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Environmental concern in the era of industrialization: Can financial development, renewable energy and natural resources alleviate some load?

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ABSTRACT

Economic development accelerates the process of industrialization that has amplified the worth of extracted natural resources. Extensive exploitation of natural resources through total reserves, financial development, and renewable energy can influence the atmosphere. In view of this, this study examines the influence of industrialization, total reserves and the expansion of financial, renewable and natural resources on the ecological footprint. This research applies panel data for the period from 1990 to 2019 in newly industrialized countries. The findings of the augmented mean group (AMG) panel algorithm are robust to heterogeneity, and cross-sectional dependence points to the heterogeneous effect of industrialization, total reserves and financial development in significantly driving environmental pollution in these countries. In contrast, the abundance of natural resources and renewable energy significantly mitigates environmental pollution in the long-run. These results are also consistent with long-run and disaggregate level estimation. Moreover, the panel Dumitrescu and Hurlin causality test results revealed a unidirectional causality association from industrialization and renewable energy to ecological footprint and from ecological footprint to natural resources. A bidirectional causality relation was also found between financial development and total reserves, and the ecological footprint. Finally, several important policy implications are suggested to protect environmental quality in newly industrialized countries.

1. Introduction

Global warming and atmospheric variation cause a major incompatibility between people and international sustainable development. These are also the greatest threats to prosperity, security and human and natural lives. Carbon dioxide (CO_2) accounts for approximately 75% of global greenhouse gas (GHG) emissions. Anthropogenic climate change and global warming are the significant consequences of CO_2 emissions, as are severe climate events/measures include (floods, droughts, heavy rains, and heatwaves) that have occurred repeatedly during the previous decade (Abbasi et al., 2021). Global warming derives primarily from an increase in GHG emissions. Individual actions in the course of exploiting natural resources and the use of non-renewable energy produce significant amount of GHG emissions, which consequently aggravate global warming and climate change. Several studies have focused on CO_2 emissions in their research in relation mainly to ecological vulnerability since it is the greatest contributor to GHG emissions, and its records can be easily assessed. According to the report by the United Nations Framework Convention on Climate Change (UNFCCC), the share of carbon emissions in the environment is high and causes extensive harm in the form of floods, drought, extreme weather events, rising sea levels, melting glaciers and high temperatures (UNFCCC, 2017). Non-renewable carbon emissions add to environmental issues and global warming (Ozturk et al., 2017; Adedoyin et al., 2020; Usman et al., 2021a). CO_2 emissions are considered to be a very fragile indicator, and ecological vulnerability is not restricted to the environment. Carbon emissions are a weak indicator, especially when applied to reserves of renewable and other natural resources such as mining, oil, soils and forests (Nathaniel et al., 2021).

The industrialization process of an economy affects the sustainability of its development in two different dimensions: economic growth (GDP) and ecological excellence. In spite of its constructive effects on GDP growth, particularly due to the revolution in industrialization, it is the single greatest contributor to pollution levels (Carvalho et al., 2018).

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This damaging effect may be significant as an economy's industrial sector is a major consumer of fossil fuels, and particularly in emerging countries such as Brazil, Russia, India, China, and South Africa (BRICS), Asia-Pacific Economic Cooperation (APEC), Middle East and North Africa (MENA), the newly industrial zone and other trade blocs, with inefficient and environmentally polluting types of technology (Li et al., 2016; Usman and Hammar, 2021; Nasrollahi et al., 2020). More advanced countries such as the Organisation for Economic Co-operation and Development (OECD) nations operate highly well-organized technologies that mitigate this ecologically harmful effect. In the early stage of the industrialization process, technological innovations can play a negative role in protecting environmental quality; however, air quality can also benefit from the use of a variety of energy-efficient methods and systems.

Financially viable expansion can be achieved through cooperation with ecological variation and green sustainability. This type of economic growth accelerates the industrialization process that increases the use of natural resources and renewable energy consumption in industrial output. All these economic activities hasten the depletion of natural resources by increasing the volume of toxic waste generation (Sarkodie, 2018). The extraction of natural resources through industrialization, cultivation, deforestation and mining also substantially affects air quality. The use of natural resources is a vital indicator in the production process, so an appropriate pattern of supply diminishes the overall price level and boosts oil use (Balsalobre-Lorente et al., 2018). The dilemma between the importance of environmental quality and natural resources drives governments to provide non-viable financial support for the use of non-renewable energy sources, which raises an economy's carbon footprint. The extraction of natural resources helps reduce ecological deterioration, as it releases fewer devastating chemicals into the land, air and water.

The vastly improved knowledge of the association between financial development, GDP growth, natural resources, and environmental deterioration helps governments and policymakers alleviate pollution levels and promotes the expansion of cleaner energy. Numerous researches have explored the influence of the extraction of natural resources on real income growth, although there are few studies on how these factors influence the ecological footprint. This current research fills this gap, as very small numbers of studies have produced mixed outcomes (Balsalobre-Lorente et al., 2018, 2021; Pata et al., 2021). The complementary views based on inconclusive findings in earlier literature, which explores the diverse impact of financial development, economic growth and cleaner energy on environmental degradation, highlight the need for an additional empirical examination of the soundness of the association between the financing of natural resources and economic expansion, and the contamination of the ecological footprint in newly industrialized countries (NICs). One of the key objectives of this research is to investigate financial development and the abundance of natural resources and renewable energy concerning total reserves and the ecological footprint in NICs, which can help to minimize the inconsistency associated with real economic growth.

Another objective of this study is to verify the impact of financial progress on the ecological footprint. Air quality is higher in nations with highly sensitive and well-organized financial institutions and markets than in those with low levels of financial institutions and systems (Ozturk and Acaravci, 2013; Usman et al., 2020; Dasgupta et al., 2001). Some of the current literature has shown that the development of the financial sector can play a vital role in influencing environmental excellence (Usman et al., 2021a), and that a solid and highly-developed financial system in an economy is favourable for environmental quality. A well-organized financial sector initially attracts foreign investment (FDI), which increases domestic research and development (R&D) activities in countries, and decreases the overall level of environmental pollution (Usman et al., 2021). Financial growth also accelerates technical innovation, which helps decrease the pollution level (Kumbaroğlu et al., 2008). A good financial sector offers loans/credits at a very cheap rate for eco-friendly ventures (Tamazian and Rao, 2010), advancing environmental quality. A highly-developed financial system also has the ability to assist companies in installing modern technology in their industrial sector, which will increase environmental quality (Frankel and Rose, 2002). Financial institutions and markets give more credits/loans to firms that meet the terms of the state environmental regulations, which reduce the atmospheric deficit (Usman and Hammar, 2021). Hence, a well-organized and sound financial sector leads to a reduction in environmental deterioration. Some researchers have found that the financial sector has an adverse effect on environmental quality, including several who observed that financial development mitigates carbon emissions by escalating real GDP growth, while others reported that financial development drives industrial activities by offering uncomplicated financing, which will ultimately raise the overall ecological footprint and environmental contamination (Usman et al., 2021b; Sadorsky, 2010).

The burden placed on the ecosystem by human exploitation of products and services is associated with the current environmental deterioration, weather crises, ecological distortions and economic difficulties (Alola et al., 2019). The term ecological footprint (EFP) was introduced by Wackernagel and Rees (1998) to investigate environmental quality. EFP has been used to estimate the effect of human activities on the Earth's accessible resources, and the dynamics of EFP were established to provide more information. The EFP is an inclusive and comprehensive indicator when applied to the accumulation of reserves and resources (Usman and Makhdum, 2021). The EFP is concerned with environmental sustainability and anthropogenic strain on the atmosphere. As a variable, it contrasts individual-based utilization with the biosphere's regenerative capacity (Rees, 1992). Some EU states face alarming situations in terms of their environmental quality and their deficit in ecological resources, coupled with a decline in the fertility rate (Rees, 2015). The EFP also identifies the direct and indirect effects of human consumption and production on the atmosphere. The impact of these anthropogenic behaviours on the EFP concerns six types of different land footprints, namely cropland, grazing land, fishing grounds, built-up land, forest area, and carbon demand on land. Global warming and temperature levels are broadly covered by EFP by considering the influence of land use, deforestation rates and CO_2 emissions on environmental variations and global warming. The latest studies (Yang et al., 2021; Usman and Makhdum, 2021; Nathaniel et al., 2021; Usman et al., 2021b) adopt the EFP indicator in place of other environmental proxies such as NOx, CO_2 and GHG emissions due to its completeness and comprehensiveness.

