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RESEARCH ARTICLE

Does foreign direct investments impair the ecological footprint? New evidence from the panel quantile regression

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Abstract

This study examines the impact of foreign direct investments on ecological footprint along with other explanatory variables of 92 countries from the year 2001 to 2016. Here, we applied the panel quantile regression model to meet the purpose of our study as it considers unobserved country heterogeneity, unlike other statistical methods. The study reveals that foreign direct investment has a positive relationship with the ecological footprint in each quantile except one, which proves the constancy of the pollution haven hypothesis. Moreover, we also tried to detect the impact of economic growth, manufacturing value-added, the percentage of world exports, and institutional quality on the ecological footprint in this study. The findings of this study also reveal that economic growth and manufacturing value-added are negatively associated with the ecological footprint. With respect to the percentage of world exports and institutional quality, we found a positive relationship with the ecological footprint. From the result of our study, different policy implications have been proposed for host countries and foreign investors on improving the economy through foreign direct investment with minimal ecological footprint.

Keywords FDI · Ecological footprints · Panel quantile regression · Pollution haven hypothesis

Introduction

In the contemporary world, foreign direct investment (FDI) is a frequently quoted economic instrument for the countries to confront the severe economic challenges (Charfeddine and Mrabet 2017). Almost every country of the globe tries to persuade a vast amount of foreign capital to their country for the extension of the economy (Solarin and Al-Mulali 2018). Countries that do not have enough capital, manufacturing skills deliver the highest effort to hold foreign companies for investing in their businesses to achieve sustainable economic development (Wang and Chen 2014). Likewise, Deng and Xu (2015) stated that foreign direct investment has a positive influence on the host nation's environment by benefiting the country with scale and technique effects. However, Liu and Wang (2017) argued that countries have to pay a high cost of environmental quality for the inflow of foreign direct investment and development, as the natural environment is used almost in every form of manufacture. Countries invite devastating damage with FDI to their environment as it is evident that affluent countries invest in other countries to produce those products which are not environmentally friendly or if the manufacturing system of those products harms their countries' environment (Destek and Okumus 2019; Doytch 2016). So, there is an unremitting debate about the effect of foreign direct investment on the environment. Consequently, ecological degradation has turned out substantial attention for academic and practical life. Due to this reason, in the last two decades, researchers emphasized environmental issues for their study purpose and to provide some measures that can be helpful for policymakers (Khan et al. 2019; Udemba 2020c).

There is a comprehensive impact of the ecological footprint as it dictates the civilization's influence on the ecosystem.

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People all around the world mercilessly use the resources from the environment by ignoring the demolishing consequence of this type of behavior toward the environment (Wackernagel and Rees 1996). Ecological footprint has been used in our study as it highlights the vivid unsustainability of current activities besides the disparity in resource consumption among the nations. The ecological footprint, as a measuring tool of a population's utilization of renewable resources, can be linked to biocapacity (Udemba 2020a).

It is identified that countries exhibit a diversified amount of ecological footprint, and affluent countries are recently taking measures for controlling their footprint (Solarin and Al-Mulali 2018), whereas most of the developing or underdeveloped countries are not conscious enough to save their environment (Gabriel Aremo and Ayobami Ojeyinka 2018). They frequently use the resources of nature; their manufacturing system is not suitable for the environment, or even they use their non-renewable products unconsciously (Kissinger and Rees 2010; Wackernagel et al. 2006). In this context, Aremo and Ojeyinka (2018) have cautioned from their forecast about the financial damages in the next decades from environmental degradation, which seems to be greater than the last two world wars.

However, foreign direct investment has become an essential device of sustainable economic growth in the last decades for many countries, especially in developing and underdeveloped countries (Wang and Zhao 2015). It plays an emergent role in building financial and societal influences of nations all around the earth, particularly in less developed countries (Huynh and Hoang 2019; Saini and Sighania 2019). In this context, Bilgili et al. (2020) and Zafar et al. (2019) have said that FDI is a twofold operator in impacting the ecological footprint as it brings the economic growth under its positive effect. Moreover, FDI stimulates innovation and technological advancement and imports clean technological inputs in the production process for the host countries (Cumming and Von Cramon-Taubadel 2018; Meng and Yu 2012). However, a number of studies (Bildirici and Gokmenoglu 2020; Danish and Wang 2018; Jorgenson 2006; Sarkodie and Strezov 2019) argued that FDI stimulates the utilization of heavy-duty and extreme energy exploiting machines which consequently erode the environmental quality of the host country. The massive amount of FDI inflows are toward pollution-intensive industries since developed countries tend to invest in foreign countries while the industry is unfit for their environment (Abdo et al. 2020). In light of the above discussion, we can acknowledge that, till now, the relationship between foreign direct investment and ecological footprint is empirically inconclusive.

This study aims to ascertain the determinants of ecological footprint that have an essential role in visualizing the variation of ecological footprint due to the shifts in different variables along with foreign direct investment under the control of external factors. This paper attempts to contribute to the empirical study by examining the impact of foreign direct investment on the ecological footprint in three areas. Firstly, we have considered the most recent value for ecological footprint with the highest possible countries, 92 in number, to get a global viewpoint. Studies on foreign direct investment and ecological footprint with focusing on global perspectives are generally scarce. Our paper fills this gap and intensifies the literature in this arena. Secondly, panel quantile regression has been used in our study for empirical analysis to consider unobserved country heterogeneity. Finally, to interpret our empirical findings, we have used a framework containing four hypotheses, i.e., pollution haven hypothesis, pollution halo hypothesis, EKC hypothesis, and race to the bottom hypothesis. Our findings incline to recommend that administration and legislation authorities should identify and take necessary measures to deal with the impact of foreign direct investment on ecological footprint. Other than supporting a large portion of established literature, our study evidenced a statistical environmental effect of foreign direct investment in countries' ecological footprint. Along with FDI, the percentage of world export and institutional quality were found to have a positive relationship with the ecological footprint. Our results also reveal that the relation of ecological footprint is negative with economic growth and manufacturing value-added.

