Economic Research-Ekonomska Istraživanja

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rero20

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To cite this article: Haiyang Qiu & Qilong Wan (2023) Inclusivity between digital trade, human development, and environmental quality: moderating role of green innovations in BRICS countries, Economic Research-Ekonomska Istraživanja, 36:3, 2150872, DOI: 10.1080/1331677X.2022.2150872

To link to this article: https://doi.org/10.1080/1331677X.2022.2150872

Published online: 04 May 2023.

ECONOMIC RESEARCH-EKONOMSKA ISTRAŽIVANJA
2023, VOL. 36, NO. 3, 2150872
https://doi.org/10.1080/1331677X.2022.2150872

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Inclusivity between digital trade, human development, and environmental quality: moderating role of green innovations in BRICS countries

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ABSTRACT

This research investigates the role of digital trade, human development, globalization, and green innovations on ecological footprints (EFP) for BRICS countries. Unlike the earlier studies, this research expands the empirical contribution while examining the moderating effect of green technologies on the relationship between stated explanatory variables and EFP. Initially, we testify the presence of cross-sectional dependence, unit root tests, cointegration, and slope heterogeneity and subsequently apply cross-sectionally augmented autoregressive distributed lags (CS-ARDL) using annual data from 1995 to 2019. The empirical findings exhibit the significance of digital trade, human development, and green technology innovations in complementing low EFP in the long run. However, globalization tends to increase ecological footprints. Moreover, the findings in the short run provide a symmetrical (positive/negative) effect of stated explanatory variables on EFP; however, their marginal impact is lower. Additionally, the moderating effect of green technologies on the relationship between digital trade and EFP and between human development and EFP is significantly negative, supplementing the existing association. Therefore, an inclusive digital and human development policy is imperative to ensure sustainable ecology.

ARTICLE HISTORY
Received 8 June 2022
Accepted 23 October 2022

KEYWORDS
Digital trade; human development; green innovation; environmental sustainability; BRICS

JEL CODES
N7; O13; E24

1. Introduction

Over the past three decades, the science of sustainability has emerged as among the prominent fields to deal with the changing environment resulting from human-nature interaction (Lin et al., 2018). Therefore, the subject matter of sustainability specifies as a solution-oriented discipline that examines the complex association between nature and humanity (Sala et al., 2013). More specifically, the ecological footprint (EFP) is an account-based indicator system. The underlying phenomenon states that

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a finite amount of biological production supports all life on Earth (Wackernagel et al., 2018). In this regard, a significant measure of sustainability, EFP, is accepted as a multiscale and integrated approach to analyzing the overutilization of natural resources and the subsequent impact on the ecological system (Gao et al., 2021; Muthu, 2021). In recent years, the most severe environmental challenges are regarded as EFP and in the form of other greenhouse gas emissions. For this reason, environmental policies and strategies have become an essential cornerstone for both developed and developing economies. W. E. Rees proposed the initial concept of EFP, further expanded by Rees et al. (1996), reflecting an aggregate measure of environmental degradation and pollution.

Moreover, EFP is widely used in the current literature in terms of production and consumption dynamics, hence can be utilized as a key measure to examine the trends in sustainable development (Dong et al., 2019). The title of BRICS economies combines five emerging states to promote different economic matters. These economies host approximately 40% of the global population with a combined GDP of 23%. Moreover, these economies are observed with a total energy consumption of 40% globally (IEA, 2020). Additionally, the members like Brazil and Russia contain a significant amount of biocapacity reserves, which are now in the declining phase. Meanwhile, the ecological footprints among these economies have also been observed with some dramatic trends. For example, the EFP (constant perf capita) was 2.81, 1.61, 5.15, and 3.62 for Brazil, India, Russia, and China in 2016 (GFN, 2021). More specifically, China, India, and South Africa were entitled as economies with a deficit in biocapacity with the EFP of 1.2, 3.6, and 3.2 per person, respectively, throughout 2016 (GFN, 2019).

With the industrial and technological changes, it is believed that the popularity of information technology has emerged with some dramatic acceptance in different sectors and economies. During the outbreak of COVID-19, digital technology has played a vital role while empowering both products and services with some new business models. Moreover, towards sustainable economic recovery, the digital economy and trade play a vital role in facilitating the production and consumption of goods and services (Jiang, 2020). At the same time, the impact of technological development has recorded major changes in economic development and the environment. This is because shifting the economy from traditional activities to digital scale has significant potential while contributing to the natural environment in decarburization and demobilization (Ma et al., 2022). However, the nexus between the digital economy and the environment has been explored from three different perspectives in the existing body of literature. For example, the first theme for the relationship between the digital economy and the environment reveals that the former harm later. However, the second point reflects that the digital economy helps protect the natural environment to some extent. Thirdly, with the help of internet openness, it is quite obvious for the community members to actively engage themselves in ecological governance (Zhong & Jiang, 2021). Another view regarding the role of the digital economy and environmental quality has been expressed by Ma et al. (2022), who claim that shifting towards a digital economy can decrease waste like logistic necessities, shop space, and printed catalogs; however, it still it requires some energy-intensive computers which contributes directly towards consumption-based carbon emission. Nevertheless, the nexus between digital trade and ecological footprints is still a missing part in the existing studies for which current research has tried to fill this gap.

Considering the Millennium Ecosystem Assessment (MEA), human well-being and development are intrinsically linked with environmental betterment. Good management of environmental issues may provide a range of better human outcomes; hence positive synergies exist between both (Assessment Millennium Ecosystem, 2005). However, the pressures on the core dimensions of human development entitled education and health are expected to increase because of urban expansion, globalization, non-sustainable production, and consumption and growth of the population (Kassouri & Altıntaş, 2020). Meanwhile, working to improve human well-being while stopping the increasing pressure on the natural environment is also a fundamental point under the umbrella of sustainable development goals (SDGs), as expressed by Moyer and Bohl (2019). Although the association between human development and environmental quality has been under the significant attention of many stakeholders, including environmental activists, the current path of human and environmental development is not sustainable for various reasons. The environmental system is under significant pressure at the micro and macro levels, where billions of human beings are directly suffering due to a lack of clean energy, water, and food facilities (DeLonge et al., 2016). Because of these challenges, SDGs have been developed while integrating a development sensitive to both humans and nature.

