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RESEARCH ARTICLE

Meditation for role of productive capacities and green investment on ecological footprint in BRI countries

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Abstract

The Belt and Road Initiative (BRI) is a development strategy with a focus on enhancing connectivity, promoting economic growth, and improving people's livelihoods. However, it has also raised concerns about its effect on the environment. This study explores the impact of productive capacities and green investment in mitigating the ecological footprint of BRI countries. The role of productive capacities on ecological footprint is very little discussed in earlier studies. This study investigates the effect of productive capacities index and green investment on ecological footprint for 42 BRI participating countries covering the time span of 2000-2018. Different methods are applied to tackle the problem of dependence of cross sections; then Lagrange multiplier bootstrap method is applied to find co-integration. The long run relationship is uncovered by "augmented mean group" (AMG) and "common correlated effects mean group" (CCEMG). The findings of the study show that both productive capacities and green investment have a significant negative impact on ecological footprint, depicting that promoting sustainable development and environmental protection is feasible through increasing productive capacities and investing in green technologies. The findings of this study have important implications for policymakers, who should focus on promoting sustainable environment by prioritizing productive capacities and green technologies.

Keywords Ecological footprint · Productive capacities · Green investment · BRI countries

Introduction

The Belt and Road Initiative (BRI) is a significant development project, aimed at connecting countries in Asia, Europe, and Africa through infrastructure development, trade, and investment. However, this initiative has raised concerns about its potential negative impact on the environment and climatic changes. Climatic changes have posed serious threats to human's ability to survive and progress. These climatic changes are causing the extreme weather, food shortages, and ecological degradation (Abid 2016). The Paris Agreement was endorsed by conference attendees in December 2015, and they also recognized the importance of global warming and carbon emissions (Zhao et al. 2021).

The economic activities are causing the environmental threats, so both developing and developed countries are struggling hard to maintain a balance between environmental and economic goals. Currently, there is an increasing awareness among various sectors of society, including global organizations, policymakers, and researchers, regarding the need to decrease the impacts of climate change (Caglar and Mert 2022). As a result, policymakers are compelled to set growth targets for environmental sustainability in response to the rising levels of environmental degradation (Caglar et al. 2022). On the one side, countries have been able to create essential infrastructure, combat poverty, and raise the living standard of people due to global economic growth. On the other side, natural capital is destroyed extensively on behalf of rapid economic advancement through biodiversity loss, land degradation, water and air pollution, and deterioration of energy resource (Alvarado et al. 2021; Pata 2021; Langnel and Amegavi 2020). These problems coexist with social instability, the depletion of natural assets, and an increase in usage of energy. It is estimated that the energy use and production sector are responsible for 25 percent of worldwide pollution (Shahbaz et al. 2022). Governments

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are therefore developing and implementing the policies to slow down the environmental deterioration and tackling the issues related to the environment (Charfeddine 2017; Madni and Anwar 2020). Nevertheless, in spite of attempts to lower carbon emissions and energy use, several nations are vulnerable in reducing their ecological footprint (Saud et al. 2020). Due to climatic changes and global warming, a sizable portion of earth residents are facing multiple problems like fatal diseases, famine, water shortages, and floods (Ahmad et al. 2022; Adekoya et al. 2021; Dagar et al. 2021; Jahanger 2021; Khan et al. 2021a, b; Ouyang et al. 2022). There is a broad agreement that rising global warming trends have forced the policymakers for mitigation of climate change strategies to clean up the environment.

Since carbon dioxide accounts for the biggest part of greenhouse gases, it is frequently used as a proxy of environmental deterioration (Kamal et al. 2021). However, many researchers argue that carbon emissions are only a small portion of the whole ecosystem and inadequately capture environmental degradation. Nathaniel and Khan (2020) are of the view that carbon emissions are not an appropriate proxy to measure environment quality because it does not accurately forecast stock of existing resources like soil, gas, timber, and oil. We require an alternate variable that can fully account for environment describing a more comprehensive approach to measure the environmental quality for policymakers and concerned quarters. So the ecological footprint (EF) seems a more suitable proxy of the environment that can be used for management and assessment of natural resources (Khan et al. 2021a, b; Qian and Madni 2022).

The increasing ecological footprint of human activities has been a major concern for many years. Human activities like urbanization and industrialization have led to overuse of natural resources and environmental degradation. Unfortunately, the world's ecological footprint has been increasing at an alarming rate.