This research differs from earlier literature in the following four areas: initially, to the best of the authors' knowledge, this article is the first to examine the dynamic relationship between industrial value-added, natural resources, financial development, total reserves, renewable energy use and the ecological footprint. This association was initially considered for NICs during the long panel from 1990 to 2019. To comply with the targets of the sustainable development goals (SDGs), it is imperative to review the influence of industrialization, natural resources, financial development, total reserves and renewable energy use on the natural competence of NICs. When focusing on the goal of climate action (SDGs 13), the study of air pollutants alone may not give an accurate picture; this research, therefore, focuses on the influence of isolated energy factors on the ecological footprint. In addition, the NICs are established in the way of execution courses that have been undertaken to comply with the SDGs targets, so it is essential to understand how they are using their energy and natural resource mix to protect environmental quality. This study will address this goal. In a methodological perspective, we also consider possible cross-sectional dependence (country interdependence), second-generation panel stationarity tests, Westerlund bootstrap panel cointegration test, pooled mean group (PMG), Driscoll and Kraay (D-K), augmented mean group (AMG) and common correlated effect mean group (CCEMG) estimators to estimate the long-run elasticity of the variables analyzed. The study also applies the Dumitrescu and Hurlin (D-H) non-causality test to resolve the problem of the reliance between slope heterogeneity and cross-section units. Finally, the empirical findings acquired in this research provide guidelines at a practical policy level to implement the natural resources, energy and associated economic strategies to achieve sustainable economic and environmental development.

The remaining sections of the study are planned as follows. Section 2 presents a literature review. Data sources, model construction and the methodological framework are described in Section 3. The empirical findings are discussed in Section 4, and finally Section 5 contains the conclusions and policy implications.

2. Literature review

Human activities have led to the degradation of the environment, which ultimately affects its quality as a result of the depletion of natural resources, the expansion of species, a change in the weather and ecology deprivation (Ulucak and Bilgili, 2018). Industrialization is a key element for development but has a negative impact on the environment. NICs pay a high price in terms of natural resource depletion and environmental degradation. This literature investigates the link between industrialization, natural resources, financial development, energy utilization and environmental deficit for emerging industrialized economies.

Many studies explore numerous variables to measure environmental quality for a sustainable environment. Among them, financial development, globalization and energy consumption have recently attracted the most attention in analyzing environmental quality (Yang et al., 2021). Environmental standards and norms became stricter thanks to the transition to an efficient production framework and a rise in income levels, coupled with a decline in revenues from industrialization and the financial growth of the business (Usman et al., 2021). Environmental damage is the consequence of an increase in the number of energy-intensive industries in industrialized economies (Shahbaz et al., 2016). Firms have access to capital at a low cost to increase their acquisition of equipment, machinery and new production plants thanks to a highly-developed financial sector, which consequently drives the demand for energy consumption (Sadorsky, 2010). Industrialization is promoted by an advanced financial sector, which produces toxic waste and increases the degradation of the natural environment. This in turn leads to greater risk diversification, which fuels the consumption of energy sources and eventually reduces ecological quality (Acheampong, 2019; Omri et al., 2015; Sadorsky, 2011; Usman and Makhdum, 2021).

Industrialization is driven by economic development due to an increase in the extraction of natural resources and excessive use of resources in agriculture, manufacturing and mining, which ultimately has a negative effect on the environment (Baloch et al., 2019). The equal increase in both income and natural resource extraction increases the ecological footprint (EFP) and degrades biocapacity. The EFP has become a yardstick for measuring environmental degradation in the recent literature and is now in widespread use (Destek et al., 2018; Bello et al., 2018; Baloch et al., 2019; Solarin, 2019; Aydin et al., 2019; Ozcan et al., 2019; Sarkodie and Strezov, 2018). Industrialized countries mainly rely on traditional energy sources such as oil, coal and natural gas in the manufacturing process and are dependent on natural fuel imports (Balsalobre-Lorente et al., 2018). Green energy sources are plentiful and tenable compared to fossil fuels, although their use raises the EFP (Owusu and Sarkodie, 2016). Financial development plays a vital role for NICs, both for their sustainability and the growth of their economy and improving environmental quality. Therefore, the growth of the financial sector has the potential to protect environmental quality. Several studies have shown that the industrialized financial sector contributes to environmental deterioration (Huang and Zhao, 2018; Sadorsky, 2010; Saud et al., 2020; Usman and Hammar, 2021; Ehigiamusoe and Lean, 2019). Environmental quality is accelerated by renewable energy and financial development, wherein the long run is positively affected by the increase in technological innovation activities, economic growth and population size. There is a bidirectional causality relationship between technological revolutions, renewable energy consumption, economic growth, financial development, population size, and ecological footprint, as shown by the Dumitrescu and Hurlin non-causality test (Usman and Hammar, 2021). The link between economic growth and environmental quality is also complex. There is conflicting evidence of the role of financial growth in environmental degradation in both the theoretical and empirical literature. For instance, financial development emphatically impacts the weather (Lu, 2018; Bekhet et al., 2017); and, interestingly, financial development and ecological quality have a hostile relationship in different relevant settings (Saidi and Mbarek, 2017; Dogan and Seker, 2016; Omri et al., 2015; Usman et al., 2021).

Furthermore, Usman et al. (2021) observed that financial development and the use of renewable and non-renewable energy sources were found to reduce the level of the carbon footprint and increase growth in 15 countries with a high success rate in 1990–2017. This study also reported that the environmental deficit was due to non-renewable energy consumption and accelerated economic growth, while renewable energy, financial development and trade openness was helpful in controlling this deficit. In addition, Khan et al. (2017) found the causal nexus between monetary development, trade liberalization, greenhouse gas emissions, urbanization and the consumption of reusable and non-reusable energy for 34 upper middle developing economies. The Dumitrescu and Hurlin causality test was used for the panel data and revealed a strong relationship between financial development, bio energy and GHG emissions in Europe, while a significant reduction in pollution in Asia and American countries through financial development combined with the greater use of renewable energy alleviated environmental damage and the negative impact on the environment. Fernandes and Reddy (2020) deployed the autoregressive distributive lag (ARDL) model, Johansen's cointegration test, vector error correction model (VECM), vector autoregressive (VAR) and the Toda and Yamamoto causality test for six NICs (China, India, Indonesia, Philippines, Malaysia and Thailand) and explored the nexus between energy use and economic growth. They concluded that for China, India and Indonesia, energy use and economic growth are cointegrated in the long run, while VECM showed that both real GDP as the endogenous variable and energy consumption as the exogenous variable are unable to correct the economy to equilibrium after a shock.

On the other hand, Lahiani (2020) found an environmentally-friendly role of financial development in the case of China. This study concluded that financial development increased environmental quality when monetary funds were provided to businesses for environmental plans that eventually enhanced efficiency and reduced energy use. Moreover, Godil et al. (2020) examined the association between tourism, foreign direct investment (FDI), and Turkey's environmental footprint from 1986 to 2018. The findings of this study suggest that foreign direct investment, globalization and tourism all contribute to environmental degradation. Renewable energy systems enhanced national savings, whereas environmental quality was boosted by the financial system and bioenergy growth. On the other hand, economic development continues to contribute to the deterioration of environmental quality (Salahuddin et al., 2020). Renewable energy sources and financial growth were the main indicators for determining the level of sustainable development in the countries studied in the report (Ulucak and Khan, 2020). Economic expansion and the use of renewable energy depend heavily on the development of human capital in managing ecological degradation.

Industrialization process, energy consumption, financial development, natural resources, total reserves, and overall environmental pollution have been escalating in NICs. For this reason, there is a dire requirement to review and scrutinize the nexus between industry-finance-energy-resource-ecological footprints and to discover the interrelationship. Moreover, as seen from the abovementioned literature, there are a limited number of researches for the NICs on this subject. Thus, the major aim of the current study is to fill this gap in the extant literature. Even supposing, most of the existing studies pay no attention to the cross-sectional dependence, resulting in biased and contradictory conclusions.