While investigating the interlinkage between globalization and environmental quality like EFP, several studies have been observed. Globalization refers to the international collaboration between different economies covering commerce, financial operations, and other trade areas. Moreover, globalization covers the social, economic, and political dimensions where positive and negative consequences on the natural environment have been observed in the literature. For example, with the rising economic globalization, trade barriers would be reduced with more economic activities. Such efforts result in more energy utilization from coal and fuel, hence more carbon emission and mismanagement of the natural resource.

Additionally, with the rise in trade activities, overall production-related activities will also increase (scale effect), hence another way of environmental pollution (Yilanci & Gorus, 2020). However, the literature gap specifies that relatively few studies have explored the trends in globalization, specifically from the context of economic, political, and social perspectives for ecological footprints in BRICS economies. In addition, according to the World Bank, technological innovations in emerging economies have increased from 0.11 million applications of patents to 1.74 million from 1980 to 2016. This dramatic increase has provided sufficient evidence to claim that if such technologies and innovations have been given reasonable attention, they can significantly help achieve sustainable growth and efficient utilization of natural resources (Song et al., 2019). Therefore, the world economy can reasonably overcome the scarcity of natural resources while meeting the needs of the increasing population with the help of technological innovations. In this way, transitioning from traditional technologies to environmentally friendly will lead to sustainable economic growth (Bekun et al., 2019). However, this nexus is only valid when a win-win situation exists, specifically in the form of environment and economy. Following the above-stated arguments, there is extended literature on the role of technological innovations, globalization, and human development toward EFP. Yet, investigating the association between stated variables needs dire attention from the BRICS countries' context.

Additionally, digital trade has been investigated on very few grounds, specifically in estimating the environmental pollution among the selected economies, for which a prominent literature gap is yet to fill. Moreover, this research also covers the literature gap while investigating the moderating effect of technological innovations on the relationship between digital trade, human development, globalization, and EFP. Finally, one of the limitations of previous studies is that much attention has been paid to the first-generation estimations techniques, which provide misleading findings when there is a presence of slope heterogeneity and cross-sectional dependence. This study also addresses these methodological limitations while using advanced panel estimations of Cross-Sectional ARDL to estimate both long-run and short-run relationships. The rest of the paper is organized in the following manner: Section 2 covers the literature review, whereas section three discusses the research methodology. Section 4 provides empirical estimations, and the last section describes the conclusion, implications, and future directions.

2. Literature review

2.1. Digital Trend and environmental quality

The changes in digital technologies and technological advancement have been observed as key determinants of economic growth and environment. More specifically, the emergence of digital economies and trade significantly influences environmental pollution positively and negatively. Ma et al. (2022) contribute to the literature on 'sustainable digital economy and carbon emission' from the context of China. It states that the Chinese economy is leading in the global market regarding exports, imports, and gross domestic product. The investigation of trade-adjusted carbon emissions is essential. Data has been collected from different provinces of China to specify the role of the digital economy in the green economy. The panel data estimations found that the digital economy and exports significantly negatively impact trade-adjusted carbon emissions. Jiang (2020) reviews the role of digital technology specifically in the context of the COVID-19 era. They stated that the digital economy leads toward long-run economic growth in China and helps promote the digital foundation for different industries. Li et al. (2021) stated that digitalization plays a vital role in the economy, society, and environment. Under the theoretical foundation of the STIRPAT model, their study examines the impact of the digital economy and energy structure on environment quality as measured through carbon emission for the panel data over 2011-2017. The empirical estimations show that the digital economy plays a significant role in determining carbon emissions.

Moreover, they infer that with the development of the digital economy, the influence of coal-based energy structure on CO2 emission has decreased gradually.

However, this effect is more significant in non-resource than in the rest of China's provinces. Rappitsch (2017) claims that the digital economy has its significant environment and social influence, where the key sustainability dimension of digital technology and related infrastructure is the utilization of resources. Moreover, the energy consumption of overall digital infrastructure is another sustainability factor. Ciocoiu (2011) claims that green and digital economies are the most significant subjects on the environmental policy agenda. Besides, it is inferred that technology is critical in achieving long-term environmental and human development goals. Although the above studies have reasonably tried to explore the association between digital economy and trade and environmental concerns; however, it can be inferred that the most cited measure of environmental pollution entitled EFP has been widely neglected.

2.2. Human development and environmental quality

Researchers and policymakers have investigated human development and environmental quality with good attention. Yet their relationship is missing while applying the advanced panel estimations in various emerging economies. For instance, Kassouri et al. (2020) examined the MENA region to explore the relationship between human well-being and sustainability issues from 1990 to 2016. Their study mainly considers ecological footprints and dependent human development variables in two econometric models. Their findings confirm a substantial trade-off between human wellbeing (human development index) and EFP in the whole sample and subsamples. Yue et al. (2019) explore the sustainable productivity growth for 55 states under the shadow of human development and ecological footprints. Through data envelopment analysis (DEA), a new index for Sustainable Total Factor Productivity has been proposed. Based on the stated indicators, it is observed that there is slow, sustainable growth among the selected states. Long et al. (2020) examine the sustainability trends in four different Islands of China while considering the ecological footprint and human development as key variables. Their study shows a significant relationship between human development and ecological footprints. Barbier and Hochard (2018) claim that the theory of causal association between human well-being and environmental protection states that environmental pollution and fragile ecological environment weaken the well-being and health of the individuals, which aggravates the destruction of the ecological atmosphere.

Additionally, it is well stated that the well-being of humans depends on various resources like ecological products, food supplies, and climate regulations. Smith et al. (2019) infer that environmental degradation disturbs the ecological balance, adversely influencing human well-being. Sarkodie et al. (2020) have developed a conceptual framework for mitigating environmental changes while taking the role of energy consumption and human development as key determinants of environmental sustainability. It is claimed that human capital is quite conducive to escalating environmental degradation and emissions. Therefore, it is inferred that human development, well-being, and ecological dimensions are deeply integrated.