Figure 1 shows that since 1961, the use of natural resources such as food, water, cropland, fisheries, and fuel has caused the world's ecological footprint to triple, exceeding the Earth's bio capacity or ability to regenerate what is used, every year since 1971. This rising ecological footprint has led to significant losses for the environment. Natural resources are being depleted at an unsustainable rate, and the environment is being polluted by the waste generated by human activities. Climate change, caused in part by the burning of fossil fuels, is leading to rising temperatures, severity of extreme weathers, and rising sea level. Loss of biodiversity, deforestation, and desertification are also significant consequences of the rising ecological footprint. The losses caused by the rising ecological footprint have significant implications for human well-being. The depletion of natural resources threatens food security, while pollution and climate change lead to health problems and reduced quality

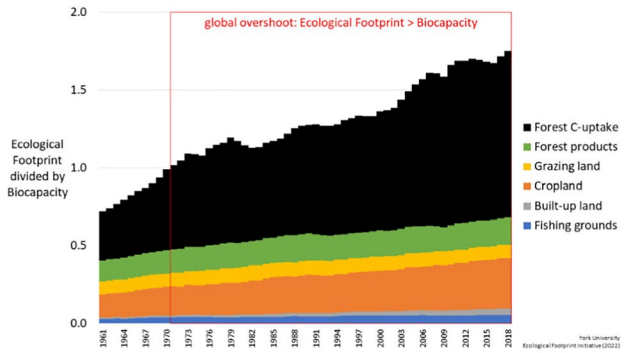

Fig. 1 Global trends of EF. Source: https://euc.yorku.ca/news-story/york-universitys-ecological-footprint-data-shows-worlds-footprint-has-tripled/ (accessed on March 19, 2023)

of life. The loss of biodiversity, deforestation, and desertification also have significant economic consequences, affecting industries such as agriculture, forestry, and tourism.

The productive economic structure of countries may play its role for environment (Can et al. 2021; Apergis et al. 2018). This structure is based on knowledge; skills of the economies are the factors that can have a major effect on the environment (Can and Gozgor 2017; Doğan et al. 2019). Numerous factors like trade diversification, export concentration, industrial structure, and economic complexity are used in the literature to describe the productive economic structure. The United Nations (UN) introduced the Product Capacities Index (UNCTAD 2021), which shows the productive economic structures of nations comprehensively. The productive capacities are the base of a nation's growth and structural transformation, representing its capacity for production of services and goods (UNCTAD 2006). Productive capacities and ecological footprint are interconnected through economic development and growth. As countries strive for economic development, they tend to consume more natural resources, which leads to increasing EF. The comparison of country groups for productive capacities index is shown in Fig. 2, which shows a rising trend of PCI with the passage of time.

Rising productive capacities index can have several benefits for the environment (Doğan et al. 2019). Firstly, it can lead to the adoption of more sustainable production practices, such as resource-efficient production processes, use of renewable energy sources, and waste reduction techniques. This can result in a reduction of greenhouse gas emissions and other pollutants, leading to improved air and water quality. Secondly, a higher productive capacities index can lead to increased investment in clean technology and innovation. This can lead to the development of new, environmentally friendly products and processes, as well as the improvement of existing ones. Thirdly, a higher productive capacities index can also result in the creation of new jobs in the

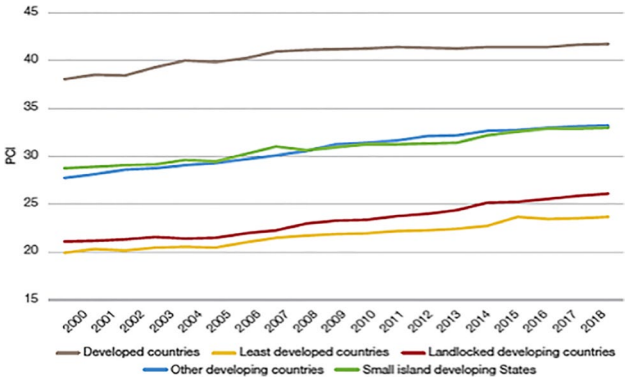

Fig. 2 PCI of Country Groups. Source: UNCTAD (2021)

green economy. This may be helpful to increase growth and reduction in poverty and in improving social welfare. Overall, rising productive capacities index can contribute to the transition towards a more sustainable and resilient economy, while also promoting environmental protection and social welfare (Can et al. 2021).

However, it is possible to attain higher levels of economic growth and development without environmental deterioration through green investment. Green investment refers to investment in renewable and sustainable energy sources, technologies, and practices that minimize the effect on environment (Baloch et al. 2019). By investing in green technologies and sustainable practices, countries can reduce their ecological footprint and achieve sustainable economic growth (Husnain et al. 2022). Green investment reduces EF as it promotes the usage of renewable energy, green technology, and sustainable practices (Caglar 2022). This can lead to a decrease in the consumption of nonrenewable resources and the emission of harmful pollutants, ultimately reducing the ecological footprint (Anser et al. 2021). In addition, green investment can also stimulate economic growth and job creation (Caglar and Ulug 2022), leading to an increase in productive capacities. On the other hand, a high ecological footprint can signal the need for more green investment. This can create an incentive for policymakers and investors to prioritize green investment and shift towards sustainable development. Thus, the relationship between EF and green investment can be seen as a feedback loop, where one drives the other towards sustainable development. There is a dire need to examine the mutual relationship of ecological footprint, productive capacities, and green investment for BRI countries as there is hardly any study exploring this relationship.

