Environment, Development and Sustainability
https://doi.org/10.1007/s10668-023-03919-1

The role of technological innovation, economic policy uncertainty, and poverty reduction in attaining environmental sustainability agenda: contextual evidence from developing South and East Asian Economies

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Received: 31 December 2022 / Accepted: 11 September 2023

Abstract

Mitigating poverty and ecological destruction signifies vital challenges to comprehend sustainable growth and development. Extensive pragmatic studies have inspected these challenges within the Sustainable Development Goals (SDGs) framework. Nevertheless, it is important to distinguish that the intensifying problem of environmental deterioration establishes a significant impediment to accomplishing SDGs and minimizing poverty. The prime objective of the present analysis is to identify the association between ecological footprint, poverty, and economic policy uncertainty within the situation of developing Asian economies. Global warming and climatic issues have recently become a persistent and critical worldwide concern. Notably, the demesne of energy and environmental literature has not recently undertaken an inclusive investigation of the complications of economic policy uncertainty with combating poverty policies on ecological footprint. The current analysis identifies the research gap, which investigates the link between poverty, GDP growth, the uncertainty of economic policies, energy consumption, technological changes, and population growth for developing South-East Asian economies from 1996 to 2018. The STIRPAT model and CS-ARDL approach were used for modeling, and for robustness check, the FMOLS test was applied. The causality estimation outcomes of the Dumitrescu–Hurlin panel revealed a two-way association among numerous important variables, namely ecological footprint with energy consumption, poverty, economic growth, economic policy uncertainty, and technological innovation. Based on these comprehensive results, we offer substantial policy suggestions. For policy implications, this analysis investigates many elements to propose strategies and promote environmentally sustainable goals, such as sustainable growth initiatives, poverty reduction, adoption of clean energy sources, enhancement of technological innovation, and mitigating ecological humiliation in the Asian region. This study makes various significant influences by reconnoitering the EKC in the context of these developing economies and proposing insights into strategies to fight ecological destruction.

Keywords GDP growth · Environment · Poverty · Energy · Ecological footprint

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Extended author information available on the last page of the article

Abbreviations

GDP	Economic growth
G-7	Group of seven
CIP	Cross-sectional augmented panel unit root test
CS-ARDL	Cross-sectional augmented autoregressive distributed lags
SDGs	Sustainable Development Goals
CO_2	Carbon dioxide
EKC	Environmental Kuznets curve (EKC)
EPU	Economic policy uncertainty
GMM	Generalized method of moments
EFP	Ecological footprint
ARDL	Autoregressive distributed lag models
ENG	Energy consumption
TEC	Technology
PVR	Poverty
PPG	Population
CSD	Cross section dependency
PM-ARDL	Pooled mean group-autoregressive distributed lag
BRICS	Brazil, Russia, India, China, South Africa
FMOLS	Fully Modified Ordinary Least Square

1 Introduction

Poverty constitutes a persistent global issue that has reaped attention from the United Nations as a prime obstruction to advancement in social and economic domains, especially in developing economies (Appiah-Otoo et al., 2022). Despite efforts, the global fight against poverty has made limited progress (Ehigiamusoe et al., 2022). Therefore, dealing with poverty is one of the most challenging problems for countries (Giannetti et al., 2023; Koçak & Celik, 2022). The increase in the poverty rate will have many economic, political, social, and environmental consequences (Appiah-Otoo & Song, 2021). The United Nations' SDGs have provided guidelines and encouraged countries to pursue remedies for poverty alleviation. The solution for most countries to deal with poverty is to increase economic growth. Economic growth is also impossible without increasing production and industrialization and has environmental dimensions. Policies based on economic growth damage ecological resources (Ali et al., 2020).

Recently, the paramount significance of environmental concerns has been enhanced, encompassing emissions control and the preservation of environmental quality. Other imperative factors exist, notably climate change, population expansion, and the global prevalence of diseases such as COVID-19, which exert heightened pressure on economic growth and adversely influence the global environment. Climate change is the variations in weather conditions caused by social and economic activities in the long term. It has become an important issue that strongly affects the world (Chandio et al., 2020; Masron & Subramaniam, 2021). The global population is experiencing a rapid and substantial increase, with projections indicating an ascent to 9.8 billion individuals by the year 2050 (Tripathi et al., 2019). Meeting the demand of the growing inhabitants requires a boost in production and subsequent exhaustion as well as natural resources destruction and the usage of inputs, for instance, fuel (especially fossil fuel) increases. These issues, along with increasing environmental pollution, for instance, CO_2 emissions, lead to climate changes such as sea level change and temperature rise. Hence, economic development, increased production, and economic activities also have environmental costs and externalities, including ecosystem change and air and water pollution (Kastratović, 2019; Ullah et al., 2021). The ecosystem represents the communication between human efforts and the environment, specifying the linkage between ecosystem functioning and human prosperity (Peng et al., 2023). Therefore, CO_2 emissions will be twofold by 2050 without practical efforts and programs. Reducing environmental damage in economic growth as a significant challenge has attracted much attention, especially in developing countries (Masron & Subramaniam, 2021; Omer, 2008). Energy consumption is a fundamental prerequisite for fostering GDP growth and facilitating comprehensive development. It creates environmental problems, which must be controlled to reach the SDGs and decline ecological ruin (Khan et al., 2021; Oryani et al., 2022a, 2022b).

Limited empirical work has been done to verify the contribution of poverty to the destruction of the environment. For some reason, the general opinion is that in least developed economies, poverty has been subsidized, severely reducing the environmental quality. Poor societies are highly reliant on natural resources; consequently, depleting natural resources and putting too much pressure on them can be a factor of devastation. About 2.4 billion inhabitants in developing economies who live near or in the forest itself and are highly dependent on it can be the cause of deforestation. Also, treating natural resources as a public good and lacking property rights can be another factor for environmental deterioration (Aggrey et al., 2010; Masron & Subramaniam, 2021).