The rest of the study is structured as follows: the "Literature review and theoretical framework" section deals with literature review and theoretical framework, the "Data and methodology" section explains data source and methodology, the "Empirical results and discussions" section illustrates empirical results and discussion, and lastly, the "Policy implications and concluding remarks" section provides policy implications and concluding remarks.

Literature review and theoretical framework

Kissinger and Rees (2010) illustrated ecological footprint as the measure which captures the biophysical burden imposed by populations and industrial processes on the supportive ecosystems. There is a pair of motives to pick ecological footprint as the standard of environmental quality in our paper. Firstly, the ecological footprint implies the bearing receptivity of the globe (Kissinger and Rees 2010). Henceforth, it is an elevated assessing maneuver in comparison with contaminants for the sustainability of the environmental process (Ali et al. 2020). This biophysical burden is quantified by adding the energy, the consumption of material, the wastage creation, and the environmental efficiency for estimating the entire biological land requisite to support economic activities (Rees 2017; Rees and Wackernagel 1996). Biocapacity is the terminology that can define how a country is performing in terms of ecological footprint (McKinney 2014; Network 2019). The current scenario is more than three-fourths of the world inhabitants are living in a country with an ecological deficit (Rudolph and Figge 2017). It is an alarming issue for human sustainability (Lynch et al. 2019).

In current ages, the problems related to environmental change and global warming have raised the significance of examining the association between foreign direct investment and ecological degeneration (York 2007). Over the previous decades, a significant number of researchers had inspected the nexus among economic growth and foreign direct investment with the ecological footprint. The first set of people analyzed the impact of FDI on ecological footprint. A number of studies such as Mahmood (2012), Bildirici and Gokmenoglu (2020), Saini and Sighania (2019), Acar and Aşıcı (2017) found that the relation between ecological footprint and foreign direct investment is positive. Liu and Kim (2018) stated in their work that the ecological footprint has a biodirectional relationship with FDI, and ecological footprint exposes vigorous effect by FDI. Jorgenson (2006) argued that FDI in manufacturing positively affects the ecological footprint in developing and underdeveloped nations, while the impact is insignificant in developed nations. Sho Kawashima (2013) hypothesized that, when the level of FDI is higher, the carbon emanation level is also higher, and the ecological consumption level is also greater in the developing countries. However, researchers like Bilgili et al. (2020), Zafar et al. (2019), and Ahmed et al. (2020b) found a negative relation between FDI and ecological footprint, which states that foreign investment helps to reduce environmental degradation.

The second set of researches had analyzed the impact of economic growth on ecological footprint. A number of studies such as Acar and Aşıcı (2017), Van de Vliert and Vlek (2015), Sun et al. (2019), Sethi et al. (2020), Baz et al. (2020), Dai et al. (2010), Khan et al. (2019), He et al. (2019), Nathaniel et al. (2019, 2020a, b), Saini (2019), and Hayden and Shandra (2009) showed the positive relation between ecological footprint and economic growth. Though economic growth increases the development of society, it evacuates and contaminates nature massively (Ahmed et al. 2020a; Köksal et al. 2020; Mikkelson 2019). Whereas Jorgenson (2010) stated that the pattern of the global economy permits the developed nations to externalize their consumption based on ecological outlays, which generally directs to rise the ecological footprint in undeveloped and developing countries. In contrast, Collins and Fairchild (2007), Mukhopadhyay and Chakraborty (2006), Omoke et al. (2020), Ahmed et al. (2019), Nathaniel et al. (2020a, b), and Saud et al. (2020) showed a negative relation between ecological footprint and economic growth. Nevertheless, Danish et al. (2019), Ozcan et al. (2018), Wang and Dong (2019), and Shujah-ur-Rahman et al. (2019) labeled that economic growth and biocapacity have a significant and positive effect on ecological footprint. Infrastructure arrangements needed for FDI consists of railroads, highways, and ports of the sea need a vast area of ground, aquatic, and air resources, which are the reasons for escalating ecological footprint (Baloch et al. 2019). The accessible resources are adequate to absorb pollution and to improve the ecological footprint of the countries. According to Uddin et al. (2016), economic growth might be companionable with ecological betterment if appropriate policies are being occupied.

Apparently, in both sets, some researchers showed the relationship of economic growth or FDI with the ecological footprint neither positive nor negative (Arshad et al. 2020; Axelsson et al. 2012; Doytch 2016; Rai et al. 2019). Barrett et al. (2005) endorsed that adopting the ecological footprint to monitor the environment suggests that EF should be recomputed after a specific interval. Rai et al. (2019) and Kick and McKinney (2014) found that natural and economic forces are remarkably playing roles suggesting a need to attend to multidisciplinary dynamics.