There are a lot of valid reasons why this study is being conducted for BRI nations. The Chinese report depicts that "65 countries will actively engage in the BRI, including 24 from Europe, 15 from North Africa and the Middle East, and 26 from Asia, 30% of the world's GDP and 4.4 billion people are involved in this venture, 48 additional countries, in addition to these 65, have expressed a desire to actively engage in the BRI project" (Qian and Madni 2022). The State Information Center, however, welcomed 71 collaborating countries in 2017 and committed an investment of US$ six trillion. However, BRI countries are modernizing their industrial sector, so there is a huge rise in consumption of energy. The major energy sources are fossil fuels and combustion of fossil fuels in these countries which are causing global warming (Gurgul and Lach 2014). From the beginning of this project to 2019, "China invested US$760 billion, of which 39% went to the energy industry, about 26% to transportation, and 7% to metal. Regarding natural resources, the BRI nations generate 74.69% of the world's coal, 53.82% of its natural gas, and 55.17 percent of its known crude oil reserves" (Qian and Madni 2022). These nations contribute 35% of world trade and 31% of the world's GDP. Additionally, this initiative is responsible for 28% of CO_2 emission and an increase of 2°C across the globe. Carbon emissions are expected to rise by 66% in 2050, if this project proceeds as planned (Baloch et al. 2019). The BRI economies have significant economic importance as a result of their global and economic links. The investments are necessary to promote economic prosperity and progress for BRI nations (Ahmad et al. 2020), and technical progress is possible through mutual cooperation. But this economic integration might cause the environment to get worse. BRI economies are not ignoring the issue of environment as a result of this economic expansion, so massive research is carried out to overcome the issue of environmental deterioration. To encourage growth, natural resources must be used effectively (Kang et al. 2016; Akadiri et al. 2019; You and Lv 2018). Green investments can increase the distribution and efficiency of natural resources, as well as their capacity and longevity, helping us move toward sustainable development (Ahmad et al. 2020).

The reliance on fossil fuels and requirement of sufficient time to mature the renewable resources are significant challenges that may be addressed through productive capacities and green investment. The prior literature has overlooked this issue and concentrated solely on the research and development budgets of renewable energy. This paper fills this gap by investigating the effects of productive capacities on EF in the 42 BRI member countries between 2000 and 2018. Policy makers, governments, and public will benefit from a thorough knowledge of the study's findings in order to devise a better policy framework and awareness about the factors affecting the environment. Additionally, they will be able to foresee the role that green investments and productive capacities will play in reducing environmental footprints. Second, this study employs various techniques of estimations and robustness testing which are very little used in the literature. These techniques assist to get precise and unbiased conclusions.

Literature review and theoretical relationship

Since the foundational research by Grossman and Krueger (1991), the field of environmental economics has gained significant attention. The Environmental Kuznets Curve (EKC) hypothesis is commonly expressed through 2nd and 3rd degree equations, although the literature mostly utilizes the quadratic equation in cases of short data length and a high number of variables. The EKC mainly focuses on GDP, but to avoid omitted variable bias, many controlled variables may be added (Caglar 2022). Productive capacities index is a variable which has a strong theoretical relationship to affect the environmental quality of a country. The UN-created productive capacities index (PCI) is made up of 46 indicators, eight of which are major components, such as "i) information and communication technology, ii) structural change, iii) natural capital, iv) human capital, v) energy, vi) transport, vii) private sector, and viii) institutions" (UNCTAD 2021). It might be argued that PCI is the extensive and detailed variable ever known to evaluate the productivity of economies. When this index has a high value, it means that a country's economic structure is productive, while lower values of PCI represent lower economic productivity. Each of the sub-parameter of the productive capacities index has a connection with environmental quality which is explained below.

ICT, or information and communication technology, is a fundamental component of PCI. ICT includes the penetration levels of internet, telephones, mobile phones, etc., and earlier literature highlights its impact on productivity and economic growth (Qureshi and Najjar 2017). ICT also has the ability to have an impact on the environment. ICT boosts efficiency, lowers energy consumption, and hence lowers CO_2 emissions across a wide range of industries, particularly in the logistics and transportation sectors (Chatti 2021; Wang et al. 2015). Additionally, a key factor in determining whether environmental quality is improving or declining is the structural shift in the economy. Because the demand for energy rises as the economy shifts from agricultural to industry, countries mostly engage in energy-intensive heavy industry at this time. As a result, this phase might negatively affect the ecosystem. The shift to a high technology production structure occurs in the next stage, which results in a decrease in energy use and improving the environment (Yuan et al. 2009). So economic models excluding natural capital fail to include the contribution of natural capital in the production process. Both productivity growth and sustainable economic development depend heavily on natural capital (Brandt et al. 2017). The environmental quality may be impacted by natural resources. Numerous studies have demonstrated how human capital influences economic growth both directly and indirectly through raising productivity (Fafchamps and Quisumbing 1999). Until a certain point is achieved, humans increase the consumption of nonrenewable energy resources and pollutant emission. When this point is reached, environmental knowledge grows, eco-friendly technology is used more frequently, and CO_2 emissions are decreased (Khan 2020).