Consequently, environmental degradation is a primary issue in many Asian countries, and noxious haze can be seen in Singapore, Thailand, Indonesia, China, and Brunei. The negative effect can be seen on people and local inhabitants who face negative externalities. This analysis examines the association between environment–economic policy uncertainty–poverty nexus with a panel of selected Asian countries based on regional distribution. The present study selected Asian least developed economies because the level of poverty is high in this region; it accounts for 45% of people living in poverty (9.1% and 32.9% live in East Asia and South Asia, respectively), and 800 million people are involved in poverty (US$1.92 a day estimation of poverty line) (Baloch et al., 2020a, 2020b). Subsequently, environmental quality is worsening in Asian countries due to rapid industrialization, rapidly growing populations, and rapidly growing economies. Millions of people are no longer trapped in poverty (at the cost of environmental degradation) through rapid economic growth, trade liberalization, and industrialization in Asian countries. However, still, billions of inhabitants are in deprived conditions. Notably, in this regard, many Asian countries have worked on environmental degradation elimination and have been trying to achieve sustainable economic development and eradicate poverty (OECD, 2020).

However, it is difficult for the country to handle poverty reduction and clean environmental quality paradoxes. The environment can be deteriorated by the efforts to eradicate poverty on the one hand, but on the other hand, poverty can be accelerated by effective ecological measures and policies (Faridi et al., 2018). To solve this paradox of environment and poverty, policymakers must provide policies and solutions that simultaneously lead to sustaining the environmental quality and controlling poverty. Otherwise, accomplishing sustainable development goals is not easy (Stern, 2009). Kuznets (1955) presented a theory of the link between income and inequality and showed that initially, inequality and income increased together in the development process. Subsequently, achieving a specific development level and boost in income leads to a deterioration in income inequality (Zaman et al., 2016). Based on Kuznets's theory, Grossman and Krueger (1995) revealed the EKC and illustrated the linkage between poverty and ecological damage. Based on the mentioned theory, in the initial phases of development, with increasing production, resource discharge, and environmental degradation increase, but after reaching the point of stability and boosting the environmental quality, poverty will also decrease (Awad & Warsame, 2022). Consequently, the theoretical framework of the poverty–environment nexus for researchers, environmentalists, and policymakers is a complex and challenging debate.

As reviewed in the present analysis, numerous existing literature focused only on poverty and environmental quality paradoxes. However, a few shortcomings were found in their studies. First, the empirical studies are based on full panel Asian economies and do not provide the subgroups of Asian economies (East Asian economies and South Asian). In addition, two competing approaches are used in the existing literature, including win–win and trade-off approaches. The environment–poverty nexus is related to the trade-off approach. This approach indicates that environmental degradation by poor people increases because of generated revenues from their huge reliance on natural resources. Vice versa, the win–win approach suggested that environmental and poverty issues can be solved simultaneously (Ehigiamusoe et al., 2022; Masron & Subramaniam, 2021).

Keeping in view of prior works, the findings of empirical work on the environment–poverty nexus are inconclusive and contradictory. For instance, the trade-off approach is sustained by the analysis of Khan (2019) for the Southeast Asian economies (ASEAN) from 2007 to 2017, Baloch et al., (2020a, 2020b) used statistical analysis for African economies from 2010 to 2016, Ehigiamusoe et al. (2022) for 70 countries from period 2000–2018, Khan et al. (2022) for 18 Asian economies from 2006 to 2017. On the other hand, contradictory findings (that poverty supports environmental conservation) are concluded by (Islam et al., 2017; Nabi et al., 2020). Furthermore, mixed effects of (the air quality–poverty nexus) are found in the studies (Rizk & Slimane, 2018). The bilateral association between environment and poverty is found in the studies of (Bikorimana & Sun, 2020). Thus, the current analysis attempts to re-investigate the poverty–environment nexus by using some new variables not addressed for the Asian region.

Secondly, this research aims to identify the link among poverty, population, economic policy uncertainty, innovation, GDP growth, energy use, and ecological footprint for policy implications. Hence, the use of CO_2 emissions as an index of the ecological deterioration caused by boosting economic activities, on the other hand, has been widely criticized and is a debated and challenging issue. Many researchers have argued that CO_2 represents only a part of the environmental devastation caused by economic expansion (Khalid et al., 2021). Also, researchers claimed the CO_2 index had neglected other natural resources like oil, forests, and mining stock.

Consequently, CO_2 is not an extensive proxy; therefore, a comprehensive index is needed that includes more pollution and destruction, including water and land pollution. In this direction, Rees (1992) designed a multidimensional and integrated index, i.e., ecological footprint (EFP), that performs better than carbon in estimating environmental degradation. A few research has estimated the EP factor (Ehigiamusoe et al., 2022; Neagu, 2020). Based on the Global Footprint Network (2021) designation, the EFP revealed how many natural resources are vital to producing the population's products. Furthermore, the ecological footprint is also considered absorbing waste during manufacturing. Thus, existing literature on the EPU–poverty–ecological footprint nexus is not soundly studied; thus, the major contribution of analysis is to provide comprehensive detail to fill this gap.

Recently, in environmental debates, the importance of political uncertainty cannot be deniable in handling these environment–growth nexus and combating poverty-based issues. Uncertainty means institutional factors such as economic policy uncertainty (EPU);

it consists of policy decisions primarily based on monetary, fiscal, and trade factors (Adedoyin & Zakari, 2020). This institutional factor significantly impacts economic institutions through decisions that can affect the external and internal business environment. The EPU index was used to calculate the EFP (Baker et al., 2016). Sustainable Environment policies for environmental protection can be disrupted due to increasing EPU. The decision based on energy consumption to boost GDP growth can be hampered due to uncertainty in policy implementation.

Conversely, environmental protection policies require favorable economic conditions because companies and firms rigorously follow tight environmental policies in production, which leads to environmental protection (Pirgaip & Dinçergök, 2020). Environmental stringent policies can discourage traditional energy demand, but economic policy uncertainty leads to environmental destruction, as environmental protection policies are not instigated in the economy. However, less deterioration of the quality of the environment is a substantial concern of academia and policymakers.