3. Data sources, model construction and methodological framework

3.1. Data sources

In order to achieve the objective, this study applies a set of panel data for the top ten (10) newly industrialized countries (NICs) such as Brazil, China, Indonesia, India, Mexico, Malaysia, the Philippines, South Africa, Thailand and Turkey in the period from 1990 to 2019. All the data for this study were extracted from the World Development Indicators (WDI, 2020), except for financial development and the ecological footprint, which were derived from the International Monetary Fund (IMF, 2020) and Global Footprint Network (GFPN, 2020). The selection of these variables responds to the 2030 Sustainable Development Goals (SDGs). The measurement units for these variables are as follows: the ecological footprint is measured in per person global hectares; industrial value-added is calculated as all industrial value-added including construction (constant 2010 US dollar); natural resources are measured in natural resource rents (% of GDP); the financial development index is calculated as the country ranking on the basis of its financial market and institutional performance in terms of depth, access and efficiency (IMF, 2020; Usman et al., 2021a). The financial development variable ranges between 0 and 1, but we convert it into 0–100 for convenience for use with other variables (Usman et al., 2021); total reserves are calculated as current US$, and renewable energy use is measured by the percentage of total final energy use. A brief description of the variables is given in Table 1, and Table 2 shows the descriptive statistics and their correlation matrix, respectively.

3.2. Economic modelling

Based on the prior studies of Ulucak and Khan (2020), Khan et al. (2020), Usman and Hammar (2021) and Pata et al. (2021), we apply the following empirical model to explore the effect of industrial value-added, natural resources, financial development, total reserves and renewable energy use on the ecological footprint in Eq. (1) as follows:

$$\mathrm{EFP_{it}} = f(\mathrm{IVA_{it}},\ \mathrm{NRS_{it}},\ \mathrm{FDV_{it}},\ \mathrm{TRS_{it}},\ \mathrm{REU_{it}}) \tag{1}$$

where EFP denotes the ecological footprint, IVA refers to industrialization, NRS indicates natural resources, FDV is the financial development index, TRS is total reserves, and REU is renewable energy use.

A single multivariate framework is applied to discover the association between the variables of interest. Simultaneously, we also transform these series into a natural logarithmic algorithm to reduce the probability of heteroscedasticity, autocorrelation, dispersion and data sharpness and to estimate more consistent, efficient and reliable results as compared to the simple linear form (Yang and Usman, 2021). The log-linear econometric model for this study takes the following form as presented in Eq. (2) as follows:

$$\ln(\mathrm{EFP_{it}}) = \beta_0 + \beta_1 \ln(\mathrm{IVA_{it}}) + \beta_2 \ln(\mathrm{NRS_{it}}) + \beta_3 \ln(\mathrm{FDV_{it}}) + \beta_4 \ln(\mathrm{TRS_{it}}) + \beta_5 \ln(\mathrm{REU_{it}}) + \mu_{it} \tag{2}$$

where i represents the cross-section (from 1 to 10), t shows the time span (1990–2019), and β_0 is the intercept of the function. The coefficients of industrialization, natural resources, financial development, total reserves and renewable energy use are expressed as $\beta_1, \beta_2, \beta_3, \beta_4,$ and β_5 respectively. Finally, the stochastic error term is denoted by μ_{it}.

3.3. Methodological strategy

3.3.1. Cross-sectional dependence test

To check the interdependence between countries, this study applies the Pesaran (2004) cross-sectional dependence (CSD) test. All the study variables must be checked for possible CSD before executing the panel unit root tests as if CSD exists within the data set, the first-generation panel stationarity tests are not helpful to detect the accurate integration order. The functional expression of the Pesaran (2004) CSD test is shown in Eqs. (3) and (4) as follows:

$$CSD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\widehat{\delta}_{ij}\right) \sim N(0,1)\ i,\ j \tag{3}$$

$$R = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\widehat{\delta}_{ij}\right)\left[\frac{(T-K)\widehat{\delta}_{ij}^{2} - (T-K)\widehat{\delta}_{ij}^{2}}{Var(T-K)\widehat{\delta}_{ij}^{2}}\right] \tag{4}$$

3.3.2. Panel unit root tests

In view of the presence of CSD in the panel data set, this study applied Pesaran (2007) cross-section Im, Pesaran and Shin (CIPS) and cross-section augmented Dickey-Fuller (CADF) stationarity tests. The second-generation panel unit root tests proposed by Pesaran (2007) are able to offer consistent, reliable and robust results if the panel data has a problem of CSD. The second-generation CADF stationarity test is articulated in Eq. (5) as follows:

$$\Omega Y_{it} = \delta_i + \pi_i y_{i,t-1} + \beta_i \overline{y}_{t-1} + \Phi_i \theta \overline{y}_t + \mu_{it} \tag{5}$$

Introducing the one lag length (t-1) in Eq. (5), concluding in Eq. (6) as follows:

$$\Omega Y_{it} = \delta_i + \pi_i y_{i,t-1} + \beta_i \overline{y}_{t-1} + \sum_{j=0}^{p}\Phi_{ij}\theta\overline{y}_{t-j} + \sum_{j=1}^{p}\Psi_{ij}\theta y_{i,t-j} + \mu_{it} \tag{6}$$

where $\theta y_{i,t-j}$ and $\overline{y}_{t-j}$ denote the mean of the first lagged level and the difference in each cross-section. The Pesaran (2007) CIPS unit root test is shown in Eq. (7) as follows:

$$CIPS = N^{-1}\sum_{i=1}^{N}\pi_i(N,T) \tag{7}$$

where the term $\pi_i(N,T)$ stands for CADF[1] statistics reinstated with this parameter.

3.3.3. Panel long-run cointegration test

This research uses the panel cointegration approach developed by

Table 1
Description of the variables.

Variables	Acronyms	Measurement units	Sources
Ecological footprint	EFP	Global hectares per person	GFPN (2020)
Industrial value added	IVA	Including construction (constant 2010 US$)	WDI (2020)
Natural resources	NRS	Natural resource rents (% of GDP)	WDI (2020)
Financial development	FDV	Financial development index (1–100)	IMF (2020)
Total reserves	TRS	Current US dollar	WDI (2020)
Renewable energy use	REU	% of total final energy use	WDI (2020)

[1] $CIPS = N^{-1}\sum_{i=1}^{N} CADF_i$

Table 2
Descriptive statistics and correlation matrix.

	LnEFP	LnIVA	LnNRS	LnFDV	LnTRS	LnREU
Mean	0.77586	26.0457	0.92811	3.75328	24.7918	3.08791
Median	0.95545	25.9731	1.06484	3.72505	24.6675	3.13919
Maximum	1.49245	29.2763	3.24943	4.32153	28.9921	4.07163
Minimum	0.27277	24.2392	−1.96745	2.63434	21.4343	1.34000
Std. Dev.	0.46158	1.01775	1.04873	0.27592	1.45065	0.66738
Skewness	−0.61885	0.80742	−0.57788	−0.18607	0.52869	−0.54555
Kurtosis	2.13557	3.81680	2.83468	3.15851	3.71992	2.51683
Jarque-Bera	28.4893	40.9361	17.0391	2.04522	20.4543	17.7994
Probability	0.00001	0.00000	0.00020	0.35965	0.00036	0.00136
LnEFP	1.0000					
LnIVA	0.09524***	1.0000				
	[1.65173]	–				
LnNRS	0.11401**	0.11712**	1.0000			
	[1.98106]	[2.03582]	–			
LnFDV	0.47406*	0.10863***	0.15843*	1.0000		
	[9.29432]	[1.88647]	[2.76993]	–		
LnTRS	0.16505*	0.78691*	0.09871*	0.50069*	1.0000	
	[2.88895]	[22.0146]	[4.71221]	[9.96844]	–	
LnREU	−0.73224*	0.07437*	−0.20248*	−0.39905*	−0.15585*	1.0000
	[−18.5610]	[3.28749]	[−3.56938]	[−7.51281]	[−2.72286]	–

Note: *, ** & *** explores 1%, 5% and 10% level of significance respectively. The t-statistics are presented in [ ].

