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RESEARCH ARTICLE

Does financial development reinforce environmental footprints? Evidence from emerging Asian countries

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Abstract

In the preceding two decades, the expansion of financial services has played a vital role in pursuing economic growth agendas in the developing Asian nations. However, its harmful effect on environmental quality cannot be denied. In this backdrop, in the present study, we investigated whether the financial sector development moderated the ecological footprint, carbon footprint, and land footprint in the eight developing nations of South and Southeast Asia from 1990 to 2015. In doing so, we included the per capita income, energy solutions, and trade expansions as determinants of the ecological indicators. The results of the second-generation unit root tests and Westerlund's cointegration test reported the long-run stability and cointegration, respectively. To navigate the possible cross-country dependency, we employed the cross-sectional augmented autoregressive distributed lag approach (CS-ARDL). The results confirmed that per capita income, energy solutions, trade expansion, and financial sector development invigorated the ecological footprint, carbon footprint, and land footprint in the long run. Further, it is reported that the development in the financial sector has a significant moderating impact on the nexus between energy and environmental footprints. In other words, the financial sector development drove the association between the overall environmental quality and energy solutions in the long run. Similarly, we observed that the financial sector development worked as a significant mediator between environmental proxies and trade expansion. By including the ecological footprint, carbon footprint, and land footprint as environmental proxies, the study provides the wider environmental spectrum. Based on the outcomes of the study, we proposed a novel scheme, which may help to address the harmful environmental impacts of the financial sector development in the selected developing nations.

Keywords Ecological footprint · Carbon footprint · Land footprint · South Asian countries · Southeast Asian countries · Per capita income · Energy

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Introduction

The literature suggests that the liberal trade policies (Shahbaz et al. 2013) and financial sector development (Sharma and Kautish 2020b) have strengthened the economic growth process in the developing countries of South and Southeast. In support of this notion, the OECD (2018), in its report, ascertained that the emerging Southeast Asian economies have witnessed an annual per capita growth of 7.1% during 2012–2016, and in the coming 5 years, it is expected to grow at an annual rate of 6.3%. Similarly, the IMF (2017) in its report mentioned that the South Asian countries have recorded a GDP growth of 6.7%, whereas the overall economic growth of the world was merely 3.2% in the same year. Due to the profound population base and growing convergence between local and international markets, the high GDP growth is expected to be continued in both regions (OECD 2019). In this pursuit, the expansion of financial markets and the availability of cheap factor inputs have made emerging economies more attractive to foreign investors (IMF 2003). At the same time, liberal trade policies have facilitated the free movements of factor inputs such as labor, energy, technology, and financial resources across countries (Yeo and Deng 2019). As a result, the demand for imported energy resources has continuously increased in most of the developing countries of South and Southeast Asia. Despite having scarcity of domestic energy resources, the persistent increase in the demand for oil, coal, and natural gases indicates that these regions are involved in uplifting their domestic production. As per the report of IEA (2019), in comparison with the year 2000, the demand for energy in Southeast Asian countries has increased by 80%. Furthermore, compared with the global energy demand, the average energy demand in South Asia is expected to be doubled in the coming years, which in turn may lead to an increase in the demand for fossil fuel by 6% (Hou et al. 2019). In the exchange process of productive resources, the expansion of financial instruments and services has facilitated the cointegration in the local and international markets, which, in turn, has allowed the excessive consumption of imported energy resources (UNCTAD 2018).

These developments, undeniably, are necessary for the economic growth of an economy. However, more than 90% usage of nonrenewable energy resources to meet the commercial energy demand in the South (Rahman et al. 2011) and Southeast Asian countries (Munir et al. 2020) discloses the actual success story of the economic growth, as these nations are net buyers of fossil fuel. Furthermore, the excessive dependency on fossil fuel and external energy resources may have seriously harmful environmental consequences in the long run. The incessant consumption of nonrenewable solutions may soon deplete the available energy reserves, which, in turn, may increase the dependency on the other countries. At the same time, the combustion of nonrenewable energy solutions may continue to intensify environmental pollution, which, in turn, may reduce the net benefits of economic growth. Therefore, these regions may likely witness the *Limits to Growth* phenomenon and the economic growth process may be impeded by the scarcity of natural resources (Meadows et al. 1972). The ongoing pollution havoc appears to be the result of the casual approach towards environmental aspects in these regions. This is evident from the fact that the largest numbers of most polluted cities in the world are situated in the South (The Economics Times 2019) and Southeast Asian countries (The Jakarta Post 2019). Henceforth, to navigate the economic growth that led to environmental challenges, the South and Southeast Asian countries have to reengineer their future strategy where endogenous renewable energy resources can work as a catalyst to sustainable economic growth.

In this regard, the sustainable development goals like climate action (SDG-13), affordable and clean energy (SDG-7), and responsible consumption and production (SDG-11) are supportive in framing the sustainable growth strategy for both developed and developing nations (Sinha et al. 2020a, b). In the case of developing countries, a sustainable growth approach becomes even more necessary, as the long-term growth strategies in the developing regions are generally woven around the agriculture or allied industries where the possibility of environmental damages are more pronounced (Sinha and Bhattacharya 2016; Todaro and Smith 2017). Thus, these regions seriously need to promote environmentally viable endogenous energy resources. At the same time, the production processes and other necessary economic sectors such as the financial markets and international trade need to be aligned with the SDGs. Once the key sectors are mandated to follow the sustainability approach, the other associated sectors may automatically be aligned in the same direction, because the inherent interdependency among these sectors may bring forth a common approach of environmental consciousness. Therefore, to develop a sustainable growth framework, it requires investigating the long-run association between these variables.

Prompted from the above discussion, we intended to establish our study's objectives where three distinct representations for the environmental qualities are being considered. Our first objective is to assess the impacts of per capita income, energy consumption, financial development, and trade expansion on the ecological footprint in the emerging economies of South (India, Pakistan, Sri Lanka, Nepal, and Bangladesh) and Southeast Asia (Malaysia, Philippines, and Thailand) from 1990 to 2015. Thereafter, to get a better understanding of the air quality and land quality, we investigated the impacts of these variables on the carbon footprint and land footprint, respectively. Lastly, we investigated whether the financial sector development has reinforced the environmental footprints through energy consumption and trade expansion, because the development in the financial sector may tend to invigorate the trade expansion and energy consumption, which, in turn, may lead to the ecological footprint. In doing so, we investigated whether the association between energy consumption and environmental proxies (i.e., ecological, carbon, and land footprint) is influenced by the financial sector development. Similarly, we searched whether the association between trade expansion and environmental proxies is invigorated by the financial sector development. Here, by using the multiplicative interaction, we followed the conditional hypothesis procedure. By doing so, we reported the moderating effect of the financial sector development on the nexus between environmental indicators and energy consumption and environmental indicators and trade expansion. To simplify it, we examined the direct effects of the per capita income, trade expansion, and energy solutions on the various environmental footprints. Secondly, we investigated whether the development of the financial market worked as a significant mediator between environmental footprints and energy solutions, and environmental footprints, and trade expansion.

Rationality in doing so lays with the fact that besides GDP growth, these factors have also witnessed an upward trend and appear to be complementary to economic growth. By using the ecological footprint, carbon footprint, and land footprint as proxies for the environmental quality, we intended to generate a wider environmental spectrum, as a single environmental proxy may not be sufficient to scale the overall environment-related damages. Moreover, the included drivers of environmental pollution may have differentiated impacts on ecological footprint, carbon footprint, and land footprint. Thus, in terms of policy formulation, this kind of understanding may become vital and governments can put more effort to improve the quality of worst-hit indicators. Owing to the scarcity of environment-related budgets, such kinds of tradeoffs are essential to managing the available financial resources. The data unavailability forced us to exclude some of the countries in the present study. The selection of the countries and study period appears just as the pooling of high GDP growth registering Asian countries in terms of ecological footprint, carbon footprint, and land footprint has not been addressed in the past.