Third, previous studies mostly used the individual or total panel sample of countries-based studies; their analysis neglected the cross section dependency, and their results could be misleading. Due to surging integration among economies, such as trade liberalization policies and globalization, many countries might be affected by the shock in any one country. Thus, nations are correlated, and data cannot denote cross section dependence. The results can be biased and misleading if they ignore this cross section dependency between countries (Pesaran, 2015). The present analysis tries to re-investigate the EFP–poverty–EPU nexus under the framework of EKC from the perspective of emerging Asian countries (East Asia, South Asia, and a full panel of Asian economies) during 1996–2018. According to the author, the novelty of this study is to discuss developing Asian regions, not in a single panel but divided into subgroups of East Asian and South Asian countries under EKC, which was not discussed earlier (Ehigiamusoe et al., 2022). Given the evidence mentioned above, this study tries to answer these questions and attempts to contribute to existing literature. (1) Is there any cause-and-effect correlation between ecological destruction and poverty? (2) Are the selected Asian countries significantly deteriorating the environmental quality by improving the GDP growth rate? (3) What is the central role of poverty and EPU in deteriorating the environment quality in the full panel of Asian, i.e., South and East Asian economies within the EKC framework? (4) Do the impacts of green growth, economic policy uncertainty and poverty vary across East and South Asian regions?

This analysis adds distinctive contributions to the present body of literature. It examined a less-explored aspect by concentrating on the juncture of energy, poverty, economic policy uncertainty (EPU), and technological innovation. This exact association has not been acknowledged substantial attention in prior studies. Thus, this study is innovative in inspecting how EPU, technological innovation and poverty link to ecological footprint. Based on the author's knowledge, prior literature mostly ignores these combined aspects. Moreover, against most previous research that used CO_2 emission as an environmental pollution index, the present research uses ecological footprint (EFP) as a multidimensional environmental index. To clarify the exact linkage between the determinants mentioned above and compare the results, the modeling in this research is divided into South and East Asian nations.

The latest econometric methods are applied to attain our crucial research purposes and address various statistical concerns. One severe disquiet in panel data study is cross section dependence (CSD). Thus, the current analysis employed the second-generation CSD method established by Pesaran and Yamagata (2008). Due to these issues, traditional calculation approaches were inappropriate for time series (panel) analysis. Thus, this research successfully employed the CS-ARDL test to handle heterogeneity and CSD. This approach is a modern solution in contrast to traditional methods like fixed-effects, dynamic OLS, and Fixed OLS estimators. These methods also support us in addressing serial correlation and slope heterogeneity concerns and confirm our conclusions' robustness. For the CS-ARDL robustness check, the FMOLS test was employed.

Additionally, our statistical model considered the possibility of endogenous covariates. Here, CS-ARDL played a crucial role in controlling for endogeneity issues in our study. This analysis seeks to determine the link among EFP, poverty, and other control variables through (Dumitrescu and Hurlin's, 2012) test. The analysis results are strategic endorsements per the pursuit of some SDGs. For instance, they support actions to encourage environmental sustainability (SDG-13, SDG-1) nationally.

Furthermore, the suggestions of this research support comprehensive advancement, economic growth and industrialization (SDG-8 and SDG-9) as part of accomplishing a more sustainable development phase. Similarly, this analysis addresses the subsequent main research questions mentioned above and simultaneously signifies an impactful and fresh effect on the ongoing struggles to tackle poverty and environmental sustainability. In summary, this research reveals the connotation between EFP and EPU and delivers valuable policy intuitions to reduce ecological pollution and encourage sustainable growth and development. For policy implications, this recent analysis investigates many variables, i.e., to propose strategies and promote environmentally sustainable goals, such as sustainable growth initiatives, poverty reduction, and mitigating environmental degradation in these economies. Thus, this study makes various significant contributions (mentioned earlier) by reconnoitering the EKC in the milieu of these developing countries and proposing insights into strategies to fight ecological destruction.

The continuation of the sections of our study is outlined as follows: a concise explanation of the prior review is revealed in the second section. In addition, Sect. 3 introduces the construction of the model, theoretical framework, and methodology. Section 4 comprises the findings of this analysis. The conclusion and suggestions of the current research are indicated in Sect. 5.

2 Review of literature

2.1 Theoretical literature

The theoretical studies on the environment–poverty nexus are well discussed in different articles and explore the association between environment and poverty. The theoretical literature can be defined in three various schools of thought. The first view is about the harmful effects of poverty on the environment. Finco (2009) revealed that poor people are huge emitters of CO_2 emissions because of inefficient consumption of resources. Various researchers concluded that people's depletion of natural resources is significantly increasing environmental destruction (Masron & Subramaniam, 2019; Shuai et al., 2019). According to the second school of thought, there is no inverse association between environmental destruction and poverty.

Similarly, other factors, rather than poverty, contribute more to ecological destruction. Duraiappah (1998) examined that poverty is significantly deteriorating environmental quality. Still, many other factors like demographic, institutional quality, political stability, and social and economic issues also aggravate the ecosystem. The theoretical concept of the poverty–environment nexus is discussed above; it is concluded that recent research on poverty-CO_2 emissions has emerged and is explained in the theory of the Poverty-CO_2 Paradox" (Rizk & Slimane, 2018). This theory explains the connotation amid CO_2 emission and poverty, and the results are inconclusive. Saleem et al. (2022) explained that environmental quality could be hampered due to increased GDP growth for poverty reduction.

2.2 Literature on poverty alleviation and the environmental degradation nexus

Eradicating poverty and global warming are major interrelated problems. Since many poor persons live in rural areas, the dependence of these persons on ecological commodities this study makes various significant contributions (mentioned earlier) by reconnoitering the can be considered the first linkage between the environment and poverty. The second linkage is that energy consumption increases due to income from poverty alleviation programs. It is estimated that by eliminating forest and environmental revenues from household incomes, the extreme poverty headcount will likely increase by 10–15% (Noack et al., 2015). Some researchers have cited this link at the micro-level as a nexus between environmental issues and Poverty (Reardon & Vosti, 1995); nevertheless, others have identified it as a poverty-environment deception. This relationship indicates that rising poverty will lead to augmented erosion and deforestation due to the high dependency of the poor on natural resources (Cleaver, 1995). Hence, several international organizations have reasoned that poverty reduction can positively affect maintaining and improving environmental quality. However, over time and as research on the association between environmental problems and poverty increased, the idea lost more credibility, and it became clear that poverty and environmental-based issues are very complicated (Wunder, 2001). In this regard, Scherr (2000) and Barbier (2010) claimed that deforestation and poverty depend on market closeness, job chances, and abundant natural resources. The second channel between poverty and a decrease in the level of forests can be explored in the context of the EKC premises. Based on this framework, the environmental devastation of a country rises at low-income levels and declines at high-income groups. According to empirical studies, this theory lacks a generalization and does not provide a comprehensive analysis and framework.