It is extremely challenging to utilize energy for productive purposes with inadequate structural foundations. Particularly, lack of energy availability in rural areas restricts the economy's overall output potential, makes it difficult for businesses to produce competitively, and hinders their ability to export. Energy performance is considered an essential component of equitable and sustained growth (Ahmad and Zhang 2020). Energy use will decrease as energy efficiency improves, which will help lessen environmental damage. The convenience of transportation is a key factor in assuring energy efficiency. By significantly boosting regional productivity, investments in transportation infrastructure promote economic growth by saving time and money (Alotaibi et al. 2021). Less energy is consumed, and less pollution is produced as a result of this improvement. As transportation boosts production on the one hand, its dependency on fossil fuels also raises the possibility of increased environmental contamination (Santos 2017).

The development and extension of productive capacities are affected by the private sector. This relation can be much more expansive than what the people can handle when resources are limited. The private sector boosts productivity with creation of jobs and income for people, offers services and goods, increases revenue for the government, and contributes significantly to the advancement of technology (Hancock et al. 2011). Environmental pollution may be controlled by increased importance of private sector in economic activity that uses the resources efficiently as compared with the government (Talukdar and Meisner 2001). Given the importance of private activities regarding business in addressing human demands, it may be beneficial for the environment (Rashed and Shah 2021).

The literature on institutions generally views them as a combination of both informal and formal constraints. The impact of institutions on economic activities is the main subject of these studies. Poor institutional quality, according to studies, inhibits the productive potential of poor economies, prevents the realization of their potential, and is a barrier for the enrichment of these countries (Casson et al. 2010). According to studies, institutions can boost productivity with the help of supervisory and regulatory rules and significantly lower CO_2 emissions (Bhattacharya et al. 2017).

The use of nonrenewable energy is harming the ecosystems and is acknowledged in earlier studies on the

topic of Environment Kuznets Curve (Sinha and Shahbaz 2018). Countries prioritize protection of the environment while adopting mitigation strategies for climate change, so renewable energy plays a vital role. Because energy usage increases production capacity of industry and dependence on sources of cleaner energy sources are inevitable, so green investment is more suitable as compared with investment in nonrenewable energy sources. The report of 2020 by the UN Industrial Development states "the energy consumption in transitional and emerging nations would increase by 50% over the next 25 years, growing from 1.8 to 3.1 in the industrial sector," while annual report 2020 by International Energy Agency states the industrial sector may also lower energy intensity by 26% by declining 8% global energy consumption along with a 12.4% decrease in carbon emission. Investments in green manufacturing promote economic growth and help to reduce CO_2 emission.

Globalization is categorized as removal of barriers to the movement of goods and services, physical, and human capital across the borders and considered as a key factor of GDP and environment (Nathaniel and Khan 2020). The literature claims that globalization is a source of economic growth (Shahzad et al. 2020) due to its connectivity among economies through commerce, FDI, productivity, technology, and capital. The prior literature examined the impact of globalization on environmental quality in great detail, but they could not agree on the precise role for the environment. For example, Shahzad et al. (2020) studied how environmental performance is affected by globalization and concluded that it has a beneficial effect. Although research showed the detrimental consequences of globalization on the environment, there is still disagreement and there is no clear consensus on this issue (Bashir et al. 2020). It is essential to distinguish environmental degradation from the trend of increased energy consumption since globalization is enhancing the growth while economic growth is associated with consumption of energy. It is critical to comprehend the connections between ecological footprint and globalization. Therefore, the present study also looks at how environmental footprint, productive capacities, green investment, globalization, and growth affect economies are involved in BRI.

Methodology

Data and model

The framework of stochastic impact through regression on population, affluence, and technology (STIRPAT) was developed by Dietz and Rosa (1994). The general form of the STIRPAT approach can be described as follows:

$$I_{it} = \varphi P_{it}^{\propto 1} A_{it}^{\propto 2} T_{it}^{\propto 3} \varepsilon_{it} \quad \text{(i)}$$

In Equation (i), I represents the influence proxied by ecological footprint, P shows the population proxied by productive capacities, A shows the affluence proxied by economic growth, and T shows the technology proxied by green investment. Moreover, φ shows intercept, i is sample countries, $\propto$ represent the coefficients, t is time period, and ϵ is error term. The globalization is also incorporated in STIRPAT approach, so the equation becomes

$$I_{it} = \varphi P_{it}^{\propto 1} A_{it}^{\propto 2} T_{it}^{\propto 3} GLO_{it}^{\propto 4} \varepsilon_{it} \quad \text{(ii)}$$