Our findings manifest that the ongoing production processes, financial developments, and trade expansions have intensified the ecological footprint, carbon footprint, and land footprint in the long run. Except for the land footprint, the other two footprints (i.e., ecological and carbon) have been damaged by the usage of energy resources in the eight developing economies of South and Southeast Asia. We also confirmed that the interaction of the financial sector with energy consumption and trade expansion has reinforced the environmental pollution in the long run. Based on the outcomes, we tried to develop an appropriate and sustainable long-term growth strategy where solutions to achieve the SDG-11, SDG-13, and SDG-7 are intended.

The study contributes to the literature in many ways; firstly, a parallel analysis of the ecological footprint, carbon footprint, and land footprint enables us to comprehend whether a common environmental policy will be sufficient to fortify the overall quality of the established ecosystem in these regions. Secondly, the study proposes the need for low pollution-intense techniques and energy resources where the role of the financial sector and trade policy is judicially established. Thirdly, we observed that the financial sector development could damage the environmental quality not only directly but also indirectly. Lastly, in terms of methodology or econometric techniques, we have adopted a relatively new and robust approach. The adopted augmented cross-sectional distributed lag (CS-DL) approach is advantageous than traditional approaches, as it is efficient in handling the cross-sectional dependency which is a common problem in the pooled data. Due to the distinct features of the financial sector growth in the selected countries, a single proxy for the financial sector growth was not sufficient. Therefore, by using the principal component method, we constructed an index for it where four different proxies for the financial sector growth are used.

The second section allows us to understand the existing state of the literature; thereafter, the third section is dedicated to the research methodology. In the end, the fourth and fifth sections are exhibiting the calculated results and conclusions and policy framework, respectively.

The literature survey

As we know, economic activities tend to influence the environmental quality of a region. However, certain activities may be more harmful in terms of air pollution, whereas others may have a severe impact on the land or water quality. Therefore, the examination of merely one environmental aspect is not sufficient. Saying this, the selection of the right proxy for depicting the environmental quality of a region is the most important aspect. In this regard, environmental proxies such as CO_2 emission, NO_2 emissions, and ecological footprint are often been tested in the past. However, to widen the scope for the literature examination, we have thrown light on those studies where not only CO_2 emissions but also other environmental proxies are being considered. To keep the literature examination systematic, we have divided it into sub-parts where the association of different environmental proxies with domestic production, energy consumption, financial sector development, and trade expansion has been examined.

Nexus between economic growth and environmental quality

The association between economic growth and environmental quality is not at the standstill. Starting from Kuznets (1955) to date, it is well established that their association may vary across times and regions. When an underdeveloped country starts expanding its economic growth horizons, the investment in growth-oriented programs may overtake the investment in environment and scale effect may get operative; as a result, the quality of the environment may get worsened. However, in the second stage of development, the consistently growing income level allows industries to invest in advanced and energy-efficient techniques of production, which in turn may reduce the marginal pollution level significantly (Hettige et al. 2000). About the second stage, Shahbaz et al. (2019) in his study confirmed that the operation of the second stage (i.e., the composite effect) has intensified the growth of strategic importance industries in the Middle East and North African countries, which has a positive impact on the per capita income level and environmental quality in the long run. In the third stage, once again, the applicability of the technology effect may significantly lead to environmental distortion. Here, the over-utilization of the obsolete production techniques operated with the carbon-intense energy resources may lead to an increase in marginal pollution (Álvarez et al. 2017).

In the majority of studies, the nonlinear impact of per capita income is tested through CO_2 (Iwata et al. 2012; Mazur et al. 2015) or SO_2 (Llorca and Meunié 2009; Fosten et al. 2012) emissions, whereas other proxies for the environment quality such as ecological footprint and land footprint are ignored. This shows that the positive impacts of the increasing per capita income on the ecological or land footprint are yet to witness, which is a matter of concern for the policymakers. As merely improving the air quality through development programs is not sufficient. The preservation of the overall biodiversity should be aimed through economic and environmental policies. However, by taking a sample of 93 countries, Al-Mulali et al. (2015) in their study confirmed an inverse U-shaped association between the ecological footprint and domestic production. The timely introductions of energy-saving and low-carbon intense energy resources are observed as responsible factors to reduce the ecological footprint in these countries. Similarly, the outcomes of Ulucak and Bilgili's (2018) study established an inverted U-shaped association between per capita income and ecological footprint among high, middle, and low-income countries that are considered for examination.

In contrast, some of the study unable to find out the inverted U-shaped association while considering the ecological footprint as a variable to be explained, which indicates that all regions are not able to reap the economic growth that led to ecological improvements. For example, by taking the sample of 27 highest pollution emitter nations, Uddin et al. (2017) in their study revealed that the selected countries have witnessed a significant increase in ecological footprint caused by the increased per capita income during the study period (1991–2012). Therefore, the study recommended inculcating the healthy lifestyle and production processes to reduce the negative impacts of consumption and production, respectively. Similarly, Alola et al. (2019a, b) in their study confirmed that the increase in per capita income in European countries has increased the level of the ecological footprint in the long run. The rejection or ignorance of the U-shaped EKC in both studies indicates that until now, some of the countries or regions have not achieved the development stage where economic growth enabled to reduce the ecological footprint. To comprehend the impact of technological innovation on environmental quality, Sinha et al. (2020c) in their study developed an environmental index where four different gases are used to exhibit the environmental quality in the MENA countries. This approach allowed assessing whether technological advancement has significantly led to an increase in greenhouse gas emissions (i.e., CO_2, NO_2, CH_4, and N_2O) in the long run. Instead of segregation, they have developed a composite index where the principal component method is used. Considering the need for a comprehensive examination of the environmental quality, Bello et al. (2018) in their study analyzed the impact of per capita income on carbon, water, and ecological footprint by using the time series (1971–2016) data for Malaysia. The study confirmed that the per capita income increase has a significant impact on the ecological footprint, whereas the impact of the squared term is found insignificant. Therefore, it can be contemplated that the increased per capita income is unable to reduce the ecological footprint in the long run. However, in terms of the carbon footprint, the study established an inverse U-shaped EKC. Based on the results, we can assert that the increased per capita income may have different impacts on the various environmental indicators. Therefore, in the present study, we established the three different environmental functions where ecological footprint, carbon footprint, and land footprint are examined through a panel data set.

Nexus between energy consumption and environmental pollution

Besides supplementing the economic growth, the excessive dependency on nonrenewable energy resources has imposed certain economic and environmental challenges. As far as the economic challenges are concerned, net energy-importer countries have to spend a gigantic amount on the procurement of energy resources. And, in terms of environment-related challenges, the excessive consumption of fossil fuel has intensified the level of environmental pollution in the long run. To support this notion, Shahbaz et al. (2016), Shahbaz et al. (2017), Munir et al. (2020), Sharma and Kautish (2020a), and Ike et al. (2020) in their respective studies ascertained that the increased consumption of energy resources have contributed to increasing CO_2 emissions in the long run. At the same time, the results of Alola et al. (2019a, b), Destek and Sinha (2020), and Sharif et al. (2020) ascertained that the nonrenewable energy consumption has played a significant role in raising the ecological footprint in 16-EU, OECD countries, and Turkey, respectively. Contrarily, the literature supports that the increased consumption of renewable energy resources may help to fortify the environmental quality in the long run (Sharif et al. 2019b; Destek and Aslan 2020).

Here, it needs to mention that besides industries, other sectors such as transportation, agriculture and allied industries, financial activities, and household-level energy requirements have also contributed to raising the consumption of nonrenewable energy resources, which in turn might have led to pollution increase across countries (Sharvini et al. 2018). In the given situation, the increased consumption of renewable energy resources may help to reduce imported energy dependency and pollution intensity, which is an urgent need for developing regions like South and Southeast Asia. Studies in the past confirmed that renewable energy can serve as a substitute for nonrenewable energy. Secondly, in comparison with the latter, the negative environmental impacts of renewable energy consumption are less. For mitigating the negative impacts of energy consumption, the SDG-17 underlines the need for clean and affordable energy resources. However, with the existing basket of energy resources, it is doubtful to achieve the goal of sustainable development by 2030. Therefore, it is high time to introduce the mixed energy basket where a combination of both types of energy resources to be introduced to safeguard the planet earth.