2.3. Globalization and environmental quality

A dramatic transformation has been observed in the world economy because of globalization, where most nations are integrated economically, socially, and politically. The research investigation of the relationship between globalization (GLO) and environmental quality is not a novel idea in the literature. The researchers evolved multiple indexes for measuring the concept of globalization while providing mixed findings. Kirikkaleli et al. (2021) focus on Turkey to explore the role of globalization on EFP while taking the role of trade openness, energy consumption, and economic growth as control variables. Their estimations confirm that GLO positively and significantly affects the EFP in the long run. However, trade openness is negatively linked with the EFP in the short run. Ahmed et al. (2019) consider the Malaysian economy from 1971 to 2014 to check the impact of GLO on EFP through the bound ARDL test. However, findings disclose that GLO is not a significant determinant of EFP but increases ecological carbon footprints. Ahmed et al. (2021) claim that EFP is a comprehensive indicator of environmental degradation with diverse factors influencing it. Their study contributes to the literature while exploring both symmetric and asymmetric impacts of economic globalization, economic growth, and financial development on EFP. The empirical estimations confirm that economic globalization mitigates the EFP. Pata (2021) has examined the impact of renewable energy consumption, agriculture activities, and globalization on EFP from 1970 to 2016. Through long-run elasticates, it has been recognized that GLO promotes pollution-related indicators, whereas renewable energy sources help in declining it. Yang et al. (2021) consider the theoretical foundation of the STIRPAT model for exploring the role of industrialization, GLO, and economic growth on EFP and health expenditures from 1995 to 2018. However, contrary to earlier studies, it is stated that GLO helps in reducing the EFP. Similar findings have been confirmed under a robustness check.

2.4. Green technology innovations and environmental quality

The relationship between Green technology innovation (GTI) and environmental quality has been widely investigated. For instance, Ke et al. (2022) examine the efficiency of green innovation on EFP for 283 cities in the Chinese economy. Their findings confirm that such innovations are quite efficient in controlling the EFP. Ahmad et al. (2020) have applied advanced panel techniques to examine EFP trends through green technologies. The study findings confirm the presence of slope heterogeneity, panel cointegration, and cross-sectional dependence in the data. In contrast, long-run estimation confirms the stable relationship between technological innovations and EFP. More specifically, it is inferred that such technologies are helpful while negatively impacting EFP; hence, environmental pollution would be reduced. Shan et al. (2021) justify the role of ecological innovation among the key indicators for achieving a sustainable environment. BARDL estimation confirmed that GTIs and renewable energy reduce carbon emissions, leading to carbon neutrality. However, specific barriers exist to properly utilizing green innovations

Table 1. Details of the variables.

Variables and measurement	Nature	Data source
Environmental quality through EFP	Dependent	Global Footprint Network
Digital Trade (% of total trade)	Independent	
Human well-being through (HDI index)	Independent	Pen World Table
Globalization through KOF (index)	Independent	KOF database
Green Technology Innovation (Eco patents % of total patents)	Moderating	OECD.stat

Source: Author Estimation.

(Chien et al., 2022). Chu (2022) investigated determinants of EFP in OECD economies and endorsed the long-run negative relationship between green technologies and EFP.

Based on the above literature, it is inferred that the digital economy and trade, globalization, human development, and green technologies would play significant roles. However, the literature is still missing to examine their nexus with the environmental quality in terms of EFP based on the advanced panel estimations. Moreover, this research also examines the moderating role of GTI on the relationship between stated explanatory variables and EFP from the context of BRICS economies.

3. Research methods

The description of the study variables has been provided in Table 1, covering the measures, nature, and data sources. The data has been retrieved from various sources mentioned in Table 1 from 1995 to 2018. Moreover, data has been transformed into a natural logarithm for better distribution and offering coefficients in the form of elasticities. Additionally, the data's log form distribution helps address issues like autocorrelation and heteroskedasticity (Chien et al., 2021; Razzaq et al., 2021). Under panel data estimation, it is essential to investigate the cross-sectional dependence (CD), as neglecting such a trend would later generate inconsistent and biased results. Moreover, CD specifies the similarity in the regional policies across different economies; therefore, considering such an issue is essential. In addition, the consideration of the data's unit root or stationarity properties comes at the second stage once the research has finished the investigation for CD in the data. For inspecting the stationarity properties of the data, we applied the Pesaran (2007) panel unit root test with the presence of CD along with Bai & Carrion-I-Silvestre (2009) unit root tests based on the structural changes, common stochastic trends, respectively. In the third step, our research has conducted an empirical investigation to check the slope heterogeneity based on the modified version of Swamy (1970), further discussed by Pesaran and Yamagata (2008).In the fourth step, the data's cointegration properties have been investigated based on the critical suggestions of Westerlund and Edgerton (2008) test for panel integration.

Finally, this study has examined the long-run and short-run association between the stated variables using the CS-ARDL technique, which helps provide reliable findings with CD, slope heterogeneity, stationarity properties, and panel cointegration. For considering the EFP as the key dependent variable, Equation 1 provides the functional association between the study variables.

$$EFP_{,i,t} = f\ (DTR_{i,t},\ HDI_{i,t},\ GLO_{i,t}, GTI_{i,t}) \tag{1}$$

The term 'i' in equation (1) denotes the cross-section, whereas the term 't' denotes the time taken between 1995 and 2018. Equation 2 covers the regression format.

$$EFP_{it} = \beta_{1it} + \beta_{2it}DTR_{it} + \beta_{3it}HDI_{it} + \beta_{4it}GLO_{it} + \beta_{5it}GTI_{it} + \alpha_i + \delta_{it} \tag{2}$$

ARDL format has been presented in Equation 3 below:

$$W_{i,t} = \sum_{i=0}^{pw} \varphi_{i,t}W_{i,t-1} + \sum_{i=0}^{pz} \gamma_{i,t}Z_{i,t-1} + \varepsilon_{i,t} \tag{3}$$

However, equation (3) is employed for each regressor for the average cross-section to determine equation (4). CSD effects were minimized through a cross-sectional average (Török & Konka, 2018).

$$W_{it} = \sum_{i=0}^{pw} \varphi_{i,t}W_{i,t-1} + \sum_{i=0}^{pz} \gamma_{i,t}Z_{i,t-1} + \sum_{i=0}^{px} \alpha_i\overline{X}_{t-1} + \varepsilon_{i,t} \tag{4}$$

Here,

$$\overline{X}_{t-1} = (\overline{W}_{i,t-1}, \overline{Z}_{i,t-1})$$

W_{it} t reflects the EFP as outcome variable, whereas all explanatory variables have been presented through $Z_{i,t-1}$. Moreover, the average of stated variables has been covered through $\overline{X}_{t-1}$ to eliminate CD issues. P_x, P_w and P_z reflect the lagged values of the variables. The CS-ARDL test approach provides the long-term coefficient value obtained from coefficients of short-run cointegration. The long-run coefficient and mean group estimator (MGE) are given as under:

$$\hat{\pi}_{CD-ARDL,i} = \frac{\sum_{I=0}^{pz}\hat{\gamma}_{Ii}}{1 = \ \Sigma_{I=0}}\ \hat{\varphi}_{I,t} \tag{5}$$

$$\hat{\hat{\pi}}_{MG} = \frac{1}{N}\ \sum_{i=1}^{N} \hat{\pi}_i \tag{6}$$

The approximated short-term coefficients are provided as:

$$\Delta W_{it} = \vartheta_i[W_{i,t-1} - \pi_i Z_{i,t-1}] - \sum_{i=0}^{pw-1} \varphi_{i,t}\Delta_i W_{i,t-1} + \sum_{i=0}^{pz} \gamma_{i,t}\Delta_i Z_{i,t-1} + \sum_{i=0}^{px} \alpha_i\overline{X}_t + \varepsilon_{i,t} \tag{7}$$

Table 2. Results of cross-sectional dependence analysis.