Furthermore, Sutton et al. (2012), Lee and Brahmasrene (2013), Wang et al. (2019), and Khan et al. (2019) discovered both positive and negative relationships of ecological footprint with foreign direct investment and economic growth. The relationship of economic growth and foreign investment with environmental degradation had been found positive in the short-term but negative in the long-term as referred to EKC theory (Aung et al. 2017; Isik et al. 2019; Ramakrishna et al. 2020; Yasin et al. 2020). Solarin and Al-Mulali (2018) remarked that foreign direct investments enhance contamination in the developing nations while they alleviate contamination in the developed nations.

So, it could be alleged that the matter is still inconclusive and needs further study. For mitigating the dilemma, in this paper, we analyze whether foreign direct investment and economic growth have any impact on ecological footprint or not. To analyze our findings, we are using the following four hypotheses regarding the environment as the framework of our study.

Pollution haven hypothesis

Pollution haven hypothesis (PHH) advocates countries that are having a fragile environmental policy drag pollution-intensive industries in the countries, which results in greater FDI inflows to these sectors and a higher pollution level (Anh 2017). This hypothesis also infers foreign investment upsurges contamination as the conglomerate companies tend to migrate from advanced economies to emerging countries and prefer to entice more polluting industries owing to their comparatively relaxed conservational protocols for the sake of economic growth (Huynh and Hoang 2019). The instinct is that a constriction on pollution regulation reduces intercontinental competitiveness in manufacturing sectors, which are pollution-intensive in their manufacture. To attract further foreign investment and get comparative advantages in provincial economic expansion, local administration tends to make slack environmental standards (Liu and Kim 2018).

Pollution halo hypothesis

Pollution halo hypothesis claims foreign investment has a positive impact on sustainable progress by demonstration effect and employment turnover apparatus along with rivalry effect among diversified business organizations and countries (Liu and Kim 2018). Ecological actions of overseas organizations compare with local counterparts, rather than industry position, are emphasized on pollution halo hypothesis. Foreign investment is theorized to dispense optimistic ecological residual effects, as foreign investment lessens air pollution. Meanwhile, multinational corporations (MNCs) are prospective to recover ecological degradation in a developing host state by shifting their green technologies besides restored conservational reputational schemes (FakhrEldin and Elsawy 2018). FDI inflows could be the medium that proposes cleaner technology supporting the pollution halo hypothesis (Doytch 2016).

Environmental Kuznets curve

The environment and income nexus, which is generally denoted as the environmental Kuznets curve (EKC) hypothesis, deals with the correlation of environmental pollution with economic growth (Dogan et al. 2019). If ecological footprint has been used as an indication of pollution and plotted against any pointer of economic growth like income or GDP, an inverted *U*-shaped curve would be formed (He et al. 2019). The hypothesis suggests that environmental degradation initially rises along with the increase of economic growth until economic growth reaches to optimal level then it commences to decay, and a cleaner environment might appear in states having a larger amount of wealth, specifically those with higher trade volumes (Bagliani and Martini 2012; Destek and Sarkodie 2019; Gbatu et al. 2019; Uddin et al. 2016). In the beginning, economic growth and environmental degradation both are positively related. After a certain level, the affiliation among per capita income and polluting elements hypothesizes EKC with the inverted *U*-shape trend (Ahmad et al. 2019; A. Khan et al. 2019). Similarly, ecological footprint (EF) can be reduced through economic development while having an inverted *U*-shaped curve (Al-Mulali et al. 2015; Charfeddine and Mrabet 2017). This inverted *U* shape consists with both pollution halo hypothesis and pollution haven hypothesis in different phases of the curve (Fig. 1).

Race to the bottom hypothesis

Race to the bottom hypothesis evolves when countries drag industries for economic growth with less stringent and less costly regulations to compete in the global market (Potoski 2001). In the race to the bottom, governments lessen their environmental criterion to avoid losing businesses to countries with more "business-friendly" regulations (Jinyoung and Wilson 1997; Mcnally 1998). Developed country governments, in a "race to the bottom," hypothesis deregulates the rigidity of existing environmental policy, which can create a process of "ecological dumping" (Prakash and Potoski 2006; Sheldon 2006). The race to the bottom argument presumes that the regulatory behavior of a state is dependent on the regulatory decisions of other states. Though national decision-making procedures are complex and varied from country to country, most countries are supporting trade openness instead of the environmental protection for their economic growth (Konisky 2008).

Data and methodology

We collected the data of our variables from the year 2001 to the year 2016 of 92 countries from the database of theglobaleconomy.com by using random sampling method. While reviewing this issue, we explored that most of the prior studies had confined into a regional or continental context. We worked on a global context to include the maximum number of countries from all the continents. However, we have to limit countries as there is data unavailability for many countries in different variables to run panel quantile regression. Meanwhile, the latest data for the ecological footprint variable of corresponding countries is collected from the Global Footprint Network database. For the institutional quality index, we reached to the data server of the World Bank. A list of the countries of our study is available in the "Appendix Table 5" section.