Yu and Liu (2022), with the ARDL approach, indicated a direct yoke between poverty and emission (long term) and, based on the short run, an inverse relation between the mentioned variables in China. Rakshit et al. (2023) surveyed poverty’s encouragement of emissions in SSA countries. The outcomes of the GMM approach demonstrated an upsurge in poverty leads to worse ecological quality. Zhao et al. (2021) exhibited the harmful energy poverty result on the ecosystem of Chinese provinces with the help of the GMM method. In this regard, Oryani et al., (2022a, 2022b) determine the energy and poverty boosting effects on South Korea’s ecosystem by utilizing the dynamic ARDL method.

Khan et al. (2022) found a direct linkage between poverty, EFP and inequality in 18 developing economies utilizing the Driscoll–Kraay approach. Indeed, the authors alleged rising poverty levels lead to more environmental devastation. Using the ARDL approach, Kirsten et al. (2022) indicated that poverty has a positive outcome on the emissions of carbon dioxide in BRICS. The research revealed a 01% rise in poverty and a decline in air quality of 0.33%. Hassan et al., (2022a, 2022b) showed an inverse relationship between GDP, poverty (energy), and inequality in BRICS countries’ carbon dioxide emission levels. Indeed, the mentioned variables can hamper the environmental condition. Ehigiamusoe et al. (2022) scrutinized the stimulus of inequity and poverty on air pollution and EFP in 70 nations using the SYS-GMM method. The outcomes revealed that both variables raise the carbon dioxide in the whole panel. Incidentally, the results in the subgroup were different. Against the insignificant effect of poverty on pollution in high-income countries, poverty enhances the emission in middle-income economies. Uzar and Eyuboglu (2023), with the usage of the ARDL approach, pointed out the gini index deteriorates the environmental condition in the U.S. Amin et al. (2023) observed the deprived condition of people and the use of energy on the ecological conditions in emerging economies by the usage of the PMG-ARDL approach. The outcomes indicated that poverty and solar energy boost the air quality.

Recent studies revealed that environmental devastation intensifies at upper and lower levels of household revenue (Stern, 2017). Therefore, the perception of the linkage between disforestation and poverty reduction (measured by income level) is still obscure (Dasgupta et al., 2002). The interaction effects of poverty and environmental quality on each other have been studied in some research. Many of these investigations applied CO_2 emission as an alternative to ecological deterioration, and some studies' analysis methods have been unsuitable. Against this backdrop, Awad and Warsame (2022) explored the affiliation between poverty and EFP in 91 emerging nations from 1990 to 2015; unlike previous studies, the EFP proxy indicated the quality of the environment. The second-generation tests found only a bidirectional causality association between Poverty, EFP (full panel), and African states. Heger et al. (2018) find the EFP's effects on Poverty in SSA, applying two environmental proxies (aboveground and underground). The quasi-experimental method showed that the environment is imperative for reducing poverty. Also, the effect of the environment on poverty is more significant than its effect on average revenue. Finally, urbanization has an insignificant correlation with poverty alleviation.

Similarly, Rizk and Slimane (2018) investigated a study to inspect poverty and CO2 nexus, focusing on organizational quality using the 3SLS approach in 146 countries. The results revealed that improving corporate quality reduces poverty and reduces ecological demolition. Khan (2019) scrutinized the stimulus of logistical processes and poverty on air pollution in the ASEAN states. Their study used the SYS-GMM approach for 2007–2017 and determined that poverty and logistical operations accompany high environmental demolition. Koçak & Ulucak (2019) inspected the connotation between poverty alleviation and air pollution for 48 SSA countries from 2010 to 2016. Estimating the quantile approach revealed a crucial relationship between poverty and pollution. In a paper on developing nations, Masron and Subramaniam (2019) tried to investigate the association between poverty and milieu-based issues. The GMM approach displayed that poverty is one of the leading causes of ecological destruction. Also, Dhrifi et al. (2020) observed the Poverty–environment nexus for the panel of developing countries. Their study used a simultaneous equation method and revealed a causality (bidirectional) nexus between the global panel of FDI–poverty–pollution.

Similarly, Azzarri and Signorelli (2020) inspected the influence of climate fluctuations on expenditure in 24 SSA economies. The spatial method outcomes revealed that flood shocks convoyed a 35% decline in food use and a 17% upsurge in poverty. Li et al. (2021) highlighted emerging and advanced economies' energy poverty and efficiency association. With the usage of DEA and entropy approaches, it was determined that energy poverty leads to a decrease in GDP. In addition, governments may significantly reduce social welfare if energy poverty is not reduced in the long run. This finding rejects the traditional concept that merely achieving energy efficiency is sufficient for stakeholders. This result showed the importance of productivity and efficiency in the energy supply.

As previously cited, due to the restrictions of CO_2 emissions as a flawless proxy of ecological conditions, excluding the research of Baloch et al. (2020c), the other studies used the representative of CO_2 emissions in research. In addition, most of the studies in this field overlooked the possibility of CSD. Therefore, the consistency of their results can be questioned. Also, most previous studies have tried to survey the linkage of variables in the context of causality. Similarly, no analysis has been provided to study the nexus of poverty and the environment between countries in diverse regions. Therefore, the current research seeks to address the shortcomings and limitations of previous studies using second-generation tools in data analysis. In data analysis, the second-generation tests investigated CSD and the unit roots, and the homogeneity or heterogeneity of coefficients was inspected. Lastly, the poverty–environment association was explored with Dumitrescu and Hurlin's (2012) panel approach, recognized as an efficient instrument for solving heterogeneity and cross section dependency problems.

2.3 Literature on the nexus between energy consumption–income and environmental quality

Various research demonstrates that household composition and energy consumption depend on revenue (Leach, 1992). Thus, poverty reduction may lead to an increment in energy consumer assets such as fridges, which changes their energy consumption in terms of extensity and intensity. Gertler et al. (2013) revealed that in nations with pro-poor growth (growth that benefits people with low incomes), the tendency to increase energy consumption is higher than in countries with regressive growth. Rodriguez-Oreggia and Yepez-Garcia (2014) evident a direct relevance between revenue and energy consumption.