Westerlund (2007) to detect the presence of a long-run relationship among the study series. This approach is robust in the presence of the interconnection of the countries and variables in the long panel data-set. As conventional methods (e.g., First-generation) do not allow cointegration in the presence of CSD, this study applies the Westerlund (2007) bootstrap cointegration test to spotlight structural dynamics against residual dynamics. This test is based on two mean groups and panel statistics (i.e., G_a, G_t, P_a, and P_t). P_t and G_t statistics are calculated by applying the residual parameters in the error correction model. P_a and G_a are accustomed to heteroscedasticity and autocorrelation, which are based on the standard stochastic error term. The Westerlund cointegration test is stated in Eq. (8) as follows:

$$\Omega X_{i,t} = \delta'_i d_i + \xi_i\left(X_{i,t-1} - \omega'_i Y_{i,t-1}\right) + \sum_{j=1}^{q} \xi_{i,j}\Omega X_{i,t-j} + \sum_{j=0}^{q} \lambda_{i,j}\Omega Y_{i,t-j} + \varepsilon_{i,t} \tag{8}$$

where ξ_i denotes the speed of adjustment that adjusts the system back to the stable equilibrium. The error correction model (ECM) developed by second-generation cointegration tests includes four different test statistics, for instance two mean group cointegration (G_t, G_a)[2] and Panel long-run cointegration statistics (P_t and P_a)[3] are anticipated.

3.3.4. Long-run elasticity estimates

To approximate the long-run elasticity of the study variables, we applied the long-run elasticity estimate parameters by using Driscoll and Kraay (D-K), pooled mean group (PMG), augmented mean group (AMG) developed by Eberhardt and Bond (2009), and common correlated effects mean group (CCEMG) proposed by Pesaran (2006) estimators. The AMG method denotes the long-run parameters for the aggregate and disaggregates estimation of the panel and individual country estimates. This approach is robust and consistent against other conventional approaches even in the presence of CSD and heterogeneity. This approach is based on two-stage constraints. The AMG approach is shown in Eq. (9) as follows:

AMG (1st stage):

$$\Omega Y_{it} = \lambda_i + \lambda_i \Omega X_{it} + \pi_i f_t + \sum_{t=2}^{T} \rho_i \Omega D_t + \mu_{it} \tag{9}$$

While the second stage of the AMG test is shown in Eq. (10) as follows:

AMG (2nd stage):

$$\widehat{\lambda}_{AMG} = N^{-1}\sum_{i=1}^{N}\widehat{\lambda}_i \tag{10}$$

This study also applied the CCEMG method to address the issues of correlation and heterogeneity, specifically among individual cross sections. This test also produces good results with non-stationarity, heterogeneous slopes and CSD, and deals with unobservable factors (Pesaran, 2006; Usman et al., 2021b). The functional appearance of this test is presented in Eq. (11) as follows:

$$X_{it} = \alpha_{1i} + \beta_i Y_{it} + \gamma_i \rho_{it} + \mu_{it} \tag{11}$$

The amplified disparity with an average of the individual cross section of all the study series (response and explanatory variables) is shown in Eq. (12) as follows:

$$X_{it} = \alpha_{1i} + \beta_i Y_{it} + \Psi_i \bar{y}_{it} + \omega_i \bar{z}_{it} + +\lambda_i \rho_{it} + \varepsilon_{it} \tag{12}$$

This study applied the D-K and PMG approach for the robustness analysis, which also tackles the problems of autocorrelation, heteroscedasticity, slope heterogeneity and endogeneity.

3.3.5. Error correction model (ECM) for short-run elasticity estimates

In order to investigate the impact of the short-run elasticity of the regressors analyzed on the dependent variable, this study used the error correction model (ECM) as earlier applied by Hossain (2011), and Khalid et al. (2021). The functional demonstration of the ECM for the ecological function is presented in Eq. (13) as follows:

$$\begin{aligned}\Delta\ln(\mathrm{EFP}_{it}) = \delta_0 + \delta_1\Delta\ln(\mathrm{IVA}_{it}) + \delta_2\Delta\ln(\mathrm{NRS}_{it}) + \delta_3\Delta\ln(\mathrm{FDV}_{it}) \\ + \delta_4\Delta\ln(\mathrm{TRS}_{it}) + \delta_5\Delta\ln(\mathrm{REU}_{it}) + +\mathrm{ECM}_{it-1} + \varepsilon_{it}\end{aligned} \tag{13}$$

where δ_0 denotes the intercept; $\delta_1, \delta_2, \delta_3, \delta_4$, and δ_5 show the elasticity of the regressors; the term λ shows the ECM coefficient that explores the annual change in equilibrium from short-run to long-run; and the term ε_{it} refers to the contemporaneous error expression.

3.3.6. Panel causality analysis

The final procedure in the empirical analysis is to detect the direction of causality of one variable to another. This study applied the Dumitrescu and Hurlin (D-H) panel causality test developed by Dumitrescu and Hurlin (2012). This test also produces robust outcomes in the

[2] $G_\tau = \frac{1}{N}\sum_{i=1}^{N}\frac{\omega_i}{SE(\widehat{\omega}_i)}$, $G_a = \frac{1}{N}\sum_{i=1}^{N}\frac{T\omega_i}{\omega'_i(1)}$

[3] $P_\tau = \frac{\widehat{\omega}_i}{SE(\widehat{\omega}_i)}$, $P_a = T\widehat{\omega}$.

presence of CSD and heterogeneity. The Dumitrescu and Hurlin causality test is exceptionally imperative and more suitable in the occurrence of CSD error terms. Additionally, this causality test is more appropriate in circumstances where there is a smaller cross-section (N which is the NICs including 10 countries) and larger time period (T which is 30 years comprising 1990–2019 for this study) in balanced panels. The null hypothesis (H_0) of the D-H panel causality test is placed on the hypothesis of no causal relationship between variables quite the opposite to the alternative hypothesis (H_1), which supports the occurrence of panel granger causal nexus in the model. In order to test the null hypothesis of does not homogeneously causality relationship, the Wald test statistic for all panel is deliberate by averaging the individual Wald test statistics values for each cross-section (N). The functional form of this test is denoted in Eq. (14) as follows:

$$X_{it} = \pi_i + \sum_{\kappa-1}^{K} \delta_i^{\kappa} X_{i(t-\kappa)} + \sum_{\kappa-1}^{K} \Phi_i^{\kappa} Z_{i(t-\kappa)} + \mu_{it} \tag{14}$$

where X and Z indicate the study variables, and δ_i^{κ} and Φ_i^{κ} show autoregressive (AR) parameters and simple OLS regression respectively. The null hypothesis (H_0) of panel causality is estimated through the Wald ($W_{N,T}^{HNC}$) approach as expressed in Eq. (15) as follows:

$$W_{N,T}^{HNC} = N^{-1} \sum_{i=1}^{N} W_{i,T} \tag{15}$$

where in the case of larger time dimension as compared to cross-sections ($T > N$), Dumitrescu and Hurlin (2012) recommended applying the test statistic as presents in Eq. (16) as follows:

$$Z_{N,T}^{HNC} = \sqrt{\frac{N}{2K}} \left(W_{N,T}^{HNC} \right) - K \tag{16}$$

H_0 and H_1 are shown in Eqs. (17) and (18) as follows:

$$H_0 : \pi_i = 0 \quad \text{for } \forall i \tag{17}$$

$$H_1 : \left\{ \begin{array}{lll} \pi_i = 0 & \text{for all} \quad i & = 1,2,3,\ldots\ldots\ldots\ldots, \quad N_1 \\ \pi_i \neq 0 & \text{for all} \quad i & = N_1 + 1,2,3,\ldots\ldots..N \end{array} \right\} \tag{18}$$

4. Results and discussion

4.1. Panel cross-sectional dependence evidence

The first and most important step in the estimation of panel data is to confirm the cross-sectional dependence (CSD) of the variables analyzed in the model. The findings of cross dependence are presented in Table 3. The results of the CSD test confirm the presence of the interdependence of countries at a 1% significance level. We, therefore, reject the null hypothesis (H_0) of no cross-sectional dependence for ecological footprint, industrialization, natural resources, financial development, total reserves and renewable energy use. Due to the presence of CSD, this research applies the recently introduced second-generation panel test procedure.