Variable	Test statistics
EFP	33.520***
DTR	21.889***
HDI	29.163***
GLO	18.627***
GTI	25.515***

Source: Author Estimations.

Here in this equation (7);

$$\Delta_i = t-(t-1)$$
$$\hat{\tau}_i = -(1-\sum_{i=0}^{pw}\hat{\varphi}_{i,t}) \tag{8}$$

$$\hat{\pi}_i = \frac{\sum_{i=0}^{pz}\hat{\gamma}_{i,t}}{\hat{\tau}_i} \tag{9}$$

$$\hat{\hat{\pi}}_{MG} = \frac{1}{N}\sum_{i=1}^{N}\hat{\pi}_i \tag{10}$$

Finally, this study applies Augmented Mean Group (AMG) and Common Correlated Effects Mean Groups (CCEMG) estimations for robustness checking following Sun et al. (2022).

4. Results and discussion

In panel data estimations, it is significantly required to examine the cross-sectional dependence in the data as neglecting such a trend may generate inappropriate findings later. The null hypothesis for CD assumes the non-existence of cross-sectional dependence, whereas H1 supports the presence of CD. For this reason, the findings in Table 2 report test statistics and their significance level. The results confirm that test statistics for ecological footprints, digital trade, human development index, globalization, and green technology innovations are significant at 1%, leading to accepting the H1 (CD exists in the data). It is important to note that the stated findings of the CD test are based on Pesaran (2015).

In the subsequent step, this study examines stationarity properties by applying the unit root test suggested by Pesaran (2007) and Bai et al. (2009). The empirical findings for both of these tests have been presented in Table 3. The results show an absence of stationarity at the level under Pesaran (2007) test, which supports the null hypothesis. Moreover, the lower portion of Table 3 indicates that data series have turned stationarity at the first-order difference using Bai et al. (2009) cointegration test. The findings indicate the rejection of Ho while supporting H1, concluding that there is unit root when considering structural breaks.

Table 3. Results of unit root test with & without a structural break (Pesaran, 2007).

	Level I(0)			First difference I(1)		
Variables	CIPS	M-CIPS			CIPS	M-CIPS
EFP	−2.698***	−4.512**			–	–
DTR	−3.041***	−6.559**			–	–
HDI	−4.485***	−8.182**			–	–
GLO	−3.385***	−3.526**			–	–
GTI	−3.687***	−6.178**			–	–
	Z	P_m	P	Z	P_m	P
Bai & Carrion-I-Silvestre (2009)						
EFP	0.152	0.308	19.527	−3.472***	5.159***	59.218***
DTR	0.122	0.118	23.626	−4.478***	4.112***	45.130***
HDI	0.192	0.275	21.527	−5.668***	5.373***	69.203***
GLO	0.274	0.105	20.368	−6.127***	3.527***	72.112***
GTI	0.104	0.214	17.820	−2.644***	5.074***	65.518***

Note: ** and *** represent a level of significance at 5% and 1%.
Source: Author Estimation.

Table 4. Results of slope heterogeneity analysis.

Statistics	Test value
Delta tilde	68.396***
Delta tilde Adjusted	76.152***

***represent significance level at 1%.
Source: Author Estimation.

In the third step, our study investigates whether slope heterogeneity exists with the help of a modified Swamy (1970) test. Moreover, the stated test of slope heterogeneity has been revisited by Pesaran and Yamagata (2008). One of the key reasons to identify the existence of slope heterogeneity is that neglecting such trends will generate inappropriate empirical estimations, leading to unreliable findings. This statement was justified in various studies (Murshed et al., 2021; Murshed et al., 2021). More specifically, the findings for the slope heterogeneity analysis have been presented in Table 4. The results confirm that Test values for Delta tilde and Delta tilde Adjusted were 68.396, and 76.152, with a significance level of 1%. It confirms the presence of heterogeneity in the slope coefficients while rejecting H0.

Once the data has been examined for the cross-sectional dependence, slope heterogeneity, and stationarity properties, the next step comes with the implication of a panel cointegration test based on the critical suggestions of Westerlund (2008). The null hypothesis assumes the non-existence of panel cointegration where data contains cross-sectional dependence. However, H1 indicates the presence of panel cointegration along with cross-sectional dependence. The results have been covered through three different stages (no break, mean shift, and regime shift), where the null hypothesis has been rejected and confirms the existence of panel cointegration. These findings are presented in Table 5.

The investigation of cross-sectional dependence, slope heterogeneity, and panel cointegration provides significant results in the preceding discussion. Therefore, moving toward analyzing long-run and short-run relationships between the study variables is very obvious. Table 6 cover the coefficients, t-statistics, and significance level while considering the digital trade, human development, globalization, and green

Table 5. Results of Westerlund and Edgerton (2008) panel cointegration analysis.

Test	No break	Mean shift	Regime shift
$Z_{\varphi}(N)$	−8.128***	−9.152***	−3.928***
P_{value}	(0.000)	(0.000)	(0.000)
$Z_{\tau}(N)$	−4.226***	−5.018***	−3.511***
P_{value}	(0.000)	(0.000)	(0.000)

***represent significance level at 1%.
Source: Author Estimation.

Table 6. Results of CS-ARDL analysis (Long run CS-ARDL Results).