Panel quantile regression model

Prior works applied several methods for inspecting the influence of foreign direct investment and economic growth on environmental issues. Some of the models were used in this issue could be mentioned, i.e., ordinary least square method, auto-regressive distributed lag model, and dynamic simultaneous equation models. Though, in these mentioned models, unobserved heterogeneity is an ignored issue (H. Khan et al. 2020; Li et al. 2019). Therefore, panel quantile regression method has been applied in this study to evaluate the model by envisaging both the distributional heterogeneity and the unobserved individual heterogeneity. The main benefit of this method is the ability to detect the heterogeneous effects of all the regressors on the ecological footprint in different quantiles. The association between the dependent variable quantiles and the regressors also gives a huge amount of indication if compared with other assessment methods. Thus, it seems more appropriate to apply the panel quantile regression model to explore the impact of various variables on

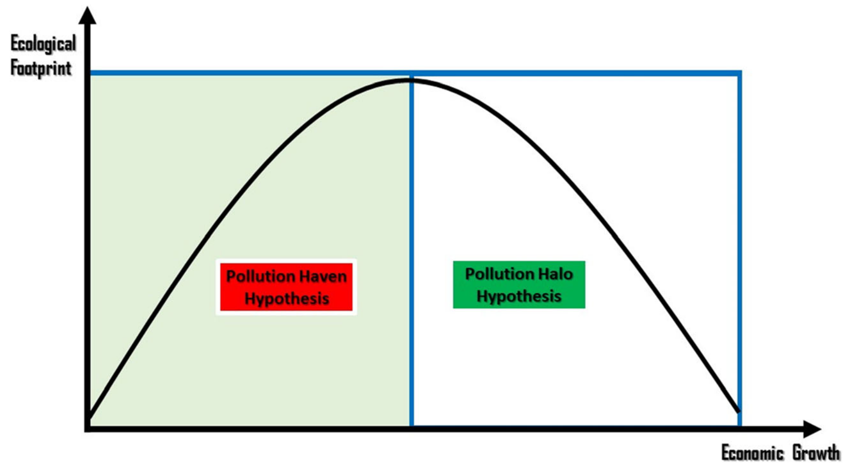

Fig. 1 Inverted-U relationship between FDI and EF (Balsalobre-Lorente et al. 2019)

the ecological footprint. Quantile regression was initially induced by Koenker and Bassett (1978) in the seminal paper as an extension of the classical ordinary least square (OLS) method. The overview of the conditional of quintile y_i to X_i is the following;

$$Q_{y_i}(\tau \mid x_i) = X_i{}^{\tau}\beta_{\tau} \tag{1}$$

Panel quantile regression examines how the provisional quantiles of any dependent variable are impacted by the quantiles of the independent variables. Mainly, panel quantile regression is functioned to scrutinize the result of a regressor on various quantiles of the dependent variable (Zhu et al. 2016). In our paper, we have employed PQR with fixed effects to examine the conditional heterogeneity and unobserved country heterogeneity. There are some other researchers like Koenker (2004), Lamarche (2010), and Galvao (2011) who had applied PQR to an analysis by considering econometric theory. The fixed effect of the PQR model can be demonstrated as following;

$$Q_{y_i}(\tau|\alpha_i x_i) = \alpha_i + X_{it}^{\tau}\beta(\tau_k) \tag{2}$$

PQR with fixed effect has a complication with the inclusion of a substantial amount of fixed effects (α_i) is concerning the incidental parameters problem (Koenker and Bassett 1978; Lancaster 2000; Neyman and Scott 1948). There will be inconsistency when the amount of observations for every cross-sectional unit is static, but the number of individuals goes to infinity (Canay 2011; Hernández 2020). Koenker (2004) had resolved a consonant methodology where he disposed of unobserved fixed effects as a parameter to be assessed generally with the covariate effects for several quantiles. The identical feature of this parameter is the commencement of a penalty term to minimize the computational problem of estimation; the parameter estimate could be computed as follows:

$$\min_{(\alpha,\beta)} \sum_{k=1}^{K}\sum_{t=1}^{T}\sum_{i=1}^{N} w_k P_{tk}\left(y_{it} - \alpha_i - X_{it}^{\tau}\beta(\tau_k)\right) + \lambda\sum_{i}^{N}|\alpha_i| \tag{3}$$

In Eq. (3), i represents the country (N) index, T presents the number of observations for countries, the index for quantiles is denoted by K, the matrix of the independent variables is given by X, and the quantile loss function is plotted by P_{tk}. Additionally, w_k is the relative weight for kth quantile. We devoted equally weighted quantiles w_k = 1/k. Moreover, the tuning parameter is represented by λ, which is used to lessen the individual effects to zero and elevate the estimate of β. When λ moves to zero, the penalty term disappears, and the usual fixed effects estimator can be obtained. However, if λ moves to infinity, an estimate of the model without individual effect can be obtained. In our study, we fixed λ is equal to 1.

This study observes the association between ecological footprint (EF) and other relational variables through the following model;

$$\begin{aligned} Q_{y_{it}}(\tau|\alpha_i,\xi_t,\chi_{it}) &= \alpha_i + \xi_t + \beta_{1\tau}FDI_{it} + \beta_{2\tau}EG_{it} \\ &+ \beta_{3\tau}logIQ_{it} + \beta_{4\tau}PWEx_{it} \\ &+ \beta_{5\tau}logMVA_{it} \end{aligned} \tag{4}$$

In Eq. (4), country and year are signified by the subscripted i and t. y_{it} is the indicator of the ecological footprint. Here, α_i represents the slope intercept; β_1, β_2, β_3, β_4, and β_5 coefficient estimated the foreign direct investment, economic growth, institutional quality index, percentage of world export, and manufacturing value-added, respectively, while ξ_t shows the error term. Moreover, the estimation of the coefficients for the τth quantile of the conditional distribution could be attained from the Eq. (5) (Powell 2019; Zhang et al. 2016).