Now the final equation for empirical analysis is written as

$$EFT_{it} = \varphi + \alpha_1 PCI_{it} + \alpha_2 GRI_{it} + \alpha 3 EGR_{it} + \alpha_4 GLO_{it} + \epsilon_{it} \quad \text{(iii)}$$

where α_0 is an intercept while α_1-α_4 represent the long run coefficients of PCI, GRI, EGR, and GLO. The EFT, PCI, GRI, EGR, and GLO represent the ecological footprint, productive capacities index, green investment, economic growth, and globalization, respectively. The EFT is measured in global hectares per person gained from "global footprint network," PCI is gained from "United Nations Conference on Trade and Development" (UNCTAD), green investment is measured as public investment in renewable energy gained from "International Renewable Energy Agency," and data of globalization is obtained from "KOF Swiss Economic Institute" while data of economic growth is gained from the world bank. The sample consists of 42 BRI countries covering the time period from 2000 to 2018. The sample and time period is selected on the basis of availability of data. The ecological footprint measures the environmental contamination because it more effectively incorporates all impacts of energy consumption and production doings. This proxy is used extensively in the literature now days because it incorporates a comprehensive measure of the environment (Khan et al. 2021a, b; Wang et al. 2020; Miao et al. 2017). The ability of a nation to produce things and services that will aid in its growth and development is determined by its productive resources, entrepreneurial skills, and production connections. It demonstrates the elements necessary for achieving equitable and sustained economic growth as well as sustainable development. 46 indicators are used to map the set of productive capacity and their unique combinations. As a result, PCI has multidimensional analytical capabilities. The index pinpoints the aspects in which an economy may be leading or trailing, indicating which policies work and which need improvement. For each of its eight components—natural capital, human capital, ICTs, structural transformation, transport, private sector, and institutions, it offers a road map for future policy initiatives and interventions.

Green investing aims to preserve the environment (Ulucak and Lin 2017). Green growth can be achieved

by cutting-edge techniques for reducing pollutants, sustainability in consumption, and halting the loss of natural resources by encouraging green investment. Green investment is helpful for energy transition to reduce pollution and achieving objectives of sustainable development. Ecological footprint is connected with economic activities and globalization process due to technological and financial inflows causing the expansion of ecological footprint. Globalization can hurt the environment by destroying biodiversity as a result of massive economic activities, but the environment may be improved through transferring ecofriendly technology and supporting the growth of renewable energy. This study used the approach adopted from Syed et al. (2022).

Econometric methodology

This study used panel data analysis while taking into account the cross sectional dependence (CSD) among variables and residuals. The methodology of this study is adopted from Qian and Madni (2022). "Since most econometric panel techniques overlook the impact of CSD and results may be misleading for test statistics in analysis of panel data, so the necessity of econometric methods dealing with issue of CSD has been increased. Variables and residual CSD may exist, therefore it is important to monitor non - observable common elements including national policies, global shocks, political systems, and the integration of socioeconomic structure that produce inter-dependence impacts among nations. The earlier studies used many CSD methods depending on the size of cross sections and time periods" (Qian and Madni 2022). The study applied the "bias corrected scaled Lagrange Multiplier" ($CDSLM_{BC}$) by Baltagi et al. (2012), "Lagrange Multiplier test" ($CDLM_{BP}$) by Breusch and Pagan (1980) to determine the dependence of cross sections. The test statistics for null hypothesis is determined as

$$CDLM_{BP} = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} P_{ij}^2 \quad \text{(iv)}$$

$$CDSLM_{BC} = \sqrt{\frac{1}{N(N-1)}}\left[\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \left(Tp_{ij}^2 - 1\right)\right] - \frac{N}{2(T-1)} \quad \text{(v)}$$

where p_{ij}^2 represents the cross section correlation among residuals obtained by regressing the OLS for panel data. The Friedman (1937), Frees (1995), and Pesaran (2021) tests are also applied to determine the CSD in the model. Then, "cross sectional augmented Dickey-Fuller" (CADF) and "cross sectional augmented Im, Pesaran, and Shin" (CIPS) unit root test (Pesaran 2007) are used to know the integration level. The test statistics of CADF and CIPS are

$$\Delta z_{it} = \beta_i + \delta_i z_{i,t-1} + \lambda_i \bar{z}_{it-1} + \eta_i \Delta \bar{z}_{it} + \varepsilon_{it} \quad \text{(vi)}$$

$$CIPS = \frac{1}{n} \sum_{i=1}^{n} t_i\,(n,\ T) \quad \text{(vii)}$$

In the above equation, $\bar{z}_{it\text{-}1}$ is the mean of lagged values of cross section while $\Delta\, \bar{z}_{it}$ is the mean value of cross sections at first difference. First of all, stationarity tests are applied, then Lagrange multiplier bootstrap panel co-integration test (Westerlund & Edgerton 2007) is applied. This test has the ability to handle the problems of CSD and heterogeneity. In addition, equation may be estimated even in presence of heteroscedasticity and autocorrelation providing unbiased estimates.