Table 3
Cross-sectional dependence results.

Series	CD-test	P-value	Corr	abs(corr)
LnEFP	10.55*	0.000	0.287	0.390
LnIVA	34.80*	0.000	0.947	0.947
LnNRS	19.53*	0.000	0.531	0.557
LnFDV	18.43*	0.000	0.502	0.652
LnTRS	35.11*	0.000	0.956	0.956
LnREU	24.24*	0.000	0.660	0.663

Note: * explores 1% level of significance. Under the null hypothesis of cross-section independence CD ~ N(0,1).

4.2. Panel unit root evidence

As CSD is present, the results of second-generation (CADF and CIPS) panel stationarity tests are given in Table 4. Both unit root tests (CADF and CIPS) provide a consistent and reliable conclusion that financial development is stationary (intercept and trend) at level. However, according to the CIPS test, natural resources are found to be stationary (intercept) at level I(0), while all other variables such as ecological footprint, industrialization, natural resources, total reserves and renewable energy use are non-stationary at level and become stationary at their first integrated order I(1). The existence of the first difference stationarity of the variables advocates for an investigation into possible long-run cointegration.

4.3. Panel cointegration evidence by Westerlund

The current research also applies a panel linear cointegration test to detect the presence of the long-run association. This long-run relationship among variables is also investigated by using the 2nd generation panel cointegration tests. To do this, Table 5 shows the findings of the bootstrap version of the panel long-run cointegration test named as Westerlund cointegration test. In the estimation of the ecological footprint function, the robust probability values (P-values) were estimated through 400 replications. The outcomes from the Westerlund (2007) cointegration test showed that all the aforementioned variables are long-run cointegrated and the null hypothesis of no cointegration is rejected at 1% significance level. This research thus confirms that all variables are long-run cointegrated in NICs.

4.4. Panel long-run evidence by D-K, PMG, AMG and CCEMG estimations

After verifying the long-run association between the series, this research applied the D-K, PMG, AMG, and CCEMG approaches to estimate the long-run impact of industrial value-added, natural resources, total reserves, financial development and renewable energy use on the ecological footprint in newly industrialized countries (NICs). The results of all these approaches are shown in Table 6. The findings of the D-K, PMG, AMG and CCEMG approaches are all similar in their coefficients, with the same sign and similar magnitudes. We discuss the findings of the AMG estimator due to the low value of RMSE to contribute robustness to the empirical estimations in this work.

Tables 6 and 7 show that industrial value-added has positively and significantly impact the ecological footprint in the overall panel and their respective countries. Specifically, a 1% rise in the industrialization process will lead to a 0.5092% increase in the ecological footprint in the NICs panel. The disaggregate (country-wise) results show that a unit change in industrialization will increase the ecological footprint in Brazil, China, India, Indonesia, Malaysia, Mexico, Philippines, Thailand and Turkey by 0.2410%, 0.1513%, 0.1677%, 0.2817%, 0.5031%, 1.3869%, 0.7457%, 0.6657% and 0.4534% respectively. The rapid increase in human activity influences global emission levels and is incontestably threatening; the industrialization process affects key day-to-day actions. Individual actions lead to a gradual increase in industrial activities, energy consumption and environmental contamination resulting in a worldwide increase in temperature levels and climate variation (Xiao et al., 2017). It is observed that an increase in industrial output can be endorsed as the energy sector transitions from low to high production (Cheng et al., 2018). Especially in NICs, the sharp rise in industrial activities has encouraged massive GDP growth and radically increased non-renewable energy use and carbon discharges. In fuel and coal utilization and the toxic waste associated with other non-renewable

[4] As suggested by Westerlund (2007), the maximum lag length is selected according to $4(T/100)^{2/9} \approx 3$. For details see Persyn and Westerlund.

Table 4
Unit root results.

Series	CADF				CIPS			
	Intercept		Intercept & trend		Intercept		Intercept & trend	
	Level	First Δ	Level	First Δ	Level	First Δ	Level	First Δ
LnEFP	−1.808	−3.473*	−1.958	−3.570*	−2.044	−4.968*	−2.279	−5.095*
LnIVA	−1.776	−3.098*	−1.743	−3.236*	−2.055	−3.913*	−1.959	−4.122*
LnNRS	−2.074	−4.475*	−2.496	−4.565*	−2.508**	−5.959*	−2.221	−5.992*
LnFDV	−1.718	−4.023*	−2.984**	−4.023*	−2.003	−5.249*	−2.993**	−5.360*
LnTRS	−1.753	−3.819*	−2.663	−3.901*	−2.008	−5.246*	−2.666	−5.325*
LnREU	−2.014	−3.389*	−2.320	−3.661*	−1.935	−4.518*	−2.119	−4.718*

Note: *, ** & *** explores 1%, 5% and 10% level of significance respectively while, Δ signifies the difference.

Table 5
Second-generation Westerlund[4] cointegration results.

Statistics	Values	Z-values	P-values	Robust P-values
Intercept				
G_τ	−2.616**	−1.298	0.097	0.040
G_a	−9.817**	0.785	0.784	0.030
P_τ	−7.841***	−1.547	0.061	0.080
P_a	−8.029	0.001	0.500	0.220
Intercept & trend				
G_τ	−2.668**	−1.458	0.072	0.033
G_a	−5.721	2.472	0.993	0.198
P_τ	−7.941***	−1.629	0.052	0.063
P_a	−9.229*	−3.115	0.018	0.001

Note: *, ** & *** explores 1%, 5% and 10% significance level respectively.

energy sources, the relation between natural resources, financial development and countries' ecological footprint is scarcely addressed in NICs. Potentially contentious increases in the ecological footprint often boost domestic economic development. A dynamic system of industrialization with a low ecological footprint can be ensured through a range of constructive methods (Wang et al., 2019).

The negative impact of natural resources on the ecological footprint is observed in all estimation approaches to be around 0.0207%–0.1511% in the panel. Specifically, it is negative and significant in the long run in China (0.0330%), Mexico (0.1604%) and Turkey (0.2349%). The adverse coefficient sign of natural resources in the NIC panel and corresponding countries is recognized to the exploitation of more natural resources sustaining to diminish environmental damages. An abundance of natural resources makes it unnecessary to import non-

Table 6
Results of panel long-run elasticity estimates (overall panel).

Series	D-K		PMG		AMG		CCEMG	
	Coeff.	Prob.	Coeff.	Prob.	Coeff.	Prob.	Coeff.	Prob.
LnIVA	0.2954*	0.000	0.5774*	0.000	0.5092*	0.000	0.5859*	0.000
LnNRS	−0.1511*	0.000	−0.0229***	0.069	−0.0207*	0.000	−0.0401**	0.029
LnTRS	0.2186*	0.000	0.3375**	0.017	0.1608**	0.047	0.1947***	0.052
LnREU	−0.4983*	0.000	−0.2225*	0.000	−0.2631*	0.002	−0.2329*	0.009
LnFDV	0.0897***	0.075	0.1185**	0.016	0.5931**	0.034	0.5706*	0.001
Constant	−2.9110*	0.000	−5.9826*	0.000	−11.3719*	0.000	−2.6668	0.305
Wald-χ^2					280.43*	0.000	131.28*	0.000
R-squared	0.6895		0.8737					
RMSE	0.2594				0.0182		0.0309	

Note: *, ** & *** denote a 1%, 5% and 10% significance level respectively.

Table 7
Country-wise evidence by Augmented Mean Group regression (Long-run).