Variables	Coefficients	t-statistics	p-values
DTR	−0.118	−5.153	***
HDI	−0.270	−2.673	**
GLO	0.448	3.431	***
GTI	−0.319	−6.950	***

Note: ** and *** represent a level of significance at 5% and 1%.
Source: Author Estimation.

technology innovations and key explanatory variables. The results show that the DTR reflects a significantly negative coefficient of 0.118 with a t-value of −5.153, indicating that digitalization of trade spurs the efficiency of host countries and helps reduce environmental footprints. Moreover, shifting trade-related activities into a digital perspective would help control the waste and low utilization of natural resources and energy from traditional sources. Such trends help improve the natural environment (Ma et al., 2022). Moreover, Li et al. (2021) also support digital trade in the economy while analyzing its role in environmental concerns like carbon emissions in China. Based on the extended STIRPAT model, it is confirmed that the impact of coal-based energy structure on carbon emission is decreasing with the presence of a digital economy. Another argument is shared by Usman et al. (2021), who claim that the digital economy helps achieve intelligent natural environment management while utilizing information technology as a significant tool. Change in trade-related activities helps reduce environmental issues like carrying capacity and scarcity of the environment (Rehman et al., 2021).

The long-run findings report the relationship between human development and EFP. The results show a significant negative coefficient of HDI (-0.270), suggesting that higher HDI helps in reducing EFP in BRICS. The literature justification for the association between human development and environmental proxies has mixed findings. For instance, Kassouri and Altıntaş (2020) investigate the MENA region for human well-being in terms of HDI and EFP over the past three decades. The empirical results observed substantial trade-offs between HDI and EFP considering the advanced-panel estimations. Authors suggest that it is crucial to achieve human well-being through which sustainable planning and environmental well-being would be established. Pata et al. (2021) investigate economies with the largest ecological footprints while considering the human development index as the key explanatory variable. One of the significant contributions is investigating the theoretical foundation of the human capital Kuznets curve, which confirms that capital development improves the natural quality while reducing EFP. Zafar et al. (2019) have investigated the role of human capital in justifying environmental sustainability. It is confirmed that sustainable consumption of natural resources would not be possible without the existence of human intellectual capital. Because capital development helps in promoting clean energy sources and ecological technologies. Besides, Ahmed et al. (2020) test the empirical linkage between human capital and ecological footprints for G7 economies. The results through CUP-FM and CUP-BC have justified that human capital helps reduce ecological burden.

Compared to DTR and HDI, globalization is positively and significantly linked with ecological footprints. More specifically, an overall increase of 0.448% in EFP has been observed due to a change in GLO. It implies that higher globalization is causing an upwards shift in the EFP, hence environmental pollution, specifically in the BRICS economies. This would suggest that globalization needs to be moved into new directions with the help of some strategic policies at a world glance so that less environmental harm would be experienced. Moreover, the direct impact of GLO on different environmental proxies has been investigated in the existing literature. In this regard, Figge et al. (2017) claim that globalization's overall index significantly increases the EFP of consumption, export, and import. Rudolph and Figge (2017) claim that social and economic globalization are essential to consider while investigating the overshoot in EFP. Miao et al. (2022) apply MMQR estimation and confirm that globalization in its financial terms reflects an indirect positive influence on the environment across middle and higher-order quantiles. Hussain et al. (2021) also claim that environmental issue has become a worldwide phenomenon for which the role of globalization cannot be neglected. Their study mainly considers the economy of Thailand over the past five decades while applying a nonlinear ARDL estimation strategy. The results show that globalization has a significant and nonlinear effect on EFP where the EKC presence is valid. Contrary to our findings, Ahmed et al. (2019) stated that globalization is not a significant determinant of EFP in the Malaysian, whereas Kirikkaleli et al. (2021) supported that globalization is positively and significantly linked with the EFP from the context of Turkish region. Our research supports the hypothesis that more globalizations tend to increase EFP in the BRICS economies.

Apart from this, the long-run findings show that green technology innovations reduce the EFP by 0.319%, for which the t-statistics justify the significant output. The negative relationship between GTI and EFP claims that more ecological innovations help reduce the dependency on natural resources like fossil fuels and coal, which control the human impacts on nature. Ahmad et al. (2020) infer that technological innovations and environmental degradation like EFP have a long-run association where such green and ecological innovations help abate environmental pollution. Sun et al. (2021) express their view of supporting eco-innovations in improving the natural environment, leading toward carbon neutrality. Shan et al. (2021) also report that environmental technologies are good sources for controlling environmental damage. Chu (2022) focused on OECD economies to check environmental technologies' impact on EFP. Data were collected from 1990 to 2015, where a long-run association exists between technological innovation and EFP. Ke et al. (2022) collected city-level data in China over the past two decades to check the efficiency of green innovation in controlling the EFP. It shows a heterogeneous effect of green innovations on EFP among different cities in China. As per the discussion, our study inferred that green technologies help resource management while reducing the EFP among BRICS.

Table 7. Moderating effect of GTI (Long run CS-ARDL results).

Variables	Coefficients	t-statistics	P-values
DTR	−0.162	−4.528	***
HDI	−0.195	−3.662	***
GLO	0.258	5.241	***
GTI	−0.294	−2.018	**
DTR*GTI	−0.313	−6.027	***
HDI*GTI	−0.352	−4.122	***
GLO*GTI	0.125	1.205	NS
CSD-statistics	–	0.658	NS

Note: ** and *** represent a level of significance at 5% and 1%, whereas NS means not significant.
Source: Author Estimation.

Table 8. Results of CS-ARDL analysis (Short-run CS-ARDL Results).

Variables	Coefficients	t-statistics	p-values
DTR	−0.086	−7.049	***
HDI	−0.192	−5.151	***
GLO	0.462	0.922	NS
GTI	−0.132	−3.110	***
ECM(-1)	−0.257	−5.720	***

Note: ** and *** represent a level of significance at 5% and 1%, whereas NS means not significant.
Source: Author Estimation.

The findings for the moderating effect of GTI have been presented in Table 7. With the interactive effect of GTI, the effect of DTR on EFP is −0.313, significant at 1%, reflecting that a better environmental outcome has generated the combined effect of digital trade and green technological innovations. The mechanism behind this significant and productive effect of DTR*GTI is that both the digital economy and green innovations may go in the same direction for reducing the environmental pollution. Considering the direct effect of DTR on EFP, the results have been found with a coefficient of −0.118 (Table 6). However, with the moderating effect, the size of the coefficient has been increased to −0.313, significant at 1%. Moreover, the interaction term between HDI and GTI reflects an overall change of −0.352 compared to the direct effect of −0.270. This moderating effect justifies that the interlinkage between human development and green technology innovations would be another sustainable solution in the form of a low ecological footprint. Moreover, the interaction effect between globalization and green innovation produces a positive but insignificant influence.

Comparatively to long-run results, the short-run findings in Table 8 show that both digital trade and human development index were negatively significant, with coefficients of -0.086 and -0.192, respectively. Similar findings have been observed under long-run results where it is justified that digital economic activities and human development are direct determinants in reducing EFP. However, the impact of globalization is positively insignificant.