$$LM_n^+ = \frac{1}{nT^2} \sum_{i=1}^{n} \sum_{t=1}^{T} \omega_{ij}^{-2} S_{it}^2 \quad \text{(viii)}$$

where S_{it}^2 shows the process of partial sum while ω_{ij}^{-2} represents the long run variance. The "augmented mean group" (AMG) and "common correlated effects mean group" (CCEMG) are applied to know the long run relationship. This technique has the capability to estimate in presence of CS and heterogeneity, and there is no need to determine the stationarity and co-integration before applying these methods.

Results

The econometric methods applied are in line with patterns of data. Biased and unreliable estimators come if a wrong technique is used. To avoid biased findings, this paper applied the CD test. It is widely known that the world has shrunk into a network of connected countries. Trade agreements, the financial crisis, and international conventions have all contributed to the widespread adoption of CD.

The empirical outcomes of $CDLM_{BP}$ test, $CDSLM_{BC}$ test, Frees, Pesaran, and Friedman tests are pasted in Table 1. It is revealed that cross sectional dependence is present among variables and residuals in a significant way for all tests. The outcomes of the tests highlight that there are regional and spillover effects among the selected countries.

Table 1 Cross-sectional dependence tests

	$CDLM_{BP}$	$CDSLM_{BC}$
Ecological footprint	359.53*	38.71*
Productive capacities index	409.11*	42.38*
Green investment	463.25*	50.73*
Economic growth	1043.53*	101.41*
Globalization	754.37*	77.621*

Pesaran Test: 2.28**; Frees Test: 2.95*; Friedman Test: 46.53*

* and ** show the significance level at 1% and 5%

Table 2 Stationarity tests

Variables	CIPS		CADF	
	Level	Difference	Level	Difference
Ecological footprint	−2.98	−5.73*	−2.64	−5.28*
Productive capacities index	−3.46	−5.49*	−4.36	−5.37*
Green investment	−3.10	−4.83*	−3.87	−5.46*
Economic growth	−2.49	−3.74*	−1.99	−3.86*
Globalization	−3.62	−4.81*	−3.67	−4.97*

* shows that a variable is significant at 1%.

The integrational characteristics have also prime importance in addition to CSD tests. The stationarity tests are selected on the basis of presence of CSD. If cross sectional presence is there, then second generation tests are preferred for estimation, so Pesaran's CIPS and CADF stationarity tests are applied.

The estimated results of CADF and CIPS unit root tests are pasted in Table 2. It is shown that all regressors are stationary at the first difference, so we may move towards co-integration analysis.

The estimated findings of co-integration test are highlighted in Table 3 which show the high *p*-values compared with significance level, so the presence of co-integration is confirmed among dependent and independent variables.

The estimated results of CCEMG and AMG for environmental footprint are shown in Table 4, demonstrating the significance of variables over the long term. It is found that there is a statistically significant negative relation between the PCT and ecological footprint. Ecological footprint will be reduced by 0.026 units for every unit increase in the productive capacities as shown by estimation of CCEMG while it is also similar through estimation of AMG. This effect is novel and has not been investigated before, as far as we know. The results somewhat validate the work of Can and Gozgor (2017), who employed the economic complexity index to represent the productive economic structure in their research. We can draw the conclusion that a country's level of productivity may be a factor in determining how good the environment is. The increased usage of smart devices and networks due to ICT's widespread adoption makes it possible to optimize logistics planning, supply chain management, and freight transportation. The extensive usage of the internet enables trade for producers and the globalization of information. As a result, it reduces time loss, boosts productivity, and lessens environmental pollution. Supporting ICT investments is crucial for policy makers in this regard. The findings of AMG and CCEMG also depict that green investment has negative and significant impact with ecological footprint. While globalization and growth have positive impact on EFT. It can be argued that expansion of economic activities increases the economic growth, but it is harming the environment. This expansion of economic activities enables the BRI countries to actively take part in globalization process, but conventional production technologies and traditional methods of production are causing to deteriorate the environment.