Nexus between financial sector development and environmental pollution

With the economic expansion, the associated growth channels such as energy consumption, market size, demand for inputs, and financial services tend to improve (Ebohon 1996; Faisal et al. 2016; Sharma et al. 2019). In the developing and open economies, the economic contribution of financial sector development cannot be ignored. By integrating the local and international markets, it facilitates the smooth exchange of goods and services (World Bank 2012). However, in terms of improving environmental quality, its role can be positive (Gill et al. 2019) or negative (Moghadam and Lotfalipour 2014) in the long run. Saying this, the results of Sadorsky's (2010) study confirmed that the improvement in financial services has led to an increase in the demand for energy in the developing countries, which, in turn, has intensified the level of CO_2 emissions in the long run. Similarly, by taking the panel of Gulf Cooperation Council nations, Bekhet et al. (2017) in their study revealed that the growth of financial sector development has a significant and negative impact on the environmental quality. Contrarily, the outcomes of Riti et al. (2017) and Baloch et al. (2018) studies revealed that the development of financial markets has fortified the air quality in the sample of 90 countries and Saudi Arabia, respectively. In contrast to the above, the results of Ozturk and Acaravci's (2013) study denied the role of the financial sector development in altering the environmental quality in Turkey.

Owing to the wide range of proxies for the financial sector development, its representation has remained a debatable topic in past studies. For example, Ang (2008a, b) and Ozturk and Acaravci (2013) used domestic credit to the private sector as a proxy for the financial sector development in China and Turkey, respectively. On the other hand, overall credit by the financial sector (Jenkins and Katircioglu 2010) and stock market capitalization (Beck et al. 1999) are considered appropriate proxies by other studies. Given the availability of the various proxies, some of the studies have constructed the financial development index where various possible proxies for financial development are considered (Ang 2008a, b; Katircioğlu and Taşpinar 2017).

Nexus between trade expansion and environmental pollution

Economic openness allowed developing countries to procure necessary inputs for economic growth (Zhang and London 2011). While addressing their growth targets, the developing countries witnessed a sharp increase in the demand for imported technology and energy resources (Sinha 2017; Shahbaz and Sinha 2019). However, the increased energy demand, especially nonrenewable energy widened the scope for greenhouse gas emissions. In support of this notion, the outcomes of Shahbaz et al. (2012) and Tiwari et al. (2013) confirmed that trade expansion has led to a significant increase in CO_2 emissions in Pakistan and India, respectively. Similarly, other studies also reported that the trade expansion can be a significant driver of CO_2 emissions (Kanjilal and Ghosh 2013; Wang et al. 2019; Sharma et al. 2020), ecological footprint (Ghita et al. 2018; Sabir and Gorus 2019), and carbon footprint (Herrmann and Hauschild 2009) in the long run. While examining the association between trade expansion and ecological footprint, Sharif et al. (2019a, b) ascertained that the level of ecological footprint changed significantly at the different levels of trade expansion. Interestingly, the results of Dogan and Seker's (2016) study ascertained that trade expansion has fortified the environmental quality in the top ten renewable energy-consuming countries. In support of this, Dogan and Seker (2016) ascertained that trade expansion has allowed countries to adopt energy-efficient and advanced techniques of production. This technology spillover, in turn, helped these countries to reduce carbon emissions in the long run. Studies of Shahbaz et al. (2013) and Sulaiman et al. (2013) also confirmed the positive impact of trade openness on environmental quality in Indonesia and Malaysia, respectively.

An in-depth examination of the literature suggests that the selected variables can be crucial drivers of CO_2 emissions. However, there is a dearth of studies where the impacts of these drivers on the ecological footprint and land footprint are examined. This research gap motivated us to carry this research where a pool of the developing nations is considered.

Research approach and data interpretation

Data definition and sources

From the close observation of the environmental series, it appears that the economic expansion and its associated channels have contributed to disturbing the established ecosystem in the developing countries. Therefore, by using the annual data series (i.e., 1989–2015), we intended to assess the impact of per capita income, total energy consumption, financial development, and trade expansion on the ecological footprint, carbon footprint, and land footprint where eight developing countries of South and Southeast Asia are being considered for this examination. Except for the ecological footprint, carbon footprint, and land footprints, other annual series are retrieved from the World Bank's data repository. The series related to environmental indicators are collected from the website of the global footprint network. Both GDP (US$ 2010) and energy (kiloton per capita) series are measured in the per capita forms, whereas trade expansion is the ratio of the sum of the export and import to GDP. All the environmental footprints are measured into the area to a hectare. The data related to the financial indicators are assessed from the World Bank's repository. After that, to establish the data uniformity, the series are converted into the natural logarithm form.

Financial development index

The assigned role of a financial indicator may depend on the monetary policy of a country; therefore, across countries, a financial indicator may have a different role to play (Ang 2008a, b). The availability of the various proxies for financial development motivated us to construct the financial development index. By doing so, we reduced the possibility of omitted variable bias and provided a comprehensive representation of the financial sector development, which can be a significant driver of environmental pollution. The broad money supply (MS), an offering by the private sector (PL), domestic offering to the private sector (DL), and government's liquid liabilities (LL) are considered to construct the financial development index (Katircioğlu and Taşpinar 2017). The liquid liabilities are in percentage of broad money, whereas other indicators are the percentage of GDP. By using the principal component method, equation (1) is used to construct the index:

$$FI = f(MS, PL, DL, LL) \quad (1)$$

Money supply and liquid liabilities are considered important instruments of financial sector development (Beck et al. 1999). However, Levin et al. (2000) ascertained that the credit supply by the private sector development may have a long-lasting impact on an economy. Also, Jenkins and Katircioglu (2010) earmarked the role of lending to the private sector in a developing economy, as it helps to intensify the fresh investments in the long run. Further, the growing trade through stock markets signifies the need for a developed stock market mechanism in recent years (Sharma and Kautish 2020b). However, while calculating the financial development index in the present study, we ignored its role. The financial markets are more vulnerable to international fluctuations and can be put as a drawback of the present study. Based on the variables carried in equation (1), we performed the principal component analysis, which facilitated us to reduce the more familiar variables into reduced unassociated but expressive variables. The varimax rotation procedure of the principal component approach enabled us to generate the financial development index where the above-mentioned variables are duly weighted. Based on the Eigenvalues, we retrieved the cumulative percentage of variations led by the respective principal components. Table 1 reveals that the Eigenvalue of only one variable approved the statistically desired criteria (i.e., 3.800 > 1.000); contrarily, other Eigenvalues are found less than one (Beck et al. 1999). The first principal component is considered better than others because about 95.100% variation in the dependent variable is explained by it. Thus, to derive the financial development, the first principal component is employed; however, based on the respective factor scores, the weights of the other components are used to develop the final financial development index. Katircioğlu and Taşpinar (2017) in their study also followed the same procedure where 73.622% variation was explained by only one component, and the values of the other four components were found less than one.

The numerical procedure to develop the index is mentioned in equation (2):

$$FI = \sum_{i=1}^{n} W_{\mathrm{i}} \times IFS_{\mathrm{i}} \quad (2)$$

Here, the financial index (FI) is constructed by multiplying the weight/load (W_{i}) (i.e., the ratio of changes made by each considered indicator to the total variation made by all indicators) to individual factor scores (IFS_{i}) of each proxy. The procedure to derive the W_{i} is mentioned in equation (3):

$$W_{\mathrm{i}} = \frac{VE_{\mathrm{i}}}{\sum_{i=1}^{n} VE_{\mathrm{i}}} \times 100 \quad (3)$$

In equation (3), W_{i} and VE_{i} are used to represent the weight and explained variance of each component (i), respectively.

