Wackernagel M, Gressot M, Winkler S (2015): Humanity's growing ecological footprint: sustainable development implications. Global Footprint Network.

Ge X, Zhou Z, Zhou Y, Ye X, Liu S (2018) A spatial panel data analysis of economic growth, urbanization, and NOx emissions in China. Int J Environ Res Public Health 15:725. https://doi.org/10.3390/ijerph15040725

Hasanov FJ, Khan Z, Hussain M, Tufail M (2021) Theoretical framework for the carbon emissions effects of technological progress and renewable energy consumption. Sustain Dev. https://doi.org/10.1002/sd.2175

Herrmann IT, Hauschild MZ (2009) Effects of globalisation on carbon footprints of products. CIRP Ann 58:13–16. https://doi.org/10.1016/j.cirp.2009.03.078

Hussain HI, Haseeb M, Tvaronavičienė M, Mihardjo LW, Jermsittiparsert K (2020) The causal connection of natural resources and globalization with energy consumption in top Asian countries: evidence from a nonparametric causality-in-quantile approach. Energies 13:2273. https://doi.org/10.3390/en13092273

Hynes W, Wang S (2012) Green growth and developing countries: a summary for policymakers. Document DCD/DAC 2012:27

Ibrahiem DM, Hanafy SA (2020) Dynamic linkages amongst ecological footprints, fossil fuel energy consumption and globalization: an empirical analysis. Management of Environmental Quality: An Int J 31:1549–1568. https://doi.org/10.1108/MEQ-02-2020-0029

Ike GN, Usman O, Alola AA, Sarkodie SA (2020) Environmental quality effects of income, energy prices and trade: the role of renewable energy consumption in G-7 countries. Sci Total Environ 137813. https://doi.org/10.1016/j.scitotenv.2020.137813

Irfan ZB, Faisal AS (2021) A cross-national analysis of the factors impacting the coastal ecological footprint. Water Productivity Journal 1:51–64

Kao C (1999) Spurious regression and residual-based tests for cointegration in panel data. Journal of econometrics 90:1–44

Kattumuri R (2018) Sustaining natural resources in a changing environment: evidence, policy and impact. Taylor & Francis 13:1–16. https://doi.org/10.1080/21582041.2017.1418903

Kirikkaleli D, Adebayo TS, Khan Z, Ali S (2020) Does globalization matter for ecological footprint in Turkey? Evidence from dual adjustment approach Environ Sci Pollut Res 28:1–9. https://doi.org/10.1007/s11356-020-11654-7

Klein LR, Marquez JR (1985): Economic theory and econometrics. Univ of Pennsylvania Pr

Koenker R, Bassett G Jr (1978) Regression quantiles. Econometrica: J Econometric Soc 46:33–50. https://doi.org/10.2307/1913643

Koenker R, Hallock KF (2001) Quantile regression. J Econ Perspect 15:143–156 https://doi.org/10.1257/jep.15.4.143

Koenker R, Xiao Z (2002) Inference on the quantile regression process. Econometrica 70:1583–1612. https://doi.org/10.1111/1468-0262.00342

Kozlova M, Collan M, Luukka P (2015) Renewable energy in emerging economies: shortly analyzing the Russian incentive mechanisms for renewable energy investments. Proceed Int Res Conference GSOM Emerging Markets Conference: Business and Government Perspectives 2016:1–7. https://doi.org/10.1155/2016/7836784

Leal PH, Marques AC, Shahbaz M (2020) The role of globalisation, de jure and de facto, on environmental performance: evidence from developing and developed countries. Environ Dev Sustain:1–20. https://doi.org/10.1007/s10668-020-00923-7

Levine S, Kendall K (2006) Energy efficiency and conservation: opportunities, obstacles, and experiences. Vt J Envtl L 8:101. https://doi.org/10.1016/S0304-4076(01)00098-7

Li J-X, Chen Y-N, Xu C-C, Li Z (2019) Evaluation and analysis of ecological security in arid areas of Central Asia based on the emergy ecological footprint (EEF) model. J Clean Prod 235:664–677. https://doi.org/10.1016/j.jclepro.2019.07.005

Lopes GP Jr (2015) The Sino-Brazilian principles in a Latin American and BRICS context: the case for comparative public budgeting legal research. Wis Int l LJ 33:1