Table 1 Summary of the variables

Description of variables	Short term	Measurement	Sources	Literature
Ecological footprint	LogEF	Constant per capita	Global Footprint Network	Rees and Wackernagel (1996)
Foreign direct investment	FDI	Percentage of GDP	theGlobalEconomy.com	Doytch (2016); Sugawara and Nikaido (2014)
Economic growth	EG	The rate of change of real GDP	theGlobalEconomy.com	Nizam et al. (2020); Hassan et al. (2019)
Manufacturing value-added	LogMVA	Constant dollars	theGlobalEconomy.com	Mahmood (2012)
Percent of world export	PWEx	Percentage of the world's total	theGlobalEconomy.com	Dogan et al. (2020); Halkos and Tzeremes (2011)
Institutional quality	LogIQ	Percentiles of the countries	World Bank	Ali et al. (2020); Kang and He (2018)

Source: Authors' compilation

$$\beta^{\wedge}(\tau) = \operatorname{argmin} \sum_{i=1}^{n} \rho_{\tau}(Y_i = x_i{}^{\tau}\beta) \tag{5}$$

Here, $\rho_\tau(u) = u\{\tau - I(u < 0)\}$, $I(u < 0) = \{\, 1,\ \ u < o\ \ 0,\ \ u \geq 0$ signifies the check function besides, I (*) is an indicator function.

From Eq. (5), it is evident that PQR is a type of weighted regression, which sets up various measures τ and 1−τ from plus to minus spillover individually. As α_i has not been included here, it signifies the consideration of unobserved regional heterogeneity. Since most of the estimators of quantile panel data include the additive fixed effects (Canay 2011; Galvao 2011; Koenker 2004; Lamarche 2010), the interpretation differs from estimator to estimator. However, this study applied the quantile regression estimator for panel data (QRPD) developed by Powell (2016) as he introduced the estimator for quantile panel data with non-additive fixed effects. This estimator is linear in parameter and also maintains the non-separable disturbance term related to panel data with quantile estimation. The underlying model is:

$$y_{it} = D_{it}\beta\left(U_{it}^{*}\right) \tag{6}$$

Here, y_{it} is the dependent variable ecological footprint. $D_{it} = (I_{it}, X_{it})$ is a vector of the independent variables at time t for individual i. β denotes the coefficient vector, whereas the general disturbance term is denoted by U.

In the next section, the discussion of all variables is narrated.

Variable description

Ecological footprint (logEF)

The only metric to measure the demand versus supply of nature is the ecological footprint (Danish et al. 2019). It can be said that ecological footprint means the quantity of space on the earth a person uses so that he could survive by using existing technology. Rees and Wackernagel (1996) inscribed the book "Our Ecological Footprint" to designate the perception. The ecological footprint is a comprehensive measure that is being used as an indication of ecological degradation (Wackernagel and Galli 2012). It implies the burden of humanoid actions on land and considered as a pointer of environmental degradation; it emphasizes manufacture and consumption activities unswervingly (Danish et al. 2019). The ecological footprint measures the diminution of the resources required to support economic activity along with contamination as a direct consequence of the monetary activity. Direct consumption effects and production effects are taken into account in measuring the footprint (Hervieux and Darné 2016; Van de Vliert and Vlek 2015).

FDI

FDI inflow is usually related to the transmission of knowledge, capital, technology, and management applications from foreign countries to host countries. FDI is acknowledged to carry a composition effect, a technique effect, and scale effect to firms' operations (Doytch 2016), as it brings investment, transfers wisdom, technology, employment, and also entrances to new sectors. As a consequence, FDI has often been observed as a carter for financial expansion (Sugawara and Nikaido 2014).

EG

Economic growth is calculated as the percent change in GDP per capita (Hassan et al. 2019). Though economic growth is considered one of the most crucial causes of ecological downfall, there is an argument that it helps for the betterment of the environment by providing enough budget for taking measures to rescue the environment (Nizam et al. 2020; Tariq 2019).

Manufacturing value-added (logMVA)

In an economy, manufacturing value-added (MVA) is hypothetically the summation of the value-added by all industrial and non-industrial manufacturing activities. Zarsky (1999) and Goldenman (1999) specified that local manufacturers are not as good as foreign investors while using production technologies.

Table 2 Summary statistically of dependent and explanatory variables

	EG	FDI	LogMVA	PWEx	LogIQ	LogEF
Mean	3.850143	4.806667	2.618999	1.011694	3.823147	1.026976
Median	3.760000	2.720000	3.000720	0.330000	3.981262	1.220361
Maximum	54.16000	103.3400	8.086539	13.73000	4.602732	2.874889
Minimum	− 33.10000	− 58.32000	− 3.912023	0.000000	0.746380	− 6.465376
Std. Dev.	4.645726	9.039017	2.269875	1.818539	0.682690	1.064961
Skewness	0.527022	4.844682	− 0.374138	3.378111	− 1.261494	− 3.523937
Kurtosis	21.82826	41.57596	2.927218	16.22802	4.741594	24.42540
Jarque-Bera	21781.39	96896.81	34.61942	13513.41	575.6654	31159.11
Observ.	1470	1470	1470	1470	1470	1470

Source: Authors' estimation

Percentage of world exports

Exports of goods and services epitomize the worth of entire products and additional market services provided to other countries of the globe. Therefore, ecological footprint and export are anticipated to have an adverse relationship. We include the percentage of total world exports in our model as it captures the rivalry of the countries in the world market (Halkos and Tzeremes 2011).

Institutional quality

Institutional quality encompasses a complex formation passing through diverse institutional regularities and distresses individual market and radical market forces (Ali et al. 2020). Institutional quality could be attained by the six components of government efficiency, containing the rule of law, voice and accountability, government effectiveness, political stability, regulatory quality, and control of corruption (Kang and He 2018). We derive the institutional quality index by averaging the percentile of these six indicators (Table 1).