After constructing the financial index, the ecological footprint, carbon footprint, and land footprint-based equations (4), (5), and (6), respectively, can be introduced where per capita GDP (PCY), energy (EN), financial index (FI), and trade expansion (TR) are carried as the independent variables.

$$EFOOT_{\mathrm{it}} = \beta_0 + \beta_1 PCY_{\mathrm{it}} + \beta_2 EN_{\mathrm{it}} + \beta_3 FI_{\mathrm{it}} + \beta_4 TR_{\mathrm{it}} + \mu_{\mathrm{it}} \quad (4)$$

Table 1 Results of principal component mechanism

Principal component	Eigenvalues	Proportion (%)	Cumulative (%)
1	3.800	0.950	0.950
2	0.120	0.030	0.980
3	0.050	0.012	0.992
4	0.017	0.008	1.000
Indicators	**Loading**	**KMO**	**Factor scores**
MS	0.500	0.877	0.157
PL	0.502	0.836	0.211
DL	0.504	0.752	0.434
LL	0.501	0.777	0.210
Overall	-	0.807	-

Source: Based on the authors' calculation

Note: The results are calculated using the first principal component. However, the weighted factor scores of other components are also used to construct the financial development Index

$$CFOOT_{it} = \alpha_0 + \alpha_1 PCY_{it} + \alpha_2 EN_{it} + \alpha_3 FI_{it} + \alpha_4 TR_{it} + \mu_{it} \quad (5)$$

$$LFOOT_{it} = \gamma_0 + \gamma_1 PCY_{it} + \gamma_2 EN_{it} + \gamma_3 FI_{it} + \gamma_4 TR_{it} + \mu_{it} \quad (6)$$

Thereafter, for each function, we introduced the moderating effect of financial development because the availability of the financial resources with diversified financial instruments may likely to damage the environmental quality by intensifying the energy consumption and international trade in a free market place.

$$EFOOT_{it} = \beta_0 + \beta_1 PCY_{it} + \beta_2 EN_{it} + \beta_3 FI_{it} + \beta_4 TR_{it} + \beta_5 TR \times FI_{it} + \mu_{it} + \varepsilon_{it} \quad (7)$$

$$EFOOT_{it} = \beta_0 + \beta_1 PCY_{it} + \beta_2 EN_{it} + \beta_3 FI_{it} + \beta_4 TR_{it} + \beta_5 EN \times FI_{it} + \mu_{it} + \varepsilon_{it} \quad (8)$$

$$CFOOT_{it} = \alpha_0 + \alpha_1 PCY_{it} + \alpha_2 EN_{it} + \alpha_3 FI_{it} + \alpha_4 TR_{it} + \alpha_5 TR \times FI_{it} + \mu_{it} + \varepsilon_{it} \quad (9)$$

$$CFOOT_{it} = \alpha_0 + \alpha_1 PCY_{it} + \alpha_2 EN_{it} + \alpha_3 FI_{it} + \alpha_4 TR_{it} + \alpha_5 EN \times FI_{it} + \mu_{it} + \varepsilon_{it} \quad (10)$$

$$LFOOT_{it} = \gamma_0 + \gamma_1 PCY_{it} + \gamma_2 EN_{it} + \gamma_3 FI_{it} + \gamma_4 TR_{it} + \gamma_5 TR \times FI_{it} + \mu_{it} + \varepsilon_{it} \quad (11)$$

$$LFOOT_{it} = \gamma_0 + \gamma_1 PCY_{it} + \gamma_2 EN_{it} + \gamma_3 FI_{it} + \gamma_4 TR_{it} + \gamma_5 EN \times FI_{it} + \mu_{it} + \varepsilon_{it} \quad (12)$$

If we apply the partial differentiation with respect to TR_{it} (trade expansion) and EN_{it} (energy consumption) in equations (7) and (8), respectively, the actual impact of FI_{it} can be calculated through equation (13).

$$\frac{\partial EFOOT_{it}}{\partial TR_{it}} = \beta_4 + \beta_5 \times FI_{it} \text{ and } \frac{\partial EFOOT_{it}}{\partial EN_{it}} = \beta_2 + \beta_5 \times FI_{it} \quad (13)$$

By following the same procedure in other equations, we can estimate the impact of FI_{it} on the carbon and land footprint. If the coefficients $\alpha_4 + \alpha_5 \times FI$, $\alpha_2 + \alpha_5 \times FI$, $\gamma_4 + \gamma_5 \times FI$, and $\gamma_2 + \gamma_5 \times FI$ are statistically significant, it will confirm the role of financial development in improving/deteriorating the environmental quality. Stating differently, the long-run marginal effects of TR_{it} and EN_{it} on ecological footprint, carbon footprint, and land footprint depend on the financial sector development (FI_{it}) if the calculated values are statistically significant. However, in doing so, we need to consider the sign and strength of β_4, β_2, α_4, α_2, γ_4, and γ_2 also. These constant values are integral parts of these equations and may change the overall impact in a different direction. Further, the differentiation of equation (13) with respect to FI_{it} will enable us to get the mediating effect of FI_{it}, which serves as a mediator between an environmental proxy and independent variables (i.e., TR_{it} and EN_{it}). This is given in equation (14) hereunder:

$$\frac{\partial^2 EFOOT_{it}}{\partial TR_{it} \partial FI_{it}} = \beta_5 \text{ and } \frac{\partial^2 EFOOT_{it}}{\partial EN_{it} \partial FI_{it}} = \beta_5 \quad (14)$$

It means that, even before interaction, the coefficient β_5 was carrying moderating effect, that is, the ecological footprint is influenced by FI_{it} through TR_{it} and EN_{it}. When FI_{it} is kept constant, the intensity of influence of TR_{it} and EN_{it} on the ecological footprint depends on $\beta_4 + \beta_5$ and $\beta_2 + \beta_5$, respectively. The same econometric treatment allows us to extract the moderating impact of FI_{it} on the carbon and land footprint.

Data description

The basic attributes of the data series are mentioned in Table 6 (Appendix). Among all the variables, the land footprint reports the maximum deviation, whereas the minimum standard deviation is shown by trade expansion in the panel model. In the case of per capita income, India's per capita income has shown maximum deviation, whereas the per capita income in Bangladesh has reported minimum deviation in the considered countries. Further, the energy consumption in Sri Lanka has observed maximum deviation in the given country list.

Panel unit root test

The stationarity of the series is a prerequisite to establishing reliable and consistent results. Therefore, we employed the common panel unit root test proposed by Levin et al. (2002) and abbreviated as LLC in the present study. Thereafter, by using the augmented Dickey-Fuller (ADF) test, we established the individual stationarity of the series. The series stability is checked at intercept and intercept and trend; however, to manage the space, the results with the constant are mentioned in Table 7 (Appendix).

Due to the possibility of the inter-country convergence, we cannot rely on the traditional stability tests, because the traditional stationarity tests may give inconsistent results if countries possess interdependency in the long run. To navigate this possible error, we employed the stationarity tests that are efficient in handling cross-sectional dependence and provide reliable results. In Table 2, we reported results of cross-sectional augmented Dickey-Fuller and cross-sectional augmented Im-Pesaran-Shin tests, which are termed as CADF and CIPS, respectively.

The results of the panel stationarity tests given in Table 2 reveal that all the variables are either stationary at the level or the first difference. In other words, the series are of I(0) or I(1) types. Therefore, we need to adopt an approach where the cointegration of such kind of variables is possible. As mentioned earlier, in the panel data model where variables such as per capita income, energy, financial development, and trade expansion are included, the cross-sectional dependency is likely to emerge because these variables tend to generate international economic shocks (Liu 2013; Bello et al. 2018). Thus, before proceeding further, it requires to examine whether the variables are really influenced by the cross-border shocks. For doing so, we employed the cross-sectional dependency tests, which may confirm the relevance of the CADF and CIPS procedures in the present study.