However, less consideration was found to discuss the connection among energy sources, economic growth and CO_2 contamination. Still, it is unclear whether rising energy use due to poverty reduction increases environmental degradation because this nexus rests on several issues and the kind of energy source. To resolve the problem of energy poverty, a multi-objective solution must be designed that, while improving social welfare, also helps reduce power poverty through green energy (Alemzero et al., 2021). Energy poverty has severely challenged 840 million people worldwide until 2019. It can affect the costs and fluctuations in seasonal energy efficiency that weather change affects. Therefore, the SDGs paid much attention to this issue and could control energy poverty to a large extent.

According to available data, approximately 640 million people in developing countries worldwide will face inadequate access to electricity by 2030 (Sun et al., 2020). Both developing and developed countries face these challenges. Given the importance of this issue, Resolution 65 of the U.N. General Assembly put energy poverty on its agenda as "sustainable energy for all" (U.N., 2011). The resolution noted that energy poverty significantly impacts various areas, including efficiency, health, education, global climate change, and food and water security. It also explains how the inaccessibility to clean and reasonably priced energy, an imperative factor in the disability to attain the Millennium Development Objectives, has constrained human, social, and economic development. An inadequate understanding of energy poverty is also a significant factor limiting a household's ability to access energy and omnific power poverty. Thus, constrained energy resources cannot meet all the energy needs in advanced countries, referred to as the poverty of energy.

Using the ARDL approach, Sikder et al. (2022) demonstrated that energy and growth enhanced the air pollution level in developing economies. Mirziyoyeva and Salahodjaev (2022) used the GMM approach. They determined that green energies boost the environmental condition; on the contrary, GDP worsens the environmental circumstances in economies with the most emissions. Karaaslan and Çamkaya (2022) proved renewable energy's positive role in reducing pollution. Also, economic expansion and fossil fuel have a determined influence on the rise in emissions in Turkey. Liu et al. (2023) showed that more utilization of energy and economic growth drastically hit China's environmental circumstances. Alnemer et al. (2023) bid to model the linkage between fossil fuel, green energies, GDP, and CO2 in Saudi Arabia. The wavelet approach implied that non-green energies drop the environmental quality. Vice versa, green energies help catch sustainable development (boosting the GDP and diminishing pollution) objectives. Li et al. (2023) stated research on the role of green energies in the environment by implementing the Threshold approach. The outcomes revealed that green energies hedge the boost in pollution.

Furthermore, green energies controlling emissions are more effective in weak than wealthy economies. Chen et al. (2023) claimed that green energies are vital in alleviating pollution. Against that, traditional energies and GDP have an enlarging role in enhanced emissions. Jahanger et al. (2023) articulated that the new energy generation diminishes the CO_2, and economic expansion harms the environment in the countries leading in nuclear energy. Sharif et al. (2023) investigated the analysis using the CS-ARDL approach, confirming that expanding green energies reduced emissions in Northern Europe. Against that, income drops the quality of the environment.

2.4 Literature on economic policy uncertainty (EPU) and environmental quality nexus

The subsequent literature stands for the environment–EPU nexus, where various studies could not conclude the conclusive results. For instance, the use of EPU and clean energy nexus was discussed by Ahmed et al. (2021) for the United States. The statistical estimation designates that CO_2 emissions cannot be minimized through only renewable energy in the USA. Also, environmental quality can significantly affect EPU in the USA. Furthermore, the analysis of Esmaeili et al. (2023) scrutinized the influential sway of trade liberalization, EPU, natural resources, life expectancy, and prosperity on the EFP in the context of various countries (energy-intensive) for 1997–2018. The inverse connection was determined between EPU and EFP. Cary (2020) explored that CO_2 emissions are significantly affected by energy's state-level US economic decisions.

Adams et al. (2020) demonstrated that energy use, economic expansion, and EPU boost the level of emission in economies with resource abundance. Furthermore, a bidirectional causality connection between carbon dioxide and EPU was found in their statistical estimation. In this way, Khan et al. (2020b) presented a direct nexus between China's industrial emissions and EPU. In other words, the authors specified that an upsurge in EPU has led to an expansion in contamination. Xue et al. (2022) pointed out that the EPU and GDP worsen the environmental condition in France by using the ARDL method.

Moreover, the results informed that green energies don't help reduce emissions. Amin and Dogan (2021) attempted to survey EPU–energy and emission nexus using Chinese statistics from 1980 to 2016. The dynamic ARDL estimation indicated a direct effect of GDP, energy, and EPU on pollution. Also, the authors implied the inverse effect of renewable energy on emission levels. Wen and Zhang (2022) indicated that EPU could hamper the environment. Indeed, the outcomes implied that the rise in EPU has enhanced the SO_2 pollution in China. Oryani et al. (2022a) and the NARDL method exhibited that adverse/

positive shocks of EPU have a direct and inverse impress on EF, respectively, in South Korea. The results presented a deteriorative effect of fossil fuel and expansion of economic activities on the environmental condition. Hassan et al. (2022a) explored a negative link between pollution and EPU in China by operating the newest econometrics approach. Pata et al. (2023) proved the positive impact of EPU in emission alleviation, especially during the battle between Russia and Ukraine. Tee et al. (2023) pointed out a direct linkage between EPU and carbon footprint in 60 countries. Indeed, the outcomes exhibited that a rise in EPU has led to the descent of environmental quality. Jiang et al. (2023), with the help of a quantile method, exposed that EPU and green energies have a reverse and direct impact on clean development in E7 economies, respectively. Ayhan et al. (2023) claimed that EPU helped to curb pollution in the USA, Japan, and Italy. The results of the quantile method in G-7 economies showed the deteriorative impact of GDP and traditional energies.

2.5 Evaluation of the literature

Based on theoretical analyses of existing literature and inconclusive findings, this study tries to reinvest the EPU–poverty–environment nexus to resolve an inconsistency in the preliminary analysis. Previous findings could not check the direct link between poverty and ecological quality in the presence of EPU, especially for developing Asian economies. This analysis addresses the CSD and slope heterogeneity concerns to avoid spurious results. This analysis addressed the above issues using the latest methodology to fill the research vacuum. Thus, this study examines EPU, energy use, poverty, and green technology in the context of developing Asian economies.