Contrary to this, the effect of GTI on EFP is negatively significant, where the coefficient confirms an overall change of -0.132 in the short run. Table 9 also produces the same results with moderation in the shorter run. The error correction terms (ECT) are significantly negative, confirming the long-run stable equilibrium between model variables.

Table 9. Moderating Effect of GTI (Short-run CS-ARDL results).

Variables	Coefficients	t-statistics	p-values
DTR	−0.058	−1.260	NS
HDI	−0.157	−2.364	**
GLO	0.103	3.697	***
GTI	−0.052	−5.274	***
DTR*GTI	−0.117	−4.667	***
HDI*GTI	−0.052	−1.375	NS
GLO*GTI	0.227	1.257	NS
ECM(-1)	−0.118	−4.628	***

Note: ** and *** represent a level of significance at 5% and 1%, whereas NS means not significant.
Source: Author Estimation.

Table 10. Results of AMG & CCEMG for Robustness Check.

	(AMG)			(CCEMC)		
Dependent variables	Coefficients	t-statistics	p-values	Coefficients	t-statistics	p-values
DTR	−0.048	−3.94	***	−0.120	−3.628	***
HDI	−0.147	−6.28	***	−0.093	−4.731	***
GLO	0.169	7.60	***	0.104	2.212	**
GTI	−0.662	−5.30	***	−0.328	−4.157	***
Wald test	–	17.588	***	–	21.873	***

Note: ** and *** represent a level of significance at 5% and 1%.
Source: Author Estimation.

AMG and CCEMG approaches are applied for robustness in Table 10. Digital trade, human development, and green technology innovations show a highly negative and significant effect on EF; however, the coefficient marginally varied from CS-ARDL. Lastly, globalization increases the EFP in both estimators.

5. Conclusion and policy recommendation

A growing notion is that shifting business and trade-related activities to digital horizons can help reduce the waste of natural resources with less dependency on traditional energy sources and foreign technology spillovers. Therefore, this research has examined the role of digital trade, human development, and globalization on the ecological footprints among the BRICS economies. Advanced-panel estimations entitled the CS-ARDL model have been applied while checking for the cross-sectional dependence, slope heterogeneity, and cointegration properties. The estimations driven by a series of econometric models confirm that CD exists in the data, followed by slope heterogeneity and panel cointegration. Moreover, long-run findings through CS-ARDL demonstrate that digital trade and human development are worthwhile for managing environmental pollution in the form of low ecological footprints. It is worth noting that the digital economy and international trade under this new mechanism would help control the waste and mismanagement of natural resources and environmental footprints. At the same time, digital trade helps in technology transfer and energy conservation. It lessens the carbon emission as the development of such an economy where more reliance on digital transactions would reduce the impact of traditional energy structures, specifically coal and oil. These findings imply that promoting digital trade is imperative for sustainability, and therefore developing countries should join Information Technology Agreement (ITA) to ensure zero tax on digital traded goods. It would help to increase the trade of ICT goods in host countries. Similarly, the negative influence of globalization can be minimized through regional integration and the transfer of eco-technologies across regions using north-north and north-south cooperation. For adopting foreign technologies, reasonable human capital is imperative; thus, effective measures should be taken to improve labor quality and educational/skills level. Integrating ITA with adequate measures of human development and green transformation would help to attain green growth agenda in BRICS countries.

A few limitations have also been highlighted for the upcoming studies. The distinct effects of political, social, economic, and financial globalization can be explored. The role of other core variables can be investigated in coordination with digital trade, such as institutional governance, ecological policies, and industrialization. Lastly, a comparative analysis would help unveil the global and regional differences.

Disclosure statement

No potential conflict of interest was reported by the author.

References

Ahmad, M., Jiang, P., Majeed, A., Umar, M., Khan, Z., & Muhammad, S. (2020). The dynamic impact of natural resources, technological innovations and economic growth on ecological footprint: An advanced panel data estimation. *Resources Policy*, *69*, 101817. https://doi.org/10.1016/j.resourpol.2020.101817

Ahmed, Z., Wang, Z., Mahmood, F., Hafeez, M., & Ali, N. (2019). Does globalization increase the ecological footprint? Empirical evidence from Malaysia. *Environmental Science and Pollution Research International*, *26*(18), 18565–18582. https://doi.org/10.1007/s11356-019-05224-9

Ahmed, Z., Zafar, M. W., Ali., & S., Danish. (2020). Linking urbanization, human capital, and the ecological footprint in G7 countries: An empirical analysis. *Sustainable Cities and Society*, *55*, 102064., https://doi.org/10.1016/j.scs.2020.102064

Ahmed, Z., Zhang, B., & Cary, M. (2021). Linking economic globalization, economic growth, financial development, and ecological footprint: Evidence from symmetric and asymmetric ARDL. *Ecological Indicators*, *121*, 107060. https://doi.org/10.1016/j.ecolind.2020.107060

Assessment Millennium Ecosystem. (2005). *Ecosystems and human well-being: Wetlands and water*. World resources institute.

Bai, J. (2009). Panel data models with interactive fixed effects. *Econometrica*, *77*(4), 1229–1279.

Bai, J., & Carrion-I-Silvestre, J. L. (2009). Structural changes, common stochastic trends, and unit roots in panel data. *Review of Economic Studies*, *76*(2), 471–501. https://doi.org/10.1111/j.1467-937X.2008.00530.x

Barbier, E. B., & Hochard, J. P. (2018). Land degradation and poverty. *Nature Sustainability*, *1*(11), 623–631. https://doi.org/10.1038/s41893-018-0155-4

Bekun, F. V., Alola, A. A., & Sarkodie, S. A. (2019). Toward a sustainable environment: Nexus between CO2 emissions, resource rent, renewable and nonrenewable energy in 16-EU countries. *Science of the Total Environment*, *657*, 1023–1029. https://doi.org/10.1016/j.scitotenv.2018.12.104

Chien, F., Kamran, H. W., Nawaz, M. A., Thach, N. N., Long, P. D., & Baloch, Z. A. (2022). Assessing the prioritization of barriers toward green innovation: small and medium enterprises Nexus. *Environment, Development and Sustainability*, *24*(2), 1897–1927. https://doi.org/10.1007/s10668-021-01513-x

Chien, F., Sadiq, M., Kamran, H. W., Nawaz, M. A., Hussain, M. S., & Raza, M. (2021). Co-movement of energy prices and stock market return: Environmental wavelet nexus of COVID-19 pandemic from the USA. *Environmental Science and Pollution Research*, *28*(25), 32359–32373. https://doi.org/10.1007/s11356-021-12938-2

Chu, L. K. (2022). Determinants of ecological footprint in OCED countries: Do environmental-related technologies reduce environmental degradation? *Environmental Science and Pollution Research International*, *29*(16), 23779–23793. https://doi.org/10.1007/s11356-021-17261-4

Ciocoiu, C. N. (2011). Integrating digital economy and green economy: Opportunities for sustainable development. *Theoretical Empirical Researches in Urban Management*, *6*(1), 33–43.