Cross-sectional dependency test

To address this issue, Pesaran (2004) cross-section unit root test and Pesaran Lagrange multiplier tests are performed. The former is more suitable for a large number of countries and a short study period, whereas the latter is recommended where the numbers of countries are less but the study period is long. Besides Pesaran's CD and LM tests, we have employed Breusch and Pagan's (1980) test to confirm the possibility of the cross-sectional dependency. The computational procedure for the cross-sectional dependency is given in equation (15) where the independence of the variables is considered as the null hypothesis provided the size of the population (SP) goes up to infinity and study time (ST) is sufficiently large.

$$CST = \frac{\sqrt{2ST}}{SP(SP-1)}\left(\sum_{i=1}^{SP-1}\sum_{r=l+1}^{SP}\mathrm{p_{ir}}\right) \qquad (15)$$

A modified form of equation (15) can provide the cross-sectional dependency test result if the study carries the unbalanced data set. However, in this study, the procedure for that is not mentioned because our data set is perfectly balanced. The results related to the above-mentioned cross-sectional dependence tests are shown in Table 3.

The results of Table 3 reported the need for an estimation technique that can provide reliable results after considering the cross-sectional dependency because all the mentioned tests have rejected the possibility of cross-sectional independence at the 1% level of significance. In the given situation, the traditional approaches such as the panel-ARDL, FMOLS, and DOLS may provide misleading results.

Table 2 Second-generation stationarity tests

Variable	CADF (level) Calculated t-bar values	CADF (1st Dif.). Calculated t-bar values	CIPS (Level) Calculated *F* values	CIPS (1st Dif.) Calculated *F* values
EFOOT	− 1.948	− 2.959***	− 2.052	− 4.778***
CFOOT	− 1.139	− 3.370***	− 1.700	− 5.141***
LFOOT	− 1.411	− 3.903***	− 1.076	− 5.338***
PCY	− 1.598	− 3.349***	− 1.025	− 4.712***
FI	− 1.116	− 4.001***	− 0.740	− 4.372***
EN	− 1.105	− 2.495**	− 1.117	− 4.393***
TR	− 1.151	− 3.841***	− 1.118	− 4.476***

Notes: Based on the authors' calculation

Notes: The rejection of unit root at a 1% and 5% significance level is displayed by *** and **, respectively

Table 3 Cross-sectional dependence test

Variables	CD test (Pesaran)	Scaled LM test (Pesaran)	LM test (Breusch-Pegan)
EFOOT	25.220*** (0.000)	79.800*** (0.000)	632.555*** (0.000)
CFOOT	24.338*** (0.000)	75.227*** (0.000)	598.950*** (0.000)
LFOOT	22.585*** (0.000)	64.1421*** (0.000)	515.995*** (0.000)
PCY	28.144*** (0.000)	87.233*** (0.000)	678.111*** (0.000)
FI	7.342*** (0.000)	23.258*** (0.000)	477.994*** (0.000)
EN	16.079*** (0.000)	58.964*** (0.000)	476.365*** (0.000)
TR	5.199*** (0.000)	19.217*** (0.000)	172.888*** (0.000)

Source: Based on the authors' calculation

Notes: The rejection of cross-country independency at a 1% significance level is displayed by ***

Westerlund test for the long-run cointegration

However, before embarking further, it is required to establish whether the comprised set of variables are cointegrated in the long run. For doing so, we employed the Westerlund (2007) panel cointegration test. The econometric procedure to retrieve the results of this test is mentioned as follows:

$$\Delta z_{i,t} = \phi_i d_t + \delta_i \left(z_{i,t-1} - \theta y_{i,t-1} \right) + \sum_{m=1}^{pt} \delta_{i,m} \Delta z_{i,t-m} + \sum_{m=-qt}^{pt} \Lambda_{i,m} \Delta y_{i,t-m} + \varepsilon_{i,t} \quad (16)$$

The cross-sectional ($i = 1, \ldots$) and time series ($t = 1, \ldots$) units are used together. In calculation, the deterministic components like constant and time (d_t) and error correction terms parameters (δ_i) are also used. By employing the least square method on equation (16), $\bar{\varepsilon}_{i,t}$ and $\bar{\Lambda}_{i,t}$ are to be calculated. Thereafter, the variance estimators for Newey-West are to be calculated by using the following equation (17).

$$\bar{u}_{i,t} = \sum_{m=-qi}^{pi} \bar{\Lambda}_{i,t} \Delta y_{i,t-m} + \bar{\varepsilon}_{i,t} \quad (17)$$

These derived values will be used to extract $\bar{\delta}_i = \frac{\bar{\delta}_{ui}}{\bar{\delta}_{zi}}$; here, $\bar{\delta}_{ui}$ and $\bar{\delta}_{zi}$ are the variance estimators which are calculated from $\bar{u}_{i,t}$ and $\Delta z_{i,\ t}$, respectively. Thereafter, by using the standard errors (SE), the group mean estimators Gt ($\frac{1}{N} \sum_{i=1}^{N} \frac{\bar{\delta}_i}{SE\bar{\delta}_i}$) and Ga (($\frac{1}{N} \sum_{i=1}^{N} \frac{T\bar{\delta}_i}{\bar{\delta}_{i(1)}}$) are to be calculated. Similarly, by using the calculated standard errors, the estimators' Pt ($\frac{\bar{\delta}}{SE\delta}$) and Pa ($T\bar{\delta}$) are to be calculated, which is based on $SE\left(\bar{\delta}\right) = \left(\left(ESE_N{}^2 \right)^{-1/2} \sum_{i=1}^{N} \sum_{t=2}^{T} \overline{\delta_{i,t-1}{}^2} \right)^{-1/2}$. The calculation procedure for $ESE_N{}^2$ is $\frac{1}{N} \sum_{i=1}^{N} \frac{\bar{\delta}_1}{\bar{\delta}_{i(1)}}$); here, $\bar{\delta}_i$ are standard errors and calculated from equation (16). The results of this test are given in Table 4.

Table 4 results confirm the long-run cointegration for the selected functions. The usage of the bootstrap procedure provided a strong association among comprised variables after considering the possible cross-sectional dependency because test values in each model are statistically significant. Thereby, it can be contemplated that the selected drivers of ecological footprint, carbon footprint, and land footprint are worth examining for driving the common policy framework.

The cross-sectional distributed lag estimation

Chudik et al. (2016) introduced the CS-DL and CS-ARDL approaches to navigate the problem of cross-sectional dependency in the panel data because the inter-country economic, political, and social convergence may generate the interdependency among countries. Without addressing the inter-country dependency, the estimated results may provide misleading outcomes. Therefore, in the present study, we employed the former approach, as it has certain advantages over the latter. Firstly, the CS-DL approach is more efficient than CS-ARDL because the former may provide efficient results even with small samples and a moderate time period (Anderson and Raissi 2018). The CS-DAL approach uses the truncated lag order; therefore, it is less sensitive to the lag selection than the CS-ARDL approach. In the CS-ARDL, the inefficiency of the lag may generate small sample errors. Another advantage of the CS-DL approach is that it reduces the possibility of the serial correlation significantly and navigates the possibility of the structural break in the time series.

For deriving the CS-DL equation, initially, we need to introduce the basic ARDL approach through equations. Equation (17) is based on the panel ARDL approach where $\varepsilon_{i,\ t} = \alpha_i cf_t + \mu_i$.

$$w_{i,t} = \sum_{l=1}^{p} \delta_{i,l} z_{i,t-1} + \sum_{l=0}^{q} \xi_{i,l} v_{i,t-1} + \varepsilon_{i,t} \quad (18)$$

In equation (17), the unobserved vectors of common factors, factor loading, countries, time, dependent, and independent variables are denoted by cf_t, α_i, i, t, w_i, and v_i, respectively. Further, by assuming the absence of serial correlation, p

Table 4 Westerlund cointegration test results for the selected countries

	EFOOT			CFOOT			LFOOT		
Tests	Value	*p* value	*p* value (bootstrap)	Value	*p* value	*p* value (bootstrap)	Value	*p* value	*p* value (bootstrap)
Gt	− 2.710*	0.082*	0.110	− 3.056**	0.035**	0.025	− 3.839***	0.000**	0.030
Ga	− 3.202	0.999***	0.000***	− 6.438	0.992**	0.050	− 6.984	0.540	0.530
Pt	− 8.778**	0.024**	0.020**	− 8.019**	0.036**	0.045	− 8.914	0.601**	0.050
Pa	− 6.358	0.531***	0.000***	− 5.785	0.906	0.175	− 11.359*	0.060*	0.080

Source: Based on the authors' calculation

Notes: The rejection of no cointegration at a 1%, 5%, and 10% significance level is shown by ***, **, and *, respectively. The trend and constant are used to calculate the results. The bootstrap and maximum lag-length are set at 400 and 1, respectively

and q are used as the lag orders of the dependent and independent variables, respectively.