Variables	Brazil	China	India	Indonesia	Malaysia	Mexico	Philippines	S. Africa	Thailand	Turkey
LnIVA	0.2410**	0.1513*	0.1677**	0.2817*	0.5031*	1.3869*	0.7457*	0.2898	0.6657*	0.4534*
LnNRS	−0.0006	−0.0330*	−0.0043	−0.0198	−0.0093	−0.1604*	−0.0509*	0.0630	−0.0283	−0.2349*
LnTRS	0.0470*	−0.0033	−0.0120	0.0389***	0.1057**	0.0493	−0.1191*	0.0186	−0.1326**	0.0257
LnREU	−0.5319*	−0.5761*	−0.6987*	0.2676***	0.0898	−0.1299	−0.3797*	−0.5633**	−0.3873*	−0.4901**
LnFDV	0.1823**	0.0351***	0.0690***	−0.2424**	0.1692	−0.0265	0.4143*	−0.0022	0.0832	−0.2094**
ARDL Based Error Correction Model (ECM Short-run)										
ΔLnIVA	0.4097**	0.1115*	0.0565***	0.2627*	0.7144**	0.8651**	0.2891*	0.0632	0.2892*	0.5921**
ΔLnNRS	−0.0595**	−0.0099	0.0111	0.0063	0.0964	0.0392	−0.0341***	0.0691***	0.2611***	0.0061
ΔLnTRS	0.0551*	0.0048	−0.0121	0.6162*	0.0041	−0.0723	−0.0901**	−0.0231	0.0205	0.0675
ΔLnREU	−0.0768	−0.4228*	−0.6548**	−0.0802	−0.0396***	0.2051	- 0.0219	−0.4639**	−0.6834*	−0.2375**
ΔLnFDV	0.2123**	0.0564***	−0.0562	0.0259	0.1389**	−0.2356	0.1305**	0.0049	0.0257	−0.1243**
$ECM_{(t-1)}$	−0.2941*	−0.8122*	−0.4393*	−0.6948**	−0.7437*	−0.8309*	−0.3058***	−0.4918**	−0.4606*	−0.8700*
Years	3.41	1.23	2.27	1.43	1.34	1.21	3.27	2.03	2.17	1.14
Robustness check	**Test statistics**									
JB Normality test	0.167327	0.465736	1.863698	1.259552	0.376362	2.272031	0.392814	0.686945	4.190623	0.677875
Durbin-Watson stats	1.967530	2.189302	2.054695	2.174208	2.464981	2.248626	2.139480	1.918238	2.122199	1.942424
LM Serial Correlation test	0.505730	0.761182	0.059026	2.187387	1.942102	0.742303	0.132431	2.498030	1.296864	0.615751
ARCH Heteroscedasticity test	2.456252	2.223149	0.385307	0.002717	1.028638	0.326572	1.296779	5.64131**	0.430987	0.073454
BPG Heteroscedasticity test	0.476757	0.428858	0.622083	0.844984	0.943663	0.990733	0.488558	1.265492	0.334471	3.12979**
CUSUM & CUSUM square test	Stable	Stable	Stable	Stable	Stable	Stable	Stable	Stable	Stable	Stable

Note: *, ** & *** denotes 1%, 5% and 10% significance level respectively.

renewable energy resources, and these findings are linked to reductions in the use of alternative energy sources such as natural gas, biogas, solar, hydro and other renewable sources that emit less pollution than non-renewable energy sources (Ulucak and Khan, 2020; Usman and Hammar, 2021; Balsalobre-Lorente et al., 2018). The lower use of natural resources in China, Mexico and Turkey is due to their ability to extract large amounts of their own natural resources. This finding is consistent with the outcomes of Balsalobre-Lorente et al. (2018) for European countries, Danish et al. (2019) for BRICS, Zafar et al. (2019) for the United States, and Khan et al. (2020) for BRI countries. NICs have a wide variety of natural resources such as oil, coal, natural gas, and uranium ore, and approximately 24% of the global reserves of all industrialized countries, especially in China, India and Turkey. The fact that the use of natural resources mitigates the ecological footprint of Turkey and South Africa is directly linked with real GDP growth, which accelerates the mining of natural resources and reduces economic dependence on non-renewable energy imports.

For better inferences, proceeding to the long-run effect of total reserves on ecological footprint explored some important information not only for NICs but also for country-specific. According to the AMG estimator, total reserves significantly raise the ecological footprint by 0.1608% in the NICs panel. Specifically, a 1% increase in total reserves will raise emissions in Brazil, Indonesia and Malaysia by 0.0551%, 0.0389% and 0.1057%, respectively. Total reserves exert a significantly adverse impact on the ecological footprint in the Philippines (0.1191%) and Thailand (0.1326%). The influence of renewable energy use on the ecological footprint has a statistically significant and elastic adverse effect of 0.2631% in the NICs panel. The disaggregate analysis also shows that a 1% change in renewable energy will decrease emission levels in Brazil, China, India, Philippines, South Africa, Thailand and Turkey by 0.5319%, 0.5761%, 0.6987%, 0.3797%, 0.5633%, 0.3873% and 0.4901% respectively. Surprisingly, the role of renewable energy in reducing the ecological footprint is positive in the case of Indonesia (0.2676%), showing that renewable energy sources do not contribute to mitigating environmental pollution. This highlights the key role of fossil fuel energy in Indonesia. Alola et al. (2019) reported similar results for the Indonesian economy and found that renewable energy played a positive role in increasing the ecological footprint in European countries. A common perception that is widely supported by the empirical and theoretical evidence is that cleaner and the renewable energy consumption is very helpful in curbing the ecological consequences of human actions, considering the use of goods, land and water; this is an effective way of achieving social, economic and ecological sustainability in order to fulfil SDG 13 (Balsalobre-Lorente et al., 2018; Bilgili and Ulucak, 2018). The NICs should therefore take action to accomplish sustainable development and environmental targets in terms of their ecological footprint by adopting the use of renewable energy resources. The findings in regard to the role of cleaner energy consumption on environmental pollution coincide with the results of Ozturk and Acaravci (2013); Destek and Sinha (2020), Wang and Dong (2019) and Usman et al. (2021a). Finally, the effect of financial development on the ecological footprint is statistically significant, elastic and positive (0.5931%) for the NIC panel in the long run, suggesting that financial development significantly increases environmental contamination. The positive sign of the coefficient for financial expansion confirms that the financial systems of NICs assign monetary assets to ecological damage and do not encourage production units and organizations that install cleaner machinery. However, the effect of financial development on the ecological footprint is quite mixed at the level of individual NICs. It is damaging in the case of Brazil (0.1823%), China (0.0351%), India (0.0690%) and the Philippines (0.4143%), but not in Indonesia (0.2424%) and Turkey (0.2094%). The NICs should implement policies where the real economic development does not allocate more resources to driving the extraction of natural resources, non-renewable energy and financial development. Fig. 1 shows the long-run influence of regressors on the ecological footprint.

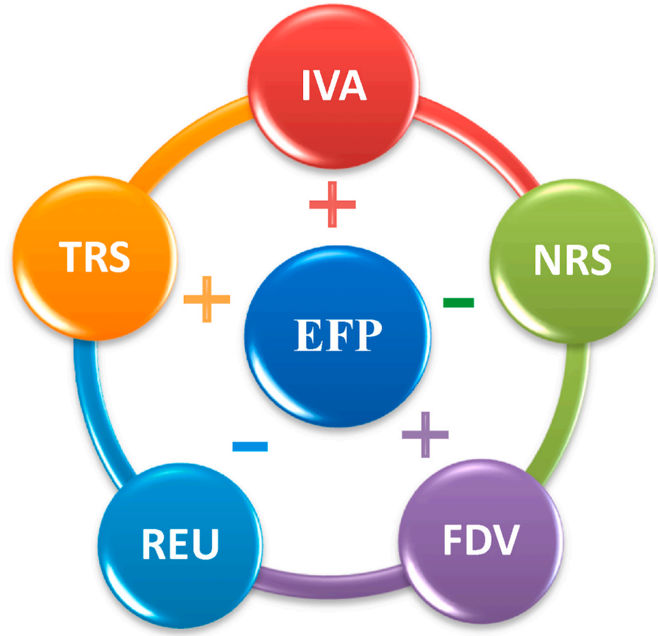

Fig. 1. Long-run effect of regressors on the ecological footprint.