Table 3 Lagrange multiplier bootstrap panel co-integration

Constant		Constant and trend	
LM-statistic	Bootstrap *p*-value	LM-statistic	Bootstrap *p*-value
4.273	0.980	6.381	0.952

Discussion

The Paris Agreement's commitment to decrease emissions of greenhouse gases makes it possible to enact global rules. The relation between productive capacities and EFT is a complex one. On one hand, higher productive capacities may lead to higher levels of economic development, which in turn can drive improvements in environmental quality. For instance, countries with higher productive capacities are more likely to invest in cleaner technologies and to implement policies that reduce environmental harm. This can lead to a reduction in the EFT of a country. On the other side, pursuit of economic growth through productive capacities can lead to an increase in use of natural resources and energy consumption, which can drive up the ecological footprint. Theoretical frameworks, such as the environmental Kuznets curve, suggest that there may be an initial positive relation between growth and environmental deterioration, followed by a negative relationship once a certain level of development is achieved. Thus, the relation between productive capacities and EFT is likely to be nonlinear, with the strength and direction of the relationship depending on a range of factors including the level of development, the mix of industries in the economy, and the policy regarding

Table 4 Results of CCEMG and AMG estimation

Variables	Coefficients	Std. errors	*p*−values
CCEMG			
Productive capacities index	−0.026	0.013	0.003
Green investment	−0.218	0.043	0.041
Economic growth	0.392	0.164	0.002
Globalization	0.438	0.293	0.004
AMG			
Productive capacities index	−0.025	0.019	0.042
Green investment	−0.127	0.095	0.033
Economic growth	0.368	0.273	0.001
Globalization	0.042	0.022	0.008

environment. To be competing in the process of reducing carbon emissions, clean technology is required to be funded by subsidies and taxes. Governments pool funds to help the transportation industry in order to achieve transitioning of cheaper alternatives (Doğan et al. 2019). The outcomes of changing economic structures on the environmental quality are equally crucial. The adoption of renewable energy must be promoted during the transformation process to fulfill the rising demand of energy, and it ought to be viable to get the energy consumption from renewable energy resources at a quickening scale. Long-term compliance with environmental legislation will be made easier if regulatory and supervisory institutions in these nations are improved, and institutional reliability is ensured. The private sector is another target of the regulations. To lessen and avoid environmental contamination, the private and public sectors should join hands (Khan 2020).

The results of this study show that for every unit increase in green investment, the environmental footprint will be reduced by 0.28 units. It is found that green investments have a negative impact on ecological footprints so increasing green investments will improve environmental quality. The fact that green investment is beneficial in these countries shows how green investment supports environmental advances by encouraging cleaner ways of production, successfully tackling environment related problems, and promoting green growth. Moreover, "it is anticipated that rising environmental deterioration due to high economic growth would further push these economies to adopt technical innovation and pursue alternative renewable energy sources. The region will be able to achieve its goal of environmental sustainability by increasing green investment, which is the most viable direction to green economies" (Ahmed et al. 2020). The findings of Mensah et al. (2018); Khan et al. (2020a, b); Pata and Yilanci (2020) are consistent with outcomes of this study.

The estimated results highlight that growth of countries has pressure on natural resources so increasing the ecological footprint. These findings imply that the panel's chosen nations are mostly focused on increasing the productivity at the expense of environment so extensive utilization of brown production methods are on the way. As a result, a number of polluting industries are expanding in these countries. This tendency can be enlightened that as economic activity grows, so does the demand for natural resources. Therefore, countries with rapid economic development damage ecological resources by converting agricultural land to industrial use, harming wildlife inhabitants, forests loss, and excessive use of natural capital. These findings are in line with findings of Yilanci and Pata (2020); Mensah et al. 2018; Miao et al. (2017). Anser et al. (2021) also found that there exists a tradeoff between environmental deterioration and unemployment. Furthermore, it suggests that consumption of renewable energy leads to an improvement in environment, while the use of conventional energy sources has been found to be detrimental to the environment in the panel of the countries examined.

This research emphasizes the longrun connection between globalization (GLO) and ecological footprint. It is demonstrated that GLO damages the ecology by increasing the sampled countries' ecological footprint. Globalization unifies markets around the world, boosts consumer demand, and encourages industrialization, all of which result in overconsumption of resources, a drastic loss of biodiversity, and ecological deficiencies. Similar to this, due to increased energy usage in transportation and production, this energy consumption is polluting the environment. The impacts of globalization driven by international trade and FDI in industry also impede environmental and economic improvements. In countries with tight land and environmental regulations, it is claimed that globalization will discourage polluting enterprises and decreasing ecological footprint (Khan et al. 2020a, b). According to some earlier studies like Pata and Yilanci (2020), "globalization can increase economic activity with local changes while having a minimal ecological impact, given that the industrial sector is dedicated to environmental reforms. In order to create long-term environmental policies and achieve sustainable growth, it is crucial to take globalization into account while calculating the ecological footprint function" (Pata and Caglar 2021). The above debate is also supported by Wang et al. (2020); Ahmad et al. (2020).