Further, based on the values of δ_i, and $\xi_{i,l}$ (i.e., the short-run coefficients), we derive the long-run coefficients, which is mentioned in equation (19).

$$\theta_i = \frac{\sum_{l=0}^{r} \xi_{i,l}}{1-\sum_{l=1}^{s} \delta_{i,l}} \tag{19}$$

In the case of the CS-DL estimation, the long run coefficients can be calculated directly because this approach concentrates only on the long run relationship. This can be considered a weakness of this approach. For calculating the long run coefficients, equation (18) is to be written as follows:

$$w_{i,t} = \theta_i v_{i,t} + \alpha_i L \Delta v_{i,t} + \acute{\varepsilon}_{i,t} \tag{20}$$

In equation (20), $\acute{\varepsilon}_{i,t} = \delta(ED)^{-1}$, $\varepsilon_{i,t}$ and $\delta_i(\mathrm{ED}\ ) = 1-\sum_{l=1}^{p} \delta_{i,l} ED^l$, *similarly*, $\theta_i = \gamma(1\ )$, and $\gamma_i(ED) = \delta_i^{-1}(ED)\xi_i(ED) = \sum_{l=0}^{\infty} \gamma_{i,l}\ \ ED^l$, $\xi_i(ED) = \sum_{l=0}^{q} \xi_{i,l} ED^l$, *and* $\alpha_i(ED) = \sum_{l=0}^{\infty} \sum_{r=l+1}^{\infty} \gamma_q ED^l$.

To calculate θ_i, $w_{i,t}$ needs to be regressed on $v_{i,t}$, and $(v_{i,t})^{p}{}_{l=0}$. Here, the lag orders of the dependent variable are chosen after truncation, which depends on the increasing sample size. Further, to calculate the efficient θ_i, the coefficient of γ_i(ED) needs to be decreased exponentially. In the CS-DL estimation, exogeneity is not a mandatory condition. The CS-DL approach-based long-run coefficients ($ln\hat{\overline{\theta}} = N^{-1}\sum_i^N \overline{\theta}_i$) are to be calculated by using $\theta_{i,}$, and θ_i can be calculated by using the panel-ARDL. The calculation of ($ln\hat{\overline{\theta}} = N^{-1}\sum_i^N \overline{\theta}_i$) is based on the averages of the across units and is efficient estimators where cross-sectional dependency is addressed (Chudik et al. 2016). Specifically, equation (21) is used to calculate the final results, which is based on the preceding observations.

$$\Delta w_{i,t} = c_i + \phi' v_{i,t} + \sum_{l=1}^{p-1} \psi'_{i,l} \Delta v_{i,t-1} + \acute{\omega}_{i,w} \Delta\bar{w}_t + \sum_{l=0}^{1} \acute{\omega}'_{i,vl} \Delta\bar{v}_{t-1} + \varepsilon_{i,t} \tag{21}$$

Results and discussion

Based on the traditional unit root tests, we confirmed the stationarity in the system. Even the second-generation stationarity tests validated that the series are stable either at the level or at the first difference. Thereafter, by using the cross-sectional unit root tests, the need for an approach that can handle the cross-country dependency is confirmed. Thereafter, using the Westerlund's (2007) approach, we confirmed that all environmental proxies are associated with the comprised set of variables in the long run and each function possesses the long-run cointegration. A graphical approach mentioned in Fig. 1 may help us to understand the working mechanism of the study.

The computed long run results with the ecological footprint (models I to III), carbon footprint (models IV to VI), and land footprint (models VII to IX) are mentioned in Table 5.

First of all, we begin with the basic models I, IV, and VII where direct impacts of selected variables on the ecological footprint, carbon footprint, and land footprint are tested. By doing so, we intended to explore whether the selected variables have damaged the overall quality of the environment or only a particular proxy of the environment. The long-run results indicate that the increased per capita income has intensified the ecological (coef. = 0.227, p value = 0.013), carbon (coef. = 0.312, p value = 0.036), and land (coef. = 0.193, p value = 0.059) footprint in the selected South and Southeast Asia countries during the study period. However, in comparison with the other two proxies of the environment, it has a more severe impact on the carbon footprint. Such kind of association raises a question against the existing production processes. With the given production processes, it will be difficult to achieve the goal of responsible consumption and production (SDG-11) by 2030. The most important observation is that the existing mode of production exerting significant negative pressure on all indicators of environmental quality. Thus, we can contemplate that the selected developing countries by conceding the environmental responsibilities are busy in accomplishing the economic growth agendas.

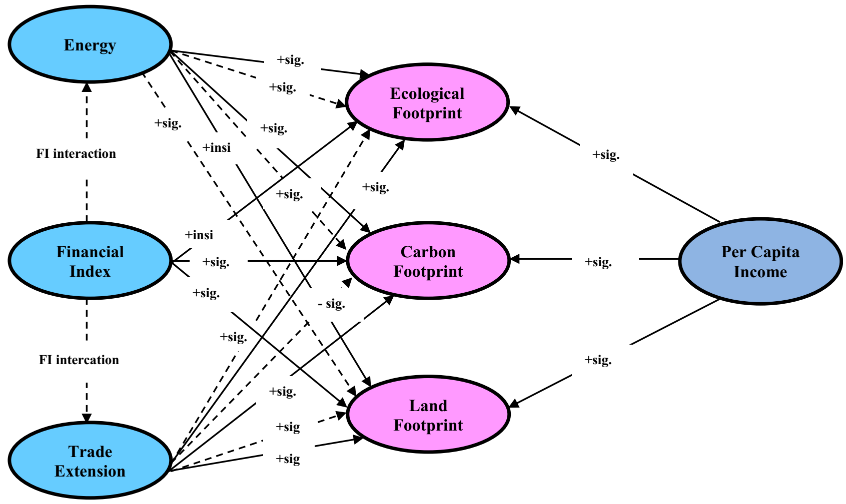

Fig. 1 Notes: Regular lines and dotted lines are used to exhibit the direct and interaction effect (with the financial development), respectively. The symbols (+) and (−) are showing positive and negative impacts, respectively

Alola et al. (2019a, b), Hubacek et al. (2017), and Edoja (2017) have also detected the direct connotation between income and ecological footprint, carbon footprint, and land footprint in their studies, respectively.

While examining the impact of energy consumption, we observed that the increased use of energy led to a significant increase in the ecological and carbon footprint in the given countries. However, its impact on the land footprint is observed insignificant but direct. Here, it can be mentioned that the additional combustion of energy, especially nonrenewable, exerts more air pollution, which in turn may disturb the air and ecological quality. However, its comparative impact on land quality may be less. That is why, in the present study, we found an insignificant impact of energy on land quality. But, the increased energy consumption may have an indirect and negative impact on land quality in the long run. These nations are heavily relying on imported nonrenewable energy resources to fulfill their energy demand. Thus, it can be ascertained that the regions may continue to struggle with the environmental challenges if the nonrenewable energy-based production techniques will be continued in the coming years. In order to avert this situation, governments have to identify alternative and endogenous energy resources, which should be less-carbon intense and cost-effective.