According to the results, a major increase in the level of ecological deprivation occurs in parallel with a rapid increase in the industrialization process, which explains why NICs have not yet achieved an industrialization process that is able to protect environmental excellence. This finding is not unexpected, as NICs have still not reached the threshold development level, not have they made sufficient technical progress towards generating eco-friendly (cleaner) equipment and technologies. To ensure a sustainable environment, extra use of natural resources should be allocated to the different kinds of cleaner and renewable energy resources, which should be cheap and cost-effective. Increasing the share of renewable energy in the energy mix can play a vital role in sustainable development by reducing the ecological footprint and atmospheric variations (Alola et al., 2019; Usman et al., 2021; Destek and Sinha, 2020). The governments of these nations can promote ecological excellence by implementing environmental strategies to encourage the use of renewable and alternative energy, replace non-renewables with renewables and increase the public-private awareness of renewable energy resources. However, the positive role of total reserves in promoting ecological footprint levels will massively increase environmental pollution, so domestic and foreign policies to increase the total reserves will need to be reformulated to lessen unintended fiscal and monetary shocks and environmental degradation. The findings of this research highlight the need to promote cleaner energy and the use of alternative energies such as wind, hydro and solar power, and bioenergy, which is one of the best solutions for a sustainable environment in NICs. Investment by private-public partnerships (PPP) in cleaner energy ventures would reduce some of the burden on NIC governments, as many of the governing bodies of these countries have liquidity restrictions and their financial sector is not sufficiently developed to undertake these projects alone (Moner-Girona et al., 2018). At the same time, precise efforts should be designed to increase the share of renewable mixed in energy utilization that will enable the countries to mitigate environmental pollution in the region. Finally, the positive effect of financial globalization means that the influx of overseas investment and the worldwide stock of assets and liabilities may offer further monetary aid to NICs through funds to support cleaner energy segments and increase carbon-free technologies.

4.5. Panel short-run evidence by ARDL based ECM estimation

For the analysis of the short-term dynamics between the selected series and their connection to the long-run equilibrium, this study further applied the error correction model (ECM) as indicated in Eq. (18), which is directly linked with the level of association reported in Equation (2). The findings of the ECM model are also shown in Table 7. The term associated with short-run convergence, the error correction term (ECT) in Equation (18), is negative and statistically significant in all individual countries (all years are estimated for individual countries at the end of the second section in Table 7), which shows the speed of convergence of the ecological footprint from a short-term to long-term stable equilibrium in the model through the channels of industrialization process, natural resources, financial development, total reserves and renewable energy use.

In the case of the anticipated short-run findings, the coefficient of industrialization process is also statistically significant, positive and more elastic. This suggests that inefficiency in industrialization significantly increases the ecological footprint in all NICs except South Africa, influencing ecological quality in the short run and extending over the long run. In contrast, the short-run coefficient of natural resources is observed to be elastic, significant and negative in the case of Brazil and the Philippines; however, a significant positive impact of natural resources on the ecological footprint is found in South Africa and Thailand. Total reserves play a role in increasing the ecological footprint for Brazil and Indonesia but have an adverse effect in the case of the Philippines. Renewable energy also significantly increases environmental quality in the NICs. Specifically, in the short run, a 1% increase in renewable energy use will reduce the ecological footprint in China, India, Malaysia, South Africa, Thailand and Turkey by 0.4228%, 0.6548%, 0.0396%, 0.46395, 0.68345 and 0.2375%, respectively. These results are also consistent with long-run estimates (both aggregate and disaggregate) and the findings of Yang et al. (2021), Khalid et al. (2021); and Usman and Makhdum (2021), and in the short run can be interpreted as showing that renewable energy follows an opposing trend to the ecological footprint in the short-run. The adverse reaction of the ecological footprint to adjustments in renewable energy becomes positive in the long run, which is helpful for designing energy policies to protect ecological excellence. Finally, the short-run influence of financial expansion is mixed and significant in the NICs. The coefficient of financial development is initially positive and statistically significant in Brazil, China, Malaysia and the Philippines but negative in the case of Turkey, showing that short-run financial development in NICs substantially moderates ecological value.

Finally, several robustness tests are applied to test the consistency, accuracy and reliability of the estimated model. The third section of the table contains the findings of these checks, and clearly shows that the data are normally distributed as confirmed by the Jarque-Bera test. We applied the Durbin-Watson and LM serial correlation test to detect the autocorrelation issue in the model. The findings explore the acceptance of the null hypothesis of no serial correlation. The results of the ARCH and BPG heteroscedasticity tests reveal no heteroscedasticity problem in the estimated model, and the findings of the CUSUM and CUSUM square tests show the stability of the model estimation in all NICs.

4.6. Panel Dumitrescu and Hurlin (D-H) causality evidence

The primary causal linkage between ecological footprint, industrialization, natural resources, financial development, total reserves and renewable energy use is analyzed through the panel heterogeneous non-causality test developed by Dumitrescu and Hurlin (2012). The findings of this test are listed in Table 8 and Fig. 2, and show a unidirectional causality association from IVA → EFP, EFP → NRS, REU → EFP, IVA → NRS, TRS → IVA, TRS → NRS, REU → NRS, and REU → FDV, and a bidirectional causality relation between FDV ↔ EFP, TRS ↔ EFP, FDV ↔ IVA, REU ↔ IVA, TRS ↔ FDV and REU ↔ TRS respectively, while there is no causal relationship between FDV ⇎ NRS. Also, bidirectional causation from TRS to EFP explores that the constant increase of total reserves may increase environmental pollution. Accordingly, policy procedures to reduce ecological footprint should highlight sustainable green growth approaches to accomplish low carbon economic expansion. However, unidirectional causality is running from IVA to EFP, which suggests that IVA significantly causes the EFP. This finding is consistent with long-run estimates.

Table 8
Panel Dumitrescu and Hurlin (D-H) causality results.

Null hypothesis:	W-Stat.	Zbar-Stat.	Prob.	Remarks
LnIVA ⇎ LnEFP	5.52560**	2.22336	0.0262	IVA → EFP
LnEFP ⇎ LnIVA	4.45507	1.13765	0.2553	
LnNRS ⇎ LnEFP	3.30357	−0.03019	0.9759	EFP → NRS
LnEFP ⇎ LnNRS	5.44650**	2.14314	0.0321	
LnFDV ⇎ LnEFP	6.18503*	2.89215	0.0038	FDV ↔ EFP
LnEFP ⇎ LnFDV	6.11211*	2.81819	0.0048	
LnTRS ⇎ LnEFP	7.15067*	3.87149	0.0001	TRS ↔ EFP
LnEFP ⇎ LnTRS	6.15411*	2.86079	0.0042	
LnREU ⇎ LnEFP	5.25436***	1.94827	0.0514	REU → EFP
LnEFP ⇎ LnREU	4.85390	1.54214	0.1230	
LnNRS ⇎ LnIVA	3.23358	−0.10117	0.9194	IVA → NRS
LnIVA ⇎ LnNRS	7.68836	4.36007	0.0000	
LnFDV ⇎ LnIVA	8.53258*	5.27300	0.0000	FDV ↔ IVA
LnIVA ⇎ LnFDV	8.09468*	4.82888	0.0000	
LnTRS ⇎ LnIVA	8.45131*	5.19058	0.0000	TRS → IVA
LnIVA ⇎ LnTRS	4.55617	1.24018	0.2149	
LnREU ⇎ LnIVA	5.68577**	2.38581	0.0170	REU ↔ IVA
LnIVA ⇎ LnREU	7.82999*	4.56044	0.0000	
LnFDV ⇎ LnNRS	4.35092	1.03202	0.3021	FDV ⇎ NRS
LnNRS ⇎ LnFDV	2.90163	−0.43783	0.6615	
LnTRS ⇎ LnNRS	5.32091**	2.01577	0.0438	TRS → NRS
LnNRS ⇎ LnTRS	4.64549	1.33077	0.1833	
LnREU ⇎ LnNRS	6.81175*	3.52776	0.0004	REU → NRS
LnNRS ⇎ LnREU	4.92686	1.61613	0.1061	
LnTRS ⇎ LnFDV	9.38665*	6.13918	0.0000	TRS ↔ FDV
LnFDV ⇎ LnTRS	7.94019*	4.67221	0.0000	
LnREU ⇎ LnFDV	8.17317*	4.90849	0.0000	REU → FDV
LnFDV ⇎ LnREU	4.27972	0.95981	0.3372	
LnREU ⇎ LnTRS	5.69431**	2.39447	0.0166	REU ↔ TRS
LnTRS ⇎ LnREU	7.11345*	3.83374	0.0001	

Note: *, ** & *** denotes 1%, 5% and 10% significance level respectively. The symbols "→, ↔ & ⇎" show the unidirectional, bidirectional and non-homogeneous causality relationship respectively.