Some points can be mentioned as a summary of previous studies. (i) Previous studies have only examined the poverty–environment nexus and have not used other influencing variables in modeling. Therefore, this analysis has considered the most critical economic, environmental, and social variables to fill this vacuum in modeling the poverty–environment nexus. (ii) Numerous prior works explained only one nation or a panel of nations. Thus, the current analysis, in addition to modeling a complete panel of Asian nations, has also designed two models separately for East and South Asian countries to study the poverty-environment relationship more precisely.

2.6 Model specification

Following (Shahbaz et al., 2016), this research uses a revised version of the IPAT and STIRPAT models to identify the correlation between ecological destruction and poverty in selected Asian economies. Ehrlich and Holdern (1971) designed the IPAT model. Their model described the mathematical distinctiveness in terms of the environment–human activities nexus. The significant determinants of the environment can be broadly described through the conceptual theme of the IPAT model. According to the IPAT model, affluence, population, and innovation (technological change) are significant factors of ecological devastation due to human activities.

$$I = P * A * T \tag{1}$$

The STIRPAT model is an arithmetical tool produced by Dietz and Rosa in 1994 to enhance human action's influence on the milieu. While IPAT also evaluates the ecological effect of human movements, it delivers an extra general hallucination of the elements contributing to ecological destruction. STIRPAT, on the other hand, employs several regression analyses to regulate the comparative weight of many elements and recognize fundamental forces of ecological change. By examining manifold factors simultaneously, the STIRPAT model gives a more nuanced understanding of the composite association between the environment and human action. Thus, the present research applied the latest form of the STIRPAT model (Stochastic Influences by Regression on " Affluence, Population and Technology").

$$I_i = aP_i^b A_i^c T_i^e u_i \tag{2}$$

The ecological influence on an economy *i* is represented by (*I*). The "*a*" symbolizes the constant term, the inhabitants of the nation (*i*) is signified by *P* (where *b* is the exponent), and "*A*" signifies the affluence of country "*i*" (with the exponent *c*), the innovation/technological change (*T*) of the nation "*i*" (represents exponent as *e*), and an error term is denoted by "*u*" and "*i*" represents the sample of emerging Asian economies. The control factors are combined (*Z*it) in Eq. 1 (Avom et al., 2020; Koçak & Ulucak, 2019; Xu & Lin, 2018). Based on numerous existing literature, extended the STIRPAT model by adding plausible control factors, i.e., energy sources of fossil fuel and technological changes (proxy of technology). The GDP growth–environment nexus also emphasizes environmental degradation, low per capita income, poverty, and sustainability (Watmough et al., 2016). A higher interrelation was found between ecological degradation and deprivation in developing economies (Cleaver & Schreiber, 1994). Thus, poverty is calculated as the final consumption expenditure (per capita) suggested by the World Bank (Awad & Warsame, 2022). This research also incorporated the square of GDP to test (EKC).

$$\ln I_{it} = \alpha + \beta 1 \ln P_{it} + \beta 2 \ln A_{it} + \beta 3 \ln T_{it} + \beta 4 \ln Z_{it} + \ln e_{it} \tag{3}$$

where natural logarithm is represented as (ln) as below,

$$\begin{aligned} \ln \mathrm{EFP}_{it} &= \beta 0 + \beta 1 \ln \mathrm{PVR}_{it} + \beta 2 \ln \mathrm{GDP}_{it} + \beta 3 \ln \mathrm{EPU}_{it} \\ &\quad + \beta 4 \ln \mathrm{ENG}_{it} + \beta 5 \ln \mathrm{TEC}_{it} + \beta 6 \ln \mathrm{PPG}_{it} + \varepsilon_{it} \end{aligned} \tag{4}$$

For speculation testing, this study likewise tests the EKC in this model.

$$\begin{aligned} Ln\,\mathrm{EFP}_{it} &= \beta 0 + \beta 1 \ln \mathrm{PVR}_{it} + \beta 2 \ln \mathrm{GDP}_{it} + \beta 3 \ln \left(\mathrm{GDP}_{it}\right)^2 \\ &\quad + \beta 4 \ln \mathrm{EPU}_{it} + \beta 5 \ln \mathrm{ENG}_{it} + \beta 6 \ln \mathrm{TEC}_{it} t + \beta 7 \ln \mathrm{PPG}_{it} + \varepsilon_{it} \end{aligned} \tag{5}$$

Equation (2) represents the STIRPAT concept, and its calculation depends on applications of stochastic regression. This analysis controls the role of energy use, as the energy used is an essential component of environmental pollution. Similarly, the literature on the EPU–environment nexus supported that EFP and EPU are inversely related. Different sustainable ecological policies are associated with uncertainties; the higher the EPU, the worse the environmental issues (Pirgaip & Dinçergök, 2020). Moreover, domestic and global uncertainties can affect a country's political and economic stability. Numerous ecological and economic problems can arise regarding environmental deterioration due to EPU, e.g., unfavorable environmental practices by industries lead to offensive production process practices (Amin & Dogan, 2021). Thus, EPU can significantly reduce the investment in environment-related technologies and renewable energy sources, which may hurt environmental quality. This study also incorporated technological innovation as the control variable. The influence of eco-friendly innovation on environmental quality is positive. Technology plays a progressive role in reducing EFP consumption per capita. An environmentally sustainable agenda can be achieved through clean technologies, as industries that use clean technologies will produce less dirty and environment-friendly goods. Poverty also suffers environmental quality, which has social, environmental, and political consequences. The impact of poverty on environmental quality is inverse; rapid GDP growth is essential to uplift people from poverty. Thus, rapid growth leads to ecological destruction. Numerous factors can impact EFP, but these factors are also incorporated in this analysis, which can severely impact environmental quality. Poverty's environmental quality and impacts on technologically embedded growth are crucial to debate across Asian nations.