Lustigová L, Kuskova P (2006) Ecological footprint in the organic farming system. ZEMEDELSKA EKONOMIKA-PRAHA 52:503

Ma Y, Chen Z, Shinwari R, Khan Z (2021) Financialization, globalization, and Dutch disease: is Dutch disease exist for resources rich countries? Res Policy 72:102048

Maddala GS, Wu S (1999) A comparative study of unit root tests with panel data and a new simple test. Oxf Bull Econ Stat 61:631–652. https://doi.org/10.1111/1468-0084.0610s1631

Majeed MT (2018) Information and communication technology (ICT) and environmental sustainability in developed and developing countries. Pak J Commer Soc Sci 12:758–783. https://doi.org/10.1007/s11356-020-09704-1

Marasinghe D (2014): Quantile regression for climate data.

Martínez E, Sanz F, Pellegrini S, Jiménez E, Blanco J (2009) Life cycle assessment of a multi-megawatt wind turbine. Renew Energy 34: 667–673. https://doi.org/10.1016/j.renene.2008.05.020

Meraya AM, Dwibedi N, Tan X, Innes K, Mitra S, Sambamoorthi U (2018) The dynamic relationships between economic status and health measures among working-age adults in the United States. Health Econ 27:1160–1174. https://doi.org/10.1002/hec.3664

Mesino Rivero L (2009) La globalización económica y sus implicaciones socio-culturales en América Latina. Revista de ciencias sociales 15: 126–138. https://doi.org/10.1590/S1413-24782011000200006

Mostafa MM (2010) A Bayesian approach to analyzing the ecological footprint of 140 nations. Ecol Indic 10:808–817. https://doi.org/10.1016/j.ecolind.2010.01.002

Musibau HO, Nepal R, Vespignani J, Yanotti M (2020): The moderating role of green energy and energy-innovation in environmental Kuznets: insights from quantile-quantile analysis. Globalization and Monetary Policy Institute Working Paper. 10.24149/gwp385

Nathaniel SP (2020): Ecological footprint, energy use, trade, and urbanization linkage in Indonesia. GeoJournal, 1-14. 1007/s10708-020-10175-7

Owusu PA, Asumadu-Sarkodie S (2016) A review of renewable energy sources, sustainability issues and climate change mitigation. Cogent Eng 3:1167990

Paltasingh KR, Goyari P (2018) Statistical modeling of crop-weather relationship in India: a survey on evolutionary trend of methodologies. Asian J Agric Dev 15:43–60. https://doi.org/10.22004/ag.econ.275688

Pao H-T, Tsai C-M (2010) CO2 emissions, energy consumption and economic growth in BRIC countries. Energy Policy 38:7850–7860. https://doi.org/10.1016/j.enpol.2010.08.045

Pehnt M (2006) Dynamic life cycle assessment (LCA) of renewable energy technologies. Renew Energy 31:55–71

Ren H, Zhou W, Ki N, Gao W, Wu Q (2010) Multi-objective optimization for the operation of distributed energy systems considering economic and environmental aspects. Appl Energy 87:3642–3651

Robert J, Castañeda K (2014): Las ciencias sociales frente a las problemáticas medio-ambientales: apuntes de un primer encuentro. Lima, 12 de noviembre de 2014. Bulletin de l'Institut français d'études andines, 668-674. https://doi.org/10.1504/IJGEI.2002.000929, 17, 23

Rosen MA (2002) Energy efficiency and sustainable development. Int J Global Energy Issues 17:23–34. https://doi.org/10.1504/IJGEI.2002.000929

Sabir S, Gorus MS (2019) The impact of globalization on ecological footprint: empirical evidence from the South Asian countries. Environmental Science and Pollution Research 26:33387—33398

Saleem N, Shujah-ur-Rahman JZ (2019) The impact of human capital and biocapacity on environment: environmental quality measure-through ecological footprint and greenhouse gases. J Pollut Eff Cont 7(237):10.35248/2375–4397.19.7.237

Sarkodie SA, Adams S (2018) Renewable energy, nuclear energy, and environmental pollution: accounting for political institutional quality in South Africa. Sci Total Environ 643:1590–1601. https://doi.org/10.1016/j.scitotenv.2018.06.320