Empirical results and discussions

Descriptive statistics

In Table 2, descriptive statistics are presented for all the examined variables. Whereas, the mean of FDI is the largest (4.806667) and varies significantly across countries (maximum = 103.3400 and minimum = − 58.32000). Average economic growth is 3.850143 in the nations, and the standard deviation is 4.645726. As of logMVA, logIQ, and percentage of world exports (PWEx) show a mean of 2.618999, 3.823147, and 1.011694, respectively. Over the period, the average of logEF of selected countries is 1.026976. In terms of standard deviation, the highest value is for the FDI variable with 9.039017, followed by EG and logMVA by 4.645726 and 2.269875, respectively.

Correlation matrix

In Table 3, the correlation (Pearson's r) matrix for the examined variables is illustrated. The table demonstrates the correlation between ecological footprint and economic growth, along with all other descriptive variables. Other variables except foreign direct investment have a positive correlation with the ecological footprint. Moreover, the correlation between institutional quality and ecological footprint is relatively high (0.440082). To put it another way, we can see that the correlation among the variables is less than 0. 80. It indicates that there is a little chance to present the multicollinearity problem among the variables.

Panel quantile regression analysis

The outcomes of the panel quantile regression estimation are demonstrated in Table 4. The results are stated at the 5th, 10th,

Table 3 Correlation (Pearson's r) matrix (n = 1470)

	LogEF	EG	FDI	logIQ	logMVA	PWEx
LogEF	1.000000					
EG	0.109554	1.000000				
FDI	− 0.150103	0.113579	1.000000			
logIQ	0.440082	0.080390	− 0.225036	1.000000		
logMVA	0.185765	− 0.139504	− 0.179357	0.459749	1.000000	
PWEx	0.177059	− 0.017898	− 0.102741	0.321918	0.661215	1.00000

Source: Authors' estimation

Table 4 Panel quantile regression

Dep. Var EF	Quantiles									
Variables	5th	10th	20th	30th	40th	50th	60th	70th	80th	90th
FDI	0.00930***	0.0117***	0.0295***	0.00854**	0.0194***	0.0155***	0.00624**	− 0.00456***	0.0243***	0.0904***
	(0.00173)	(0.000403)	(0.00282)	(0.00404)	(0.000976)	(0.000233)	(0.00300)	(0.000582)	(0.00129)	(0.000637)
EG	− 0.0705***	− 0.0619***	− 0.0232***	− 0.0344***	− 0.0261***	-0.0396***	0.00315	0.000562	− 0.0154***	− 0.00596***
	(0.000873)	(0.00109)	(0.00591)	(0.00595)	(0.00552)	(0.000693)	(0.00432)	(0.00136)	(0.000773)	(0.00151)
LogIQ	1.484***	1.732***	2.165***	2.137***	1.836***	2.015***	2.083***	2.017***	1.907***	1.904***
	(0.00590)	(0.00719)	(0.0461)	(0.0453)	(0.0233)	(0.00468)	(0.0248)	(0.0125)	(0.0233)	(0.00823)
PWEx	0.309***	0.328***	0.185***	0.355***	0.309***	0.436***	0.414***	0.852***	0.737***	0.688***
	(0.00248)	(0.00192)	(0.0395)	(0.00704)	(0.0363)	(0.00484)	(0.0199)	(0.00583)	(0.00975)	(0.00223)
MVA	− 0.000302***	− 0.000554***	2.45e−05	− 0.000582***	− 0.000316*	− 0.00139***	− 0.000594***	− 0.00245***	− 0.00229***	− 0.00259***
	(1.48e−05)	(8.97e−06)	(0.000280)	(2.60e−05)	(0.000178)	(2.03e−05)	(0.000135)	(0.000141)	(9.44e−05)	(2.71e−05)
Observations	1,470	1,470	1,470	1,470	1,470	1,470	1,470	1,470	1,470	1,470
Number of groups	92	92	92	92	92	92	92	92	92	92

This table shows the results of the panel quantile regression model with different ecological footprint as dependent variables and FDI, economic growth, institutional quality, percentage of world exports, and manufacturing value-added variables as independent variables. Figures in parentheses are t-values

*Statistical significance at the 10% level; **statistical significance at the 5% level; ***statistical significance at the 1% level

20th, 30th, 40th, 50th, 60th, 70th, 80th, and 90th percentiles of conditional ecological footprint distribution. The empirical result of the regression analysis indicates the heterogeneous or diversified impacts of various factors on ecological footprint.

With respect to FDI in Table 4, it is observed that the impact of foreign direct investment on ecological footprint is heterogeneous. To elaborate, the magnitude of the coefficient is much higher in higher quantiles. In the 20th quantile, the coefficient is 0.0295, and it becomes four times higher in the 90th quantile with the coefficient 0.0904. It implies that, if a country already holds a larger ecological footprint, then it will be more affected by foreign direct investment. However, there is an exception on the 70th quantile where it is found that the coefficient of FDI is negative and significant. On all other quantiles, FDI has positive and significant value in any level of significance, which is consistent with prior studies such as Doytch (2016), Seker et al. (2015), Udemba (2020b), and Jorgenson (2010). Rai et al. (2019) argued that a possible reason for this positive relationship between FDI and ecological footprint exists due to the large amount of investments into the polluting sector. So, it can be concluded that the foreign direct investment has a small but positive relationship with EF which is consistent with the pollution haven hypothesis (Abdo et al. 2020; Fakher 2019; Liu and Kim 2018). Our finding implies that, when any country is not functional enough, the inflow of foreign direct investments might be devastating to them in terms of inadvertent air emissions, carbon emissions, and also the other factors of the environment (Aremo and Ojeyinka 2018; Huynh and Hoang 2019; Jorgenson 2010). Countries aiming at swelling FDI inflow levels need to reconsider the environmental regulations with caution.