2.7 Data description and methodology

2.7.1 Description of data

The research analysis tries to identify the relationship between EFP and GDP, square growth with other plausible factors from 1996 to 2018 for selected 12 developing Asian countries, namely (South Asian economies such as Bhutan, India, Nepal, Bangladesh, Sri Lanka, Pakistan, and East Asian economies China, Indonesia, Malaysia, Cambodia, Philippines, Vietnam, respectively). The data on PVR are calculated as per capita final consumption expenditure (constant 2010 US$). The World Bank describes poverty as a lack of necessities for livelihood and "worsening to reach the existence level of life" (Dhrifi et al., 2020; Odhiambo, 2009). The growth is defined as GDP (constant 2010US$) per capita. The ENR is measured as the use of energy (percentage of total final energy use) (Table 1).

Similarly, TEC is a proxy of technological innovation in total patent applications. The monthly data on EPU are available as provided by Baker et al. (2013). The current paper used the annual data extracted from the index of EPU (2022) to convert the data into the annual form as a used weight for all months. PPG is described as the total population of the economy. This study examines the data of developing Asian economies where the use of natural resources is imbalanced and vulnerable. Rees (1992) introduced EFP as a quantitative approach, particularly for supply and demand nature. EFP can be calculated regarding the instant use of natural resources and waste generation by these resources.

The EFP combines grazing land, cropland, CO_2 emission, fishing grounds, forest land and infrastructure footprint (Lin et al., 2018). The data on ecological footprint (EFP)

Table 1 List of variables and description of data

Variables	Description	Units	Sources
EFP	Ecological footprint	Metric tons per capita)	Global Footprint Network (2021)
GDP	Gross domestic product	Constant 2010 US$	WDI (2020)
PVR	Poverty	Per capita final consumption expenditure (constant 2010 US$)	WDI (2020)
ENG	Energy consumption	Total final energy consumption in%	WDI (2020)
EPU	Economic policy uncertainty	Index of Economic Policy Uncertainty	Economic Policy Uncertainty (2022)
TEC	Technological innovation	Total patent applications	WDI (2020)
PPG	Population	Total population	WDI (2020)

Table 2 The statistical findings of descriptive statistics

	LEFP	LGDP	LENG	LEPU	LPPG	LTEC	LPVR
Mean	−0.262	3.020	1.831	4.78	8.059	2.868	11.042
Median	−0.175	2.982	1.911	4.77	8.139	2.674	11.044
Max	0.255	3.596	1.941	6.30	9.131	4.699	12.257
Mini	−0.989	2.614	0,111	3.30	5.846	0.602	9.009
Std. Dev	0.302	0.238	0.107	0.43	0.741	0.904	0.642
Skewness	−0.597	0.561	−0.042	0.33	−0.575	0.290	−0.466
Kurtosis	2.614	2.639	2.710	3.73	3.612	3.095	3.861
Jarque–Bera	8.132	7.184	0.471	14.62	8.773	1.786	8.337
Probability	0.0171	0.027	0.089	0.000	0.0124	0.409	0.015
Sum	−32.520	374.564	214.666	480.504	999.402	355.667	1369.244
Sum Sq. Dev	11.266	6.992	1.4161	7.852	67.618	100.632	50.774

Max and Mini indicate maximum and minimum

Table 3 The results of unit root analysis

Variable names	At level		First differences	
	CIPS	MIP	CIPS	MIP
$LEFP_{it}$	−0.055	0.158	−4.802***	−8.651**
$LGDP_{it}$	−4.002	−7.001	6.881**	−7.564**
$LGDP_{it}^{2}$	−0.597	−0.680	−2.296***	−3.643**
$LEPU_{it}$	4.842	−6.986	−7.026***	−9.650***
$LPVR_{it}$	−7.501	−4.723	−3.965***	−5.460**
$LENG_{it}$	−8.875	−5.637	−7.326**	−8.163**
$LTEC_{it}$	−5.812	−5.913	−4.347***	−5.046**
$LPPG_{it}$	−4.768	−4.807	−4.610**	−5.195***

***represents the level of significance at 1%, ** and ***indicate the significance level at 5 and 10 percent, respectively

metric tons (per capita) are gathered from the Global Footprint Network (2021); the World Bank (2020) data are used to extract the remaining data. Since 1965, the EFP has increased abruptly in Asian countries. Appendix A represents the list of selected Asian economies. The natural logarithmic form is used for variables for uninterrupted interpretation of data as elasticities. It will be convenient to interpret the data results and identify the connection between the factors.

3 Empirical results

The estimation of descriptive measurements is informed in Table 2.

Table 4 The results of CSD statistics

Test	Statistic	*p* values	Null hypotheses	Conclusion
Breusch–Pagan Chi-square	4.150	0.000	No CSD in residuals	Reject
Pearson LM normal	5.758	0.000	No CSD in residuals	Reject
Pearson CD normal	– 6.893	0.000	No CSD in residuals	Reject
Friedman Chi-square	19.741	0.000	No CSD in residuals	Reject

Rejection means the null hypothesis is rejected at a 1% significance level

Table 5 The statistical testing of slope co-efficient

Model	
$EFP_{it}=f(GDP_{it}, GDP_{it}^{2}, EPU, PVR_{it}, ENG_{it}, TEC_{it}, PPG_{it})$	
Delta (*p*-value)	Adjusted-delta (*p*-value)
10.234***	11.786***
(0.000)	(0.000)

***Signifies a 1% level of significance

3.1 Panel Unit root tests

Two methods, namely CIP and MIP, are employed in this analysis to detect the statistical outcomes of the unit root test. Based on the conclusions, this study determined that all factors are stationary at the first difference in both tests presented in Table 3.

Table 4 represents the statistical conclusions of CSD. The study used various techniques to identify the problem of CSD in the panel data analysis (as mentioned in Table 4. The alternative hypothesis is accepted, as the findings are mentioned in Table 4. Thus, the findings indicate the CSD between the time series analysis. In addition, CSD among the various nations was established through all cross-sectional techniques. The outcomes revealed heterogeneity.

3.2 Cross section dependency (CSD) test

The utilization of CSD is essential in the panel data analysis. The main reason for the CSD issue is the rising undetected standard shock and the significantly rising interrelation among socio-economic determinants; thus, the estimation (panel) will generate inconsistent findings. Moreover, inconsistent results lead to severe consequences due to neglecting the problem of CSD (Pesaran, 2015). Thus, Breitung and Pesaran (2008) resolved the issue of CSD independence (presumed in outmoded tests of stationary) has been determined by Breitung and Pesaran, (2008).