Further, we observed the direct and significant impact of the financial development and trade expansion on the ecological footprint, carbon footprint, and land footprint in the selected Asian countries. These kinds of outcomes indicate that not only direct production activities but also associated economic endeavors such as financial services, international trade, and exchange may exert the environmental footprint in the long run. Here, it can be argued that the expansion of financial and international trade-related activities may intensify the movements of various necessary factors such as transportation, construction and manufacturing, services, and most importantly energy consumption. Due to the negative working of the multiplier effect, these activities might have generated negative impacts such as scarcity of resources and environmental pollution in the long run. While taking the case of developing countries, the results of previous studies also confirmed the negative impact of financial development (Shahbaz et al. 2015; Javid and Sharif 2016) and trade expansion (Tiwari et al. 2013; Shahbaz et al. 2013) on the quality of the environment in the long run. Here, Shahbaz et al. (2015) argued that the distorted socio-economic and socio-political policies of developing countries might have intensified the environmental pollution in the developing countries, because such kinds of nations are still working with the inefficient and carbon-intense production process. Consequently, these regions are unable to get the net-benefits of the economic, financial, and trade expansions.

Further, in models II, V, and VIII, we explored the interaction effect of financial development and trade expansion on the ecological footprint, carbon footprint, and land footprint, respectively. The interaction of financial development and trade expansion has intensified the ecological footprint (model II) and land footprint (model VII) in the selected regions, as the interaction coefficients in both models have exhibited a positive and significant impact on the ecological and land footprint. It means that, at a given level of trade expansion, the growth in the financial instruments or resources may intensify the ecological footprint and land footprint. Similarly, at a given level of financial sector development, the improvement in the trade expansion may lead to the ecological footprint and the land footprint. In both models, even the cross-elasticity coefficients of energy consumption, financial development, and trade expansion have shown a direct impact on both footprints. The results of model V indicate that the interaction between financial development and trade expansion reduced the carbon footprint in the developing countries of Asia. The interaction coefficient (− 0.350) and cross-elasticity coefficient (− 0.019) with respect to trade expansion (keeping the financial development constant) is found negative and significant in model V. This may be due to the better

Table 5 The CS-DL approach-based long-run results

Variables	Model I (1, 1, 1, 1, 1)	Model II	Model III	Model IV	Model V	Model VI	Model VII	Model VIII	Model IX
	Ecological footprint			Carbon footprint			Land footprint		
PCY	0.227** (0.013)	0.172* (0.054)	0.229*** (0.007)	0.312** (0.036)	0.334*** (0.001)	0.567* (0.083)	0.193* (0.059)	0.213* (0.100)	0.292** (0.035)
EN	0.345* (0.087)	0.223* (0.097)	0.577*** (0.010)	0.592** (0.026)	0.938*** (0.000)	1.702*** (0.001)	0.002 (0.891)	0.122 (0.533)	0.160 (0.614)
FI	0.053 (0.220)	− 0.807* (0.082)	− 0.280* (0.084)	0.181** (0.043)	1.296** (0.020)	− 7.714* (0.074)	0.081* (0.074)	− 0.105 (0.150)	− 3.088* (0.064)
TR	0.265** (0.006)	0.258** (0.037)	0.305** (0.030)	0.302** (0.012)	0.286* (0.087)	0.262** (0.040)	0.313** (0.027)	0.410** (0.019)	0.427* (0.090)
FI × TR	-	0.250** (0.033)	-	-	− 0.350** (0.014)	-	-	0.341* (0.057)	
FI × EN	-	-	0.475* (0.070)	-	-	1.322* (0.055)	-		0.529* (0.054)
d.FOOT	0.450*** (0.000)	0.427*** (0.000)	0.356*** (0.000)	0.370*** (0.000)	0.265*** (0.000)	0.362*** (0.000)	0.488*** (0.000)	0.487*** (0.000)	0.460*** (0.000)
Elasticity w.r.t. FI	-	0.132	2.627	-	1.123	0.376	-	1.176	0.149
Elasticity w.r.t. EN	-	0.223	0.565	-	0.938	0.867	-	0.122	− 0.097
Elasticity w.r.t. TR	-	0.021	0.305	-	-0.019	0.262	-	0.264	0.427
CS-dependency test	− 0.97 (0.331)	0.55 (0.585)	1.03 (0.307)	− 0.73 (0.466)	1.22 (0.223)	− 0.160 (0.116)	− 0.94 (0.345)	− 0.77 (0.442)	− 0.97 (0.330)

Source: Based on the authors' calculation

Notes: The rejection of insignificant coefficients at 1%, 5%, and 10% significance level is shown by ***, **, and *, respectively. *P* values are inside the parentheses. The lag-length is set at one

and efficient utilization of the financial resources by the international-trade oriented industries. Because to remain competitive in the international markets, the export-oriented industries may tend to utilize the financial resources to procure the energy-efficient and low carbon-intense production techniques. Here, it needs to mention that cross-elasticity with respect to financial development (keeping the trade expansion constant) has remained positive. It indicates that at the given level of trade expansion, any increase in financial development may increase the carbon footprint in the long run. The outcomes of Gill et al. (2019) study also revealed that the interaction between financial development and per capita income has reduced the carbon emissions in Malaysia during the study period.

Likewise, the interaction between financial development and energy consumption is shown in models III, VI, and IX. In the first two models, i.e., ecological footprint and carbon footprint, the interaction between financial development and energy has enlarged the scope of environmental pollution. Even all the cross-elasticity coefficients also maintained the same sign. It shows that the separate and after interaction both energy and financial development lead to significant ecological and carbon footprint in the long run. Further, in the case of land footprint, the coefficient of cross-elasticity (0.149) shows that at the given level of energy, the impact of financial development on the land footprint has direct. Contrarily, at the given level of financial development, the impact of energy consumption on land footprint has remained negative. These results can be interpreted as, in intensifying the land footprint, the development in the financial sector has played a negative role. However, the increased energy consumption is not contributing significantly to intensifying the land footprint in the selected countries. Based on the outcomes, it can be ascertained that financial development has not only perturbed the environmental quality directly but also indirectly. Therefore, to achieve sustainable growth targets, the role of the financial sector needs to be redefined. Otherwise, it may continue to intensify environmental pollution directly and indirectly through other channels of economic growth.

Conclusion and policy framework

In the present study, we explored the impacts of per capita income, energy consumption, financial development, and trade expansion on the ecological footprint, carbon footprint, and land footprint in the eight selected countries of South and Southeast Asia during the study period (1990–2015). By employing Westerlund's (2007) cointegration approach, we confirmed that ecological footprint, carbon footprint, and land footprint functions are associated with the comprised set of variables in the long run and each function possesses the long-run cointegration. To compute the long-run coefficients, we applied a relatively new approach, i.e., CS-DL, which navigates the possible interdependency among selected countries. Based on the common coefficients, we intended to generate a policy framework, which may help to preserve the established eco-system.

Governments in these countries are playing dual roles, i.e., the government as a producer/consumer and the government as a benefactor. Similarly, private stakeholders are working as a manufacturer/service provider and consumer. Therefore, to weave a policy framework, the synergy between both is essential to achieve sustainable development goals. Considering the interconnectedness between financial development, energy consumption, trade expansion, and environmental footprint, first of all, the government as a producer needs to reduce the nonrenewable and imported energy dependency. In doing so, the government needs to invest in endogenous and less-carbon intense energy resources such as hydroelectricity, solar, wind, and biomass. By apportioning a mandated share of bank credit to develop the endogenous energy infrastructure, the government can resolve four problems. Firstly, it may reduce the imported energy dependency. Secondly, the renewable energy consumption may fortify the environmental quality. Thirdly, the financial sector's negative role in intensifying the environmental pollution may turn into positive; lastly, the negative impact of trade expansion may turn into positive because, with the due course of time, the industries associated with foreign trade may also start using the less-pollution intense endogenous energy resources. However, this process needs to be carried systematically without creating a production and job loss. Stating differently, in this whole process, the adaptation and diversification are crucial; otherwise, it may impede economic growth (Roy and Singh 2017; Roy et al. 2018). The gradual shift from the nonrenewable to renewable energy resources may widen the new job opportunities in the less developed areas as well, because the renewable energy resources such as solar, wind, water, and biomass are easily available in the rural areas. By doing so, the government can control the job loss caused by the technology shift, and in terms of economic growth, the country may continue to perform well. Further, if the government industries are allied according to the endogenous energy-based processes, the other industries will automatically be motivated for the same because the marginal cost of production of renewable energy resources is comparatively very less provided the basic infrastructure be developed.