On the contrary, with regards to the economic growth, it is observed that the influence of economic growth on ecological footprint is negative. However, there are a few significant discrepancies in the conditional distribution of ecological footprint across different percentiles.

In the 5th quantile, the coefficient is − 0.0705, and it rises to − 0.00596 in the 90th quantiles, which indicates that a higher level of economic growth can reduce ecological footprint more in the countries which have a larger ecological footprint. However, in the 60th and 70th quantiles, there have been positive and insignificant associations between ecological footprint and economic growth. In other quantiles, a negative and significant association exists that is pertinent to some previous studies (Tariq 2019; York 2007). It is stated that economic growth could be supportive of fighting against contaminations as regarded in pollution halo hypothesis (Ahmad et al. 2019). If a country has adequate economic growth, only then it would able to resist those foreign investments which are environmentally unfriendly. Wang et al. (2019) argued that the economic growth can be one of the features to reduce ecological footprint as it supports to construct or attain alternative energy and efficient technology by giving more funds to research and innovation.

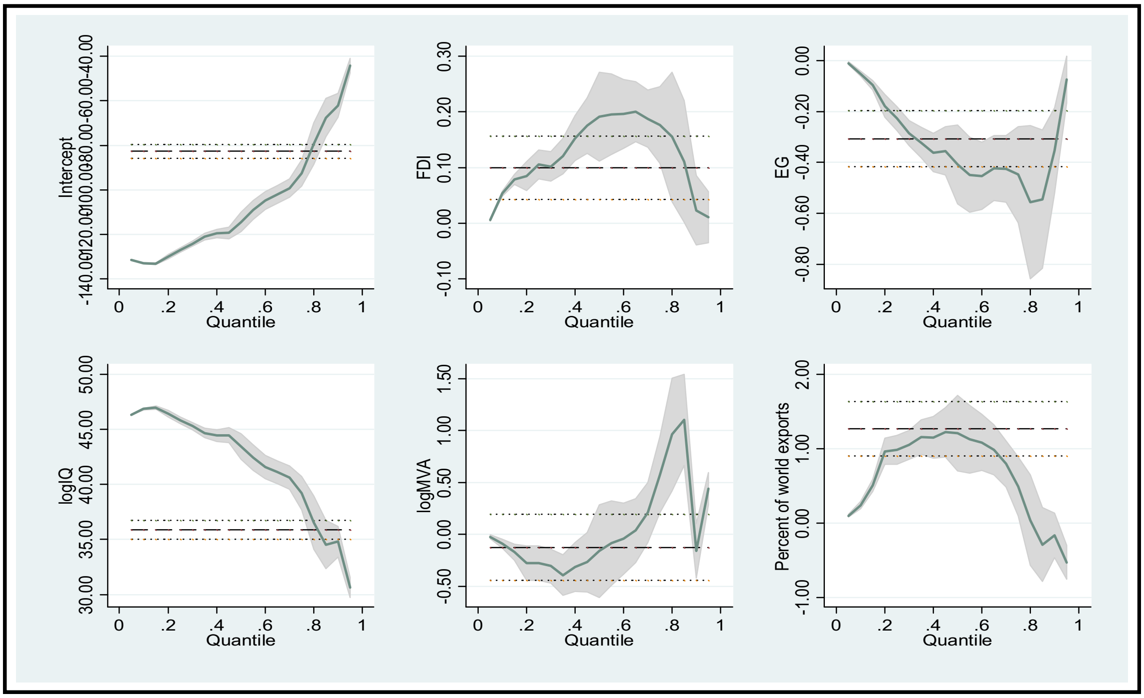

Fig. 2 Regression lines: QR vs. OLS for different variables. Source: Authors' estimation

Surprisingly, institutional quality has a significant positive association with the ecological footprint in all quantiles, and the coefficient increases in quantile to quantile. In the 5th quantile, the coefficient is 1.484, and in the 90th quantile, it reaches to 1.904, which is quite relevant to the race to the bottom hypothesis (Konisky 2007; Prakash and Potoski 2006). Our result is pertinent to Charfeddine and Mrabet (2017) and Sabir et al. (2020), who found that political institutions and government stability have not been accompanied by a reduction of environmental stress. Moreover, the misconception in regards to ecological footprint is it provides a comprehensive indicator of sustainability (Barrett et al. 2005; Konisky 2008). Though our result has been derived from the estimation of 92 countries altogether where developed, developing, and underdeveloped countries are included, it demonstrates a comprehensive interpretation. Individual country estimation could capture a more crystal-clear illustration of institutional quality issues regarding the environment and could clarify the roles of the environment in the countries' legislation procedure.

Furthermore, manufacturing value-added has an inverse relationship with the ecological footprint. In every quantile, except 20th MVA has a significant small negative impact on EF, which indicates that many underdeveloped countries are dependent on manufacturing exports to developed countries, which dwindles consumption-based environmental impacts in the host countries (Jorgenson and Burns 2007).