3.3 Tests of slope homogeneity

In addition, Pesaran and Yamagata's (2008) technique is useful for detecting slope homogeneity. Table 4 indicates to identify the findings of the heterogeneity, where the null hypothesis is not acknowledged (homogeneous slope), and the accepted (heterogeneous slope) alternative hypothesis. The slope homogeneity test is also crucial for empirical analysis (Table 5).

To categorize the long-term connotation among all selected factors, the authors try to analyze the Durbin-H cointegration test designed by Westerlund (2008). The cointegration methodology with its best performance is used in this study, as it overcomes the issues of heterogeneity and CSD; thus, the Durbin-H Panel and Durbin-H Group tests are applied in the current study.

$$\alpha_1(L)\Delta y_{it} = y2it + \beta_i\left(y_{it} - 1 - \alpha'_i X_{it}\right) + \lambda_i(L)v_{it} + \eta_{it} \tag{6}$$

where

$$\delta_{1i} = \beta_i(1)(I)\hat{o}_{21} - \beta_i\lambda_{1i} + \beta_i(1)(I)\hat{o}_{2i} and y2i = \beta_i\lambda_{2i} \tag{7}$$

Westerlund cointegration statistics can be defined in the following equation,

$$G_t = 1/N\Sigma_{i=1}^{N}\alpha'_i/SE(\alpha'_i), \tag{8}$$

$$G_a = 1/N\Sigma_{i=1}^{N}T\alpha'_i/(\alpha'_i(1)), \tag{9}$$

$$P_t = \alpha'_i/\mathrm{SE}(\alpha'), \tag{10}$$

$$P_a = T\alpha' \tag{11}$$

The group statistics are given as G_t and G_a, where P_t and P_a are symbolized as panel statistics. The no cointegration is related to the null hypothesis, and the relationship amid the factors is associated with the alternative hypothesis. Table 6 describes the estimation of the test (Durbin-H panel and Durbin-H Group). The alternative hypothesis was accepted, and the null hypothesis was rejected. Thus, it found the long-run connotation between the determinants.

3.4 Statistical results of CS-ARDL

This analysis used the method of CS-ARDL to analyze the impact of poverty on the environment with some control variables. This method's main objective is to analyze the

Table 6 Statistical results of Westerlund, 2008

Asian countries		
Variables	*t*-statistics	*p* value
Durbin-H Group stat	6.762	0.000***
Durbin-H Panel stat	4.685	0.000***

***Signifies the 1% level of significance problem of slope heterogeneity and C.S. endogeneity. Chudik and Pesaran (2013) designed the CS-ARDL test and considered various explanatory variables with hidden components and the uncertainties and sensitivities associated with limited data. The unobserved factors and elements of the analysis and the inconsistent small sample size can be handled by this technique. Thus, this study employed the CS-ARDL method with its robust assumptions. The theoretical framework of this analysis states technological change, GDP growth, poverty, economic complexity, population, and energy consumption. The following model explores the association between the above elements and their probable impact on the ecological footprint.

$$\begin{aligned}\mathrm{EFP}_{it} = \beta 0 + \beta 1\mathrm{PVR}_{it} + \beta 2\mathrm{GDP}_{it} + \beta 3\left(\mathrm{GDP}_{it}\right)^2 \\ + \beta 4\mathrm{EPU}_{it} + \beta 5\mathrm{ENG}_{it} + \beta 6\mathrm{TEC}_{it}\, t + \beta 7\mathrm{PPG}_{it} + \varepsilon_{it}\end{aligned} \tag{12}$$

where $\beta 0$ indicates the constant, $\beta 1$, $\beta 2$, $\beta 3$, $\beta 4$, $\beta 5$, $\beta 6$, and $\beta 7$ factors of energy consumption (ENG), Poverty (PVR), technological innovation (TEC), Population (PPG), economic policy uncertainty (EPU), and economic growth (GDP). Likewise, 'i' signifies the state, and 't' signifies the period.

The model of CSD-ARDL can be defined in the following equation.

$$\Delta \mathrm{EFP}_{it} = \Omega_i + \sum_{l=0}^{m} \Phi_{1il} \Delta \mathrm{EFP}_{it,t-1} + \sum_{l=0}^{m} \Phi_{2il} X_{i,t-i} \tag{13}$$

$$\Delta \mathrm{EFP}_{it} = \Omega_i + \sum_{l=0}^{m} \Phi_{1il} \Delta \mathrm{EFP}_{it,t-1} + \sum_{l=0}^{m} \Phi_{2il} X_{i,t-i} + \sum_{l=0}^{m} \Phi_{3il} Y_{it-1} + \epsilon_t \tag{14}$$

where the dependent variable is represented as ecological footprint (EFP), "Y" signifies the dependent variable's (average) value. The remaining independent factors, such as the GDP, poverty, EPU, population, technological innovation, and energy consumption, are used in this analysis; l and m are connected to the dependent factor (lag values).

Equation (15) indicates CS-ARDL techniques (long-run analysis) through the mean group estimator.

$$\pi \text{CS-ARDL}, i = \sum_{l=0}^{m} \Phi_{1il}, m/1 - \sum_{l=0}^{m} \tag{15}$$

Moreover, the mean group of the analysis is given in the following equation.

$$\pi\ \mathrm{MG}\ = 1/N - \sum_{l=1}^{N} \pi i \tag{16}$$

However, the short-run coefficients are also presented as follows,

$$\Delta \mathrm{EFP}_{it} = \phi_i \left[\mathrm{EFP}_{i,t-1} - \pi X_{i,t}\right] + \sum_{l=0}^{m} \Phi_{1il} \Delta \mathrm{EFP}_{it,t-1} + \sum_{l=0}^{m} \Phi_{2il} X_{i,t-i} + \sum_{l=0}^{m} \Phi_{3il} Y_{it-1} + \varepsilon_t \tag{17}$$

The CS-ARDL (short-run coefficient) is represented by Eq. (13), where the endogenous variable is represented by EFP (