As a benefactor, the government can introduce suggestive and directive approaches where clearly defined *Property Rights* are much needed. In the case of the former, the government can motivate the various stakeholders to safeguard environmental quality. *The Swachh Bharat Abhiyan* in India is a testimony of the success of suggestive programs where the Indian government motivated people to dump the household garbage at the assigned places. Similarly, to preserve the ecosystem, the government needs to adopt some stringent directive measures. If the Property Rights are well-defined, the graduated sanctions or penalties can be imposed on the basis of the severity of the violation of the environmental regulation. The even-odd vehicle number movement on the alternative days in Delhi, the capital of India, is one of the examples of Property Rights usage. However, to ensure the success of such programs, the conscious participation of all stakeholders is always needed. To establish the answerability of the private industries, the government needs to identify the more pollution-intense units. By providing tax-rebates or subsidies to such industries, the government can motivate the private industries to develop the renewable energy infrastructure where the financial sector can perform as a mediator. For example, to develop endogenous renewable energy resources, the financial sector can issue special financial instruments and services, which should be available to the renewable energy-based industries whether serving in local or international markets. The special concessions on establishing the new and renewable energy-based industries may gradually reduce the energy import bills, which in turn may reduce the negative impact of trade expansion as well. Furthermore, due to the reduced production cost, the increased competitiveness of such industries may compel other industries to adopt low-cost energy resources. Again, here the financial sector can come as a savior, and the negative impact of the financial sector on environmental pollution may gradually turn into positive.

At the next level, to safeguard the economic and environmental interests, a public-private-partnership-based endogenous energy infrastructure can be introduced (Shahbaz et al. 2021). By doing so, the energy supply can be maintained consistently, as the government alone may not be able to serve the total energy demand in the long run. At this stage, the subsidy/concession given by the government and financial institutions can be gradually removed and the system may become self-sustaining. After this stage, the bank lending to industries those who are serving the local and international markets can be routed through the environment-related guidelines. Further, by introducing the subjects like environmental conservation at the school and University levels, governments can achieve the twin benefits; firstly, it will create environmental consciousness among people; secondly, it will promote research and development in the renewable energy field. Once again, financing by the banking sector according to the pre-determined criteria can play a complementary role in this regard. This kind of multipronged approach may help to achieve the goals of affordable and clean energy (SDG-7), responsible consumption and production (SDG-11), and most importantly climate action (SDG-13) in the coming years.

The study with a larger time-span and a larger pool of countries may be able to provide better understanding where the segregation of countries based on income level could be followed. Furthermore, the interaction of energy resources with the income and other possible proxies of development can be explored because energy can be another catalyst of environmental pollution in the long run.

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Data availability We have prepared the data set and can be submitted as and when it is required.

Compliance with ethical standards

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

Ethical approval While preparing the manuscript, to the best of our knowledge, we have followed required ethical procedures. We would like to declare that there is no conflict from authors and any other party directly or indirectly.

Consent to participate We have consent of all authors and respective institutions to communicate the manuscript for consideration in the Journal.

Consent to publish We confirm that if the paper is accepted, it could be published in this prestigious journal.

Appendix

Table 6 The descriptive statistics

	Statistics	EFOOT	CFOOT	LFOOT	PCY	EN	FI	TR
Panel	Mean	18.333	17.197	17.218	7.069	6.27	− 1.830	4.007
	Median	− 0.072	17.304	18.405	6.861	6.120	− 0.487	3.759
	Maximum	21.140	20.524	19.913	9.410	7.990	2.900	5.508
	Minimum	16.500	13.750	15.451	5.050	4.749	− 1.700	2.604
	Std. Dev.	1.150	1.496	1.180	1.109	0.708	1.000	0.647
India	Mean	20.721	19.818	19.699	6.458	6.117	− 0.399	3.187
	Maximum	21.139	20.524	19.914	7.381	6.457	0.009	3.771
	Minimum	20.339	19.130	19.506	5.694	5.861	− 0.731	2.574
	Std. Dev.	0.249	0.435	0.128	0.597	0.191	0.295	0.383
Pakistan	Mean	18.596	17.633	17.719	6.518	6.139	− 0.716	3.443
	Maximum	18.849	18.066	17.922	7.267	6.261	− 0.575	3.632
	Minimum	18.219	17.028	17.485	5.914	5.984	− 0.907	3.192
	Std. Dev.	0.205	0.331	0.132	0.449	0.076	0.094	0.097
Sri Lanka	Mean	16.940	15.691	15.663	7.113	6.038	− 0.597	4.038
	Maximum	17.307	16.429	15.941	8.252	6.311	− 0.251	4.346
	Minimum	16.508	14.825	15.455	6.135	5.763	− 1.079	3.599
	Std. Dev.	0.191	0.428	0.126	0.684	0.171	0.221	0.229
Bangladesh	Mean	18.200	16.719	17.478	6.180	5.056	− 0.598	3.396
	Maximum	18.767	17.719	17.942	7.097	5.403	− 0.188	3.853
	Minimum	17.756	15.643	17.082	5.656	4.749	− 0.928	2.801
	Std. Dev.	0.314	0.648	0.248	0.431	0.211	0.251	0.311
Malaysia	Mean	18.297	17.595	16.611	8.584	7.682	1.597	5.049
	Maximum	18.666	18.182	16.860	9.325	7.995	2.637	5.258
	Minimum	17.684	16.466	16.222	7.796	7.098	0.430	4.840
	Std. Dev.	0.261	0.451	0.180	0.478	0.247	0.524	0.131
Philippines	Mean	18.402	17.295	17.295	7.138	6.138	− 0.460	4.162
	Maximum	18.577	17.502	17.502	7.953	6.239	0.106	4.551
	Minimum	18.113	16.825	16.825	6.552	6.026	− 0.846	3.785
	Std. Dev.	0.144	0.186	0.184	0.439	0.056	0.212	0.281
Thailand	Mean	18.734	18.067	17.320	8.004	7.176	1.612	4.543
	Maximum	19.032	18.467	17.681	8.724	7.601	2.835	4.808
	Minimum	18.301	17.437	16.918	7.319	6.608	0.776	4.165
	Std. Dev.	0.199	0.284	0.201	0.442	0.296	0.595	0.228
Nepal	Mean	16.866	14.766	15.950	5.759	5.847	− 0.436	3.596
	Maximum	17.188	15.579	16.347	6.610	5.851	0.314	3.767
	Minimum	16.558	13.756	15.550	5.141	6.067	− 0.971	3.184
	Std. Dev.	0.190	0.522	0.228	0.500	0.096	0.418	0.133

Source: Based on the authors' calculation

Notes: The natural logarithm values are considered for the calculation purpose

Table 7 Panel unit root test

Variable	LLC test (level) Common unit root	LLC test (1st Dif.).	ADF (level) Individual	ADF (1st Dif.)
EFOOT	− 0.144 (0.443)	− 11.700*** (0.000)	12.900 (0.690)	136.600*** (0.000)
CFOOT	− 2.013 (0.022)	− 4.033*** (0.000)	18.511 (0.294)	69.044*** (0.000)
LFOOT	− 0.922 (0.178)	− 7.517*** (0.000)	13.378 (0.644)	99.522*** (0.000)
PCY	2.464 (0.993)	− 5.368*** (0.000)	1.530 (1.000)	49.859*** (0.000)
FI	0.371 (0.644)	− 4.503** (0.000)	18.435 (0.299)	50.745*** (0.000)
EN	0.451 (0.640)	− 4.080*** (0.000)	9.007 (0.903)	59.600*** (0.000)
TR	− 1.658 (0.048)	− 10.500*** (0.000)	21.203 (0.170)	− 110.200*** (0.000)

Source: Based on the authors' calculation

Notes: The rejection at a 1% significance level is displayed by ***. The probability terms are under parentheses

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