In terms of the PWEx, our study found that there is a positive and significant relationship with EF in all quantiles. In the 5th quantile, the coefficient is 0.309, and it becomes double in the 90th quantile with the coefficient 0.688, which indicates that, if a country already undergoes a larger ecological footprint, then export will affect more to its ecological footprint. Our result is harmonized with some previous researches (Charfeddine and Mrabet 2017; Chen and Chang 2016; Dietzenbacher and Mukhopadhyay 2007; Halkos and Tzeremes 2011). Countries should deliver the needed budget for the agronomical section and induce innovation in technology besides the production of reusable energy for exporting (Hassan et al. 2019; Jorgenson 2006; Piovani and Li 2013).

For further testing, this study also employs a graphical depiction of the QR estimates for all variables. As it can be seen in Fig. 2 that all variable cross the significance level (upper and lower bound) after a certain level of percentile, this study confirms that there is heterogeneous feature exists in all variables including the FDI.

Policy implications and concluding remarks

The ecological footprint is inclining up day by day throughout the world, which is quite an alarming issue for the world. Moreover, foreign direct investment is a lucrative tool for any country, as it brings money, technology, and employment, and it always comes into the table while discussing ecological footprint. With that note, this study examines the heterogenous impact of the FDI on the ecological footprint for the 92 countries over the period 2001 to 2016. To reinforce our study, we also included economic growth, percentage of world exports, manufacturing value-added, and institutional quality as additional explanatory variables. Using the panel quantile regression, our study found that foreign direct investment, export, and institutional quality have a significant positive relationship with the ecological footprint over the countries, whereas the relationship is negative for economic growth and manufacturing value-added. The result of this study implies that the higher the foreign direct investment, export, and institutional quality will cause higher environmental degradation. On the other hand, if the economic growth and manufacturing value-added increase, it will have a positive impact on the environment and vice versa. The empirical analysis of this study supports most of the former literature on ecological footprint.

The findings of this paper have substantial implications for the investors, governments, and administrators, as well as to an individual. Our empirical result designates that foreign direct investment should be monitored intensively by the government as it affects adversely on the environment by increasing the level of ecological footprint. More efficient and eco-friendly environmental laws are needed to adapt to reduce the ecological damages that come from foreign direct investment. Moreover, to attract environmentally friendly foreign investors, better and conscious environmental regulations are needed to set also. Foreign investment is needed to be discouraged while the investment is for any industry which is not environment-friendly. The host countries need to make stringent laws not only to protect the economy and lifestyle but also to protect the environment as well. Legislators and regulatory boards of every country need to apply a set of comprehensive ecological rules and regulations to mitigate the ecological footprint. Law enforcement authorities have to ensure strictness to initiate that exporting products do not largely affect the biocapacity of the exporting country. A comprehensive budget should be allocated for research and innovation to develop eco-friendly technology in every sector. Countries should impose more tax on those manufacturing units, which are damaging the environment. Administrations can also announce a reward tool to inspire the polluting manufacturing sector for implementing green energy and production wastes ought to be adequately managed by a proper dumping strategy. Furthermore, foreign investors need to be aware of the environmental situation of the host country and should include all the necessary technologies to ensure assistance for improving environmental quality as their corporate social responsibility.

Besides, there are a lot of aspects to concentrate on the topic of our paper in the future. For instance, future researches could include some other variables: such as urbanization, literacy rate, longevity, or Gini coefficient as indicators of quality living. Due to data unavailability, our study is confined into only 92 countries; therefore, the future studies could extend the number of countries for reexamining the impact of FDI on ecological footprint. Another possible extension could be the examination of differences in the determinants of ecological footprint between small and large countries in terms of population. Ecological deficit or reserve could also be an issue to look at in the future studies.

Author contributions Dr. Mohammad Ashraful Ferdous Chowdhury: conceptualization, analysis, methodology, review and editing, and supervision.

Peal Ahamed Shanto: interpretation, methodology, writing original draft, review and editing. Afsana Ahmed: writing original draft, review and editing.

Rabeya Hossain Rumana: writing original draft, review and editing.

Data availability The datasets generated and/or analyzed during the current study are available in the Global Footprint Network, theglobaleconomy.com, and info.worldbank.org.

Compliance with ethical standards

Ethics approval and consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors declare that they have no competing interests.

Appendix

Table 5 List of the countries included in this study (alphabetic order)

Algeria	China	Iraq	Morocco	Saudi Arabia	United Arab Emirates
Argentina	Colombia	Ireland	Namibia	Sierra Leone	UK
Australia	Costa Rica	Israel	Nepal	Singapore	USA
Austria	Croatia	Italy	Netherlands	Slovakia	Venezuela
Azerbaijan	Czech Republic	Japan	New Zealand	Slovenia	Vietnam
Bangladesh	Denmark	Kazakhstan	Nigeria	South Africa	Zambia
Belarus	Estonia	Kenya	Norway	South Korea	Zimbabwe
Belgium	Finland	Laos	Oman	Spain	

Table 5 (continued)

Algeria	China	Iraq	Morocco	Saudi Arabia	United Arab Emirates
Bhutan	France	Lebanon	Pakistan	Sweden	
Bosnia and Herzegovina	Gabon	Liberia	Panama	Switzerland	
Brazil	Germany	Lithuania	Paraguay	Tanzania	
Brunei	Ghana	Luxembourg	Peru	Thailand	
Burma (Myanmar)	Greece	Macedonia	Philippines	Togo	
Cameroon	Guatemala	Malaysia	Poland	Tunisia	
Canada	Hungary	Mauritius	Portugal	Turkey	
Chad	India	Mexico	Romania	Uganda	
Chile	Indonesia	Mongolia	Russia	Ukraine	

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