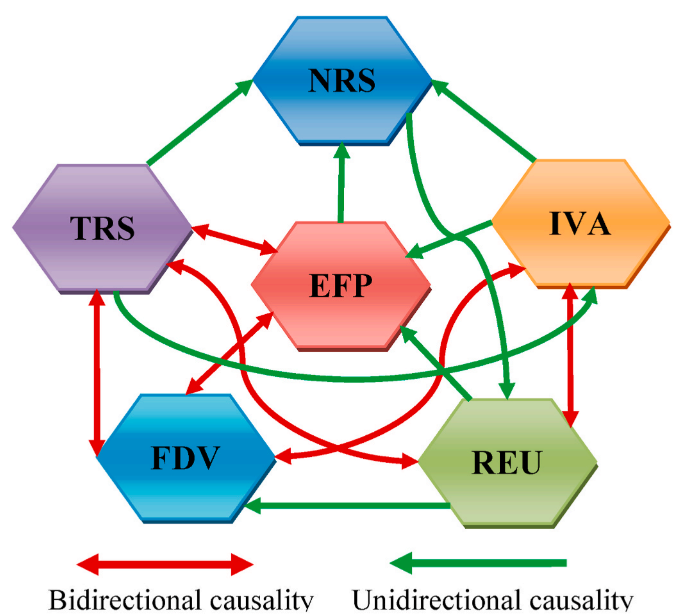

Fig. 2. Diagram of causality relationships.

In contrast, bidirectional causality exists between FDV, TRS, and EFP. This depicts that financial development in the NICs countries has the ability to preserve the environment. Further to this, total reserves and the banking sector are vital in increasing the pollution level by providing credits to the deficit economic assets. At one fell swoop, development in financial and industrial sectors can facilitate the workers to achieve their threshold income level, thus contributing to protecting environmental quality. Similarly, a bidirectional causality association has also been discovered between renewable energy, industrialization, financial development, and total reserves. This depicts that financial expansion, industrialization, total reserves, and renewable energy use have been of important substance for these NIC countries which are in a transition phase. Furthermore, both the consumption of natural resources and renewable energy diminish ecological footprint levels and the sources of financial growth improvement and decrease the environmental pollution. These results confirm that greater industrialization, total reserves, natural resources, and industrialization can play a vital role in influencing ecological footprint levels while boosting the economic growth of these NICs.

5. Conclusion and policy implications

This research explores the influence of industrialization, natural resources, total reserves, financial development and renewable energy use on the ecological footprint in a panel of the top ten newly industrialized countries (NICs) between 1990 and 2019, using the augmented mean group (AMG) estimator. In order to achieve this objective, this study initially applies the Pesaran test (2004) to detect the cross-sectional dependence among variables. After verifying the possible CSD, we applied the second-generation panel stationarity test to determine whether the variables applied in the study are stationary or not. After checking the integration order, we continued our analysis to discover the long-run association between series using the Pedroni and Westerlund cointegration tests, which confirm the presence of a long-run association among variables. The AMG method was applied to estimate the long-run panel coefficient, and D-K, PMG, and CCEMG estimators were used for the robustness analysis. Finally, this research employed the panel Dumitrescu and Hurlin (D-H) causality test to determine the causality directions.

This study explores the important relative indicators that are the chief drivers of the ecological footprint while polluting materials seriously increase overall emissions levels worldwide. Specifically, NICs are releasing huge amounts of carbon emissions due to the rapid increase in the industrialization process. Empirical evidence from the estimated findings reveals that the main driving forces causing high levels of environmental degradation in these countries are industrialization, natural resources, financial development, total reserves and renewable energy use. Therefore, it can be assumed that with a higher industrial level, the indicators most responsible for increasing the ecological footprint are total reserves and financial development. Conversely, natural resources and renewable energy use can protect the level of ecological footprint in the long run, so with the help of the estimated coefficients, it can be expected that the greater use of labour-produced goods at some stage in the industrialization process will lead to more pollution in these countries. Similarly, total reserves and financial development can also increase economic growth and the ecological footprint level in the long run. The use of natural resources and renewable energy consumption are other important factors that marginally protect the environment. The panel D–H causality test results reveal a unidirectional causality association from industrialization and renewables to ecological footprint and ecological footprint to natural resources; and a bidirectional causality relation between financial development and total reserves and the ecological footprint, although there is no causal association between financial development and natural resources.

From a policy perspective, it can be derived from the results and the abovementioned debate that governments, central authorities and policymakers in these countries should slow the rate of growth of the industrialization process, particularly for manufacturing companies that release high levels of carbon emissions into the environment. This process will curtail the increasingly dangerous impacts of the industrialization process on environmental quality. Governments must also determine the ecological rules and regulations for dirty industrial units. Research and development (R&D) institutions are needed at the private and government levels to protect environmental quality through modern technologies while promoting cast-off industrial waste as an energy source to reduce pollution levels. In order to avoid the harmful effect of financial expansion on the ecological footprint, policymakers in these countries should expand financial institutions and markets in such a way that these finances should be allocated to businesses through schemes that encourage new types of machinery powered by green and renewable energy consumption. In other words, the central authorities in NICs should focus not on the scale effect but more on the technological effect of financial development. Introducing cleaner energy facilities such as petroleum-efficient commercial and domestic technology will reduce environmental externalities, and environmental rules and regulations should be implemented to prevent unnecessary energy consumption and encourage the share of alternative sources in the overall energy supply. This will have positive economic, environmental and social consequences. Pigovian taxes and tariffs can be applied to imports of dirty and traditional capital by providing various incentives to use cleaner and more modern types of machinery in these economies; this would incentivize local financiers to advance their resources for renewable energy-efficient technologies. Environmental alleviation policies must be implemented to provide economic inducements for the financial sector.

The current research is constrained by not incorporating institutional activities and cultural indicators in the ecological footprint function for NICs, which may have various dissimilar impacts on the environment and economy. Cultural activities and institutional quality (political, social, and economic indicators) have a lot of ability to play a major role in a country's total reserves, economic growth, natural resources, financial sector development, technological innovations, and the efficient management of human capital. Moreover, the current research does not examine the environment Kuznets curve (EKC), and pollution halo, heaven (PHH) hypotheses of ecological footprint with these analyzed variables in NICs. Data availability is another main restriction of this research, which also could be expanded by incorporating other demographic variables for gender classification and household in the tentative model. Last but not least, the results can be applied to widen comparable research (especially with these indicators) for developing and developed economies, in which future scholars could control these limitations.

CRediT authorship contribution statement

Muhammad Usman: Conceptualization, Data curation, Software, Methodology, Formal analysis Manuscript writing, Project administration, Visualization, Results and Discussion, Revised draft, Writing – Review & Editing. **Daniel Balsalobre-Lorente:** Litrature review, Supervision, Validation, Implications, Results improvement.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

List of nomenclature

Acronyms

AMG Augmented mean group

APEC	Asia-Pacific Economic Cooperation
ARDL	Autoregressive distributive lag
BRICS	Brazil, Russia, India, China, and South Africa
CADF	Cross-section augmented Dickey-Fuller
CCEMG	Common correlated effect mean group
CIPS	Cross-section Im, Pesaran and Shin
CO_2	Carbon dioxide
CSD	Cross-sectional dependence
D-H	Dumitrescu and Hurlin
D-K	Driscoll and Kraay
ECM	Error correction model
ECT	Error correction term
EFP	Ecological footprint
FDI	Foreign direct investment
FDV	Financial development
GDP	Economic growth
GHG	Greenhouse gas
IVA	Industrial value added
MENA	Middle East and North Africa
NICs	Newly industrialized countries
NRS	Natural resources
OECD	Organization for Economic Co-operation and Development
PMG	Pooled mean group
PPP	Private-public partnerships
R&D	Research and Development
REU	Renewable energy use
SDGs	Sustainable development goals
TRS	Total reserves
UNFCCC	United Nations Framework Convention on Climate Change
VECM	Vector error correction model

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