DeLonge, M. S., Miles, A., & Carlisle, L. (2016). Investing in the transition to sustainable agriculture. *Environmental Science & Policy*, *55*, 266–273. https://doi.org/10.1016/j.envsci.2015.09.013

Dong, H., Li, P., Feng, Z., Yang, Y., You, Z., & Li, Q. (2019). Natural capital utilization on an international tourism island based on a three-dimensional ecological footprint model: A case study of Hainan Province, China. *Ecological Indicators*, *104*, 479–488. https://doi.org/10.1016/j.ecolind.2019.04.031

Figge, L., Oebels, K., & Offermans, A. (2017). The effects of globalization on Ecological Footprints: An empirical analysis. *Environment, Development and Sustainability*, *19*(3), 863–876. https://doi.org/10.1007/s10668-016-9769-8

Gao, C., Zhu, S., An, N., Na, H., You, H., & Gao, C. (2021). Comprehensive comparison of multiple renewable power generation methods: A combination analysis of life cycle assessment and ecological footprint. *Renewable and Sustainable Energy Reviews*, *147*, 111255. https://doi.org/10.1016/j.rser.2021.111255

Hussain, H. I., Haseeb, M., Kamarudin, F., Dacko-Pikiewicz, Z., & Szczepańska-Woszczyna, K. (2021). The role of globalization, economic growth and natural resources on the ecological footprint in Thailand: Evidence from nonlinear causal estimations. *Processes*, *9*(7), 1103. https://doi.org/10.3390/pr9071103

Jiang, X. (2020). Digital economy in the post-pandemic era. *Journal of Chinese Economic and Business Studies*, *18*(4), 333–339. https://doi.org/10.1080/14765284.2020.1855066

Kassouri, Y., & Altıntaş, H. (2020). Human well-being versus ecological footprint in MENA countries: a trade-off? *Journal of Environmental Management*, *263*, 110405. https://doi.org/10.1016/j.jenvman.2020.110405

Ke, H., Dai, S., & Yu, H. (2022). Effect of green innovation efficiency on ecological footprint in 283 Chinese Cities from 2008 to 2018. *Environment, Development and Sustainability*, *24*(2), 2841–2860. https://doi.org/10.1007/s10668-021-01556-0

Kirikkaleli, D., Adebayo, T. S., Khan, Z., & Ali, S. (2021). Does globalization matter for ecological footprint in Turkey? Evidence from dual adjustment approach. *Environmental Science and Pollution Research International*, *28*(11), 14009–14017. https://doi.org/10.1007/s11356-020-11654-7

Li, Y., Yang, X., Ran, Q., Wu, H., Irfan, M., & Ahmad, M. (2021). Energy structure, digital economy, and carbon emissions: Evidence from China. *Environmental Science and Pollution Research International*, *28*(45), 64606–64629. https://doi.org/10.1007/s11356-021-15304-4

Lin, D., Hanscom, L., Murthy, A., Galli, A., Evans, M., Neill, E., Mancini, M., Martindill, J., Medouar, F.-Z., Huang, S., & Wackernagel, M. (2018). Ecological footprint accounting for countries: Updates and results of the National Footprint Accounts, 2012–2018. *Resources*, *7*(3), 58. https://doi.org/10.3390/resources7030058

Long, X., Yu, H., Sun, M., Wang, X.-C., Klemeš, J. J., Xie, W., Wang, C., Li, W., & Wang, Y. (2020). Sustainability evaluation based on the three-dimensional ecological footprint and human development index: A case study on the four island regions in China. *Journal of Environmental Management*, *265*, 110509. https://doi.org/10.1016/j.jenvman.2020.110509

Ma, Q., Khan, Z., Tariq, M., IŞik, H., & Rjoub, H. (2022). Sustainable digital economy and trade adjusted carbon emissions: Evidence from China's provincial data. *Economic Research-Ekonomska Istraživanja*, 1–17.

Miao, Y., Razzaq, A., Adebayo, T. S., & Awosusi, A. A. (2022). Do renewable energy consumption and financial globalisation contribute to ecological sustainability in newly industrialized countries? *Renewable Energy*. *187*, 688–697. https://doi.org/10.1016/j.renene.2022.01.073

Moyer, J. D., & Bohl, D. K. (2019). Alternative pathways to human development: Assessing trade-offs and synergies in achieving the sustainable development goals. *Futures*, *105*, 199–210. https://doi.org/10.1016/j.futures.2018.10.007

Murshed, M., Haseeb, M., & Alam, M. (2021). The Environmental Kuznets Curve hypothesis for carbon and ecological footprints in South Asia: The role of renewable energy. *GeoJournal*, *87*, 2345–2372.

Murshed, M., Rahman, M., Alam, M. S., Ahmad, P., & Dagar, V. (2021). The nexus between environmental regulations, economic growth, and environmental sustainability: linking environmental patents to ecological footprint reduction in South Asia. *Environmental Science and Pollution Research International*, *28*(36), 49967–49988.

Muthu, S. S. (2021). *Assessment of ecological footprints*. Springer.

Pata, U. K. (2021). Linking renewable energy, globalization, agriculture, CO2 emissions and ecological footprint in BRIC countries: A sustainability perspective. *Renewable Energy*. *173*, 197–208. https://doi.org/10.1016/j.renene.2021.03.125

Pata, U. K., Aydin, M., & Haouas, I. (2021). Are natural resources abundance and human development a solution for environmental pressure? Evidence from top ten countries with the largest ecological footprint. *Resources Policy*, *70*, 101923. https://doi.org/10.1016/j.resourpol.2020.101923

Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics*, *22*(2), 265–312. https://doi.org/10.1002/jae.951

Pesaran, M. H. (2015). Testing weak cross-sectional dependence in large panels. *Econometric Reviews*, *34*(6–10), 1089–1117. https://doi.org/10.1080/07474938.2014.956623

Pesaran, M. H., & Yamagata, T. (2008). Testing slope homogeneity in large panels. *Journal of Econometrics*, *142*(1), 50–93. https://doi.org/10.1016/j.jeconom.2007.05.010

Rappitsch, C. (2017). *Digital economy and sustainability*. OIKOS.