Sarkodie SA, Strezov V (2019) Effect of foreign direct investments, economic development and energy consumption on greenhouse gas emissions in developing countries. Sci Total Environ 646:862–871. https://doi.org/10.1016/j.scitotenv.2018.07.365

Saud S, Chen S, Haseeb A (2020) The role of financial development and globalization in the environment: accounting ecological footprint indicators for selected one-belt-one-road initiative countries. J Clean Prod 250:119518. https://doi.org/10.1016/j.jclepro.2019.119518

Shahbaz M, Sbia R, Hamdi H, Ozturk I (2014) Economic growth, electricity consumption, urbanization and environmental degradation relationship in United Arab Emirates. Ecol Indic 45:622–631. https://doi.org/10.1016/j.ecolind.2014.05.022

Shahbaz M, Mallick H, Mahalik MK, Loganathan N (2015) Does globalization impede environmental quality in India? Ecol Indic 52:379–393. https://doi.org/10.1016/j.ecolind.2014.12.025

Shaw TM, Cooper AF, Chin GT (2009) Emerging powers and Africa: implications for/from global governance? Politikon 36:27–44. https://doi.org/10.1080/02589340903155385

Steers RJ, Funk JL, Allen EB (2011) Can resource-use traits predict native vs. exotic plant success in carbon amended soils? Ecol Appl 21:1211–1224. https://doi.org/10.1890/09-2345.1

Stern DI (2007) The effect of NAFTA on energy and environmental efficiency in Mexico. Policy Stud J 35:291–322. https://doi.org/10.1111/j.1541-0072.2007.00221.x

Usman O, Akadiri SS, Adeshola I (2020a) Role of renewable energy and globalization on ecological footprint in the USA: implications for environmental sustainability. Environ Sci Pollut Res 27:30681–30693. https://doi.org/10.1007/s11356-020-09170-9

Usman O, Akadiri SS, Adeshola I (2020b) Role of renewable energy and globalization on ecological footprint in the USA: implications for environmental sustainability. Environ Sci Pollut Res 27:1–13. https://doi.org/10.1007/s11356-020-09170-9

Victoria Flores M (2016) Globalization as a political, economic and social phenomenon. ORBIS 12:26–41

Wang S, Fang C, Wang Y, Huang Y, Ma H (2015) Quantifying the relationship between urban development intensity and carbon dioxide emissions using a panel data analysis. Ecol Indic 49:121–131. https://doi.org/10.3390/ijerph17103416

Wang Z, Rasool Y, Asghar MM, Wang B (2019) Dynamic linkages among CO2 emissions, human development, financial development, and globalization: empirical evidence based on PMG long-run panel estimation. Environ Sci Pollut Res 26:36248–36263. https://doi.org/10.1007/s11356-019-06556-2

WTO (2018) World Trade Statistical Rev:2017

Xu B, Lin B (2018) What cause large regional differences in PM2.5 pollutions in China? Evidence from quantile regression model. J Clean Prod 174:447–461. https://doi.org/10.1016/j.jclepro.2017.11.008

Xu R, Xu L, Xu B (2017) Assessing CO2 emissions in China's iron and steel industry: evidence from quantile regression approach. J Clean Prod 152:259–270. https://doi.org/10.1016/j.rser.2017.01.009

Yilanci V, Gorus MS (2020) Does economic globalization have predictive power for ecological footprint in MENA counties? A panel causality test with a Fourier function. Environ Sci Pollut Res 27: 40552–40562. https://doi.org/10.1007/s11356-020-10092-9

York R, Rosa EA, Dietz T (2003) Footprints on the earth: the environmental consequences of modernity. Am Sociol Rev 68:279–300. https://doi.org/10.2307/1519769

Zafar MW, Zaidi SAH, Khan NR, Mirza FM, Hou F, Kirmani SAA (2019) The impact of natural resources, human capital, and foreign direct investment on the ecological footprint: the case of the United States. Res Policy 63:101428. https://doi.org/10.1016/j.resourpol.2019.101428

Zhu H, Duan L, Guo Y, Yu K (2016) The effects of FDI, economic growth and energy consumption on carbon emissions in ASEAN-5: evidence from panel quantile regression. Econ Model 58:237–248. https://doi.org/10.1016/j.econmod.2016.05.003