The BRI is a project of infrastructure and development initiated by China that involves more than 100 countries across Asia, Africa, Europe, and the Middle East (Pata and Caglar, 2022). The BRI countries are also aware about environmental deterioration due to rising economic activities in the region, so energy policy is a crucial aspect of the BRI, as it seeks to develop energy infrastructure to support growth, increase energy security, and reduce CO_2 emission. China, as the main initiator of the BRI, has been promoting clean energy and low-carbon development. In 2020, China pledged to achieve carbon neutrality by 2060, and the BRI is expected to play a significant role in achieving this goal (Ouyang et al. 2022). China has been investing heavily in renewable energy sources such as solar, wind, and hydropower, and it is also developing a national carbon trading system. In addition, China has helped build power plants, transmission lines, and other energy infrastructures in many BRI countries. Pakistan is also an important participant of BRI project, and "it has set a target of generating 60% of its electricity from renewable sources by 2030" (Ahmad et al. 2022). Kazakhstan is developing its renewable energy sector, with a goal of generating 50%

of its electricity from renewable sources by 2050. The country is also exploring the use of nuclear energy, as it has significant uranium reserves. BRI countries are also implementing energy efficiency measures to reduce energy consumption and increase energy efficiency. For example, Indonesia has launched an energy efficiency program for buildings and industries to reduce energy consumption. Moreover, many BRI countries are moving away from coal and towards cleaner energy sources. Bangladesh has committed to phasing out coal power by 2050, while Vietnam aims to reduce its coal consumption and increase the share of renewable energy in its energy mix. BRI countries are also collaborating on cross-border energy projects, such as the construction of energy infrastructure and the development of renewable energy resources. For example, China and Russia are working together on the Power of Siberia pipeline project to deliver natural gas from Russia to China. Overall, the BRI countries are making significant efforts to promote sustainable and clean energy development, which could have positive impacts on both their own economies and the global environment (Ahmad et al. 2020).

Conclusion

The vision of a healthy environment is crucial to current agendas and policies. The previous few decades have seen a global push toward a sustainable environment. A variety of socioeconomic activities might lead to affect the environment. One of them is productive capacities of a country which is hardly explored in the literature for BRI countries. Growing productive capacities is identified as a significant component of attaining development progress, particularly in the least developed countries while discussing international development policy. This paper is a pioneer step to explore the effect of productive capacities on ecological footprint for a sample of 42 BRI economies. Different econometric methods are applied to check the relationship among variables and robustness of the findings. We can draw the conclusion that a country's level of productivity may be a factor in determining how good the environment is. The use of information and communication technology, efficient institutions, structural changes, and human capital are sources to increase the awareness of people for environmental risks. Moreover, economic activities are carried through environmental friendly approaches. This research indicates that green investments benefit the environment by reducing ecological footprints, but economic expansion and globalization all result in larger ecological footprints. Green investments are recognized as a way to reduce harmful impacts of economic activities.

Governments, politicians, and stake holders are advised to consider the following policy implications when developing policies for a healthier and sustainable environment. The governments of BRI nations may continue to strengthen their relations with developed economies, which are at the forefront of technological innovation, while simultaneously increasing their dependence on green technology. It will not only enhance the productive capacities of the countries but environment also. The awareness of the people for environmental deterioration and its consequences on human lives and future generations will be helpful to adopt careful attitude. The findings of the study depict that implementing policies which encourage information and communication technology, human capital, structural changes, quality institutions, and green investment may be helpful to overcome the adverse impacts on environment. In order to lessen domestic and global environmental problems, governments are advised to set up an international scientific partnership and offer incentives to private investors for green discoveries. The government should also act in a helpful manner and establish a favorable political environment encouraging investment in using modern resources to promote and use eco-friendly technologies.

Third, it is discovered that the process of globalization is directly related to environmental sustainability in these economies. To further mitigate the significant environmental repercussions of globalization, the BRI economies should consider exchanging renewable energy from developed countries, including as solar, wind, and hydropower. Additionally, governments should like to encourage FDI from nations that offer green technologies. Additionally, industries that emit pollutants above the permitted limits ought to pay high taxes. The export of energy-intensive goods and technologies should be subject to strict environmental rules adopted by these countries. These countries may impose dumping taxes on foreign partners and companies that employ outdated technology, especially those operating in the resource extraction sector.

This research makes some ground-breaking discoveries, but it also includes certain flaws that could lead to new research directions. We wanted to investigate how the production capacities index affected the ecological footprint in the sample of BRI nations. We recommend that researchers should examine the effects of PCI on a variety of environmental indicators, including carbon footprint, ecological footprint, nitrogen oxides (NOx), and sulphur oxides (SOX). Researchers can use the "Stochastic Impacts by Regression on Population, Affluence, and Technology" (STIRPAT) model to examine the effects of PCI on the environment in upcoming studies. Last but not least, the PCI sub-components may be utilized as independent variables for different country groupings, perhaps leading to fascinating literature.

Author contributions There is one single author of this paper.

Data Availability All data is freely available.

Declarations

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