Razzaq, A., Sharif, A., Najmi, A., Tseng, M.-L., & Lim, M. K. (2021). Dynamic and causality interrelationships from municipal solid waste recycling to economic growth, carbon emissions and energy efficiency using a novel bootstrapping autoregressive distributed lag. *Resources, Conservation Recycling*, *166*, 105372. https://doi.org/10.1016/j.resconrec.2020.105372

Rees, W., Wackernagel, M., & Testemale, P. (1996). *Our ecological footprint: Reducing human impact on the Earth*. New Society Publishers.

Rehman, A., Ma, H., Ozturk, I., Ahmad, M., Rauf, A., & Irfan, M. (2021). Another outlook to sector-level energy consumption in Pakistan from dominant energy sources and correlation with economic growth. *Environmental Science and Pollution Research International*, *28*(26), 33735–33750.

Rudolph, A., & Figge, L. (2017). Determinants of Ecological Footprints: What is the role of globalization? *Ecological Indicators*, *81*, 348–361. https://doi.org/10.1016/j.ecolind.2017.04.060

Sala, S., Farioli, F., & Zamagni, A. (2013). Progress in sustainability science: lessons learnt from current methodologies for sustainability assessment: Part 1. *The International Journal of Life Cycle Assessment*, *18*(9), 1653–1672. https://doi.org/10.1007/s11367-012-0508-6

Sarkodie, S. A., Adams, S., Owusu, P. A., Leirvik, T., & Ozturk, I. (2020). Mitigating degradation and emissions in China: The role of environmental sustainability, human capital and renewable energy. *The Science of the Total Environment*, *719*, 137530. https://doi.org/10.1016/j.scitotenv.2020.137530

Shan, S., Genç, S. Y., Kamran, H. W., & Dinca, G. (2021). Role of green technology innovation and renewable energy in carbon neutrality: A sustainable investigation from Turkey. *Journal of Environmental Management*, *294*, 113004. https://doi.org/10.1016/j.jenvman.2021.113004

Smith, H. E., Ryan, C. M., Vollmer, F., Woollen, E., Keane, A., Fisher, J. A., Baumert, S., Grundy, I. M., Carvalho, M., Lisboa, S. N., Luz, A. C., Zorrilla-Miras, P., Patenaude, G., Ribeiro, N., Artur, L., & Mahamane, M. (2019). Impacts of land use intensification on human wellbeing: Evidence from rural Mozambique. *Global Environmental Change*, *59*, 101976. https://doi.org/10.1016/j.gloenvcha.2019.101976

Song, M., Fisher, R., & Kwoh, Y. (2019). Technological challenges of green innovation and sustainable resource management with large scale data. *Technological Forecasting and Social Change*, *144*, 361–368. https://doi.org/10.1016/j.techfore.2018.07.055

Sun, Y., Duru, O. A., Razzaq, A., & Dinca, M. S. (2021). The asymmetric effect eco-innovation and tourism towards carbon neutrality target in Turkey. *Journal of Environmental Management*, *299*, 113653. https://doi.org/10.1016/j.jenvman.2021.113653

Sun, Y., Ajaz, T., & Razzaq, A. (2022). How infrastructure development and technical efficiency change caused resources consumption in BRICS countries: Analysis based on energy, transport, ICT, and financial infrastructure indices. *Resources Policy*, *79*, 102942. https://doi.org/10.1016/j.resourpol.2022.102942

Swamy, P. A. (1970). Efficient inference in a random coefficient regression model. *Econometrica*, *38*(2), 311–323. https://doi.org/10.2307/1913012

Török, Á., & Konka, B. (2018). Episode or hysteresis? Some theoretical and policy lessons from the crisis of 2008. *Acta Oeconomica*, *68*(s2), 45–70. https://doi.org/10.1556/032.2018.68.s2.3

Usman, A., Ozturk, I., Hassan, A., Zafar, S. M., & Ullah, S. (2021). The effect of ICT on energy consumption and economic growth in South Asian economies: An empirical analysis. *Telematics and Informatics*, *58*, 101537. https://doi.org/10.1016/j.tele.2020.101537

Wackernagel, M., Galli, A., Hanscom, L., Lin, D., Mailhes, L., & Drummond, T. (2018). Ecological footprint accounts: principles 1. In *Routledge handbook of sustainability indicators* (pp. 244–263). Routledge.

Westerlund, J. (2008). Panel cointegration tests of the Fisher effect. *Journal of Applied Econometrics*, *23*(2), 193–233.

Westerlund, J., & Edgerton, D. L. (2008). A simple test for cointegration in dependent panels with structural breaks. *Oxford Bulletin of Economics and Statistics*, *70*(5), 665–704. https://doi.org/10.1111/j.1468-0084.2008.00513.x

Yang, B., Usman, M., & Jahanger, A. (2021). Do industrialization, economic growth and globalization processes influence the ecological footprint and healthcare expenditures? Fresh insights based on the STIRPAT model for countries with the highest healthcare expenditures. *Sustainable Production and Consumption*, *28*, 893–910. https://doi.org/10.1016/j.spc.2021.07.020

Yilanci, V., & Gorus, M. S. (2020). Does economic globalization have predictive power for ecological footprint in MENA counties? A panel causality test with a Fourier function. *Environmental Science and Pollution Research International*, *27*(32), 40552–40562.

Yue, S., Shen, Y., & Yuan, J. (2019). Sustainable total factor productivity growth for 55 states: An application of the new malmquist index considering ecological footprint and human development index. *Resources, Conservation and Recycling*, *146*, 475–483. https://doi.org/10.1016/j.resconrec.2019.03.035

Zafar, M. W., Zaidi, S. A. H., Khan, N. R., Mirza, F. M., Hou, F., & Kirmani, S. A. A. (2019). The impact of natural resources, human capital, and foreign direct investment on the ecological footprint: The case of the United States. *Resources Policy*, *63*, 101428. https://doi.org/10.1016/j.resourpol.2019.101428

Zhong, W., & Jiang, T. (2021). Can internet finance alleviate the exclusiveness of traditional finance? Evidence from Chinese P2P lending markets. *Finance Research Letters*, *40*, 101731. https://doi.org/10.1016/j.frl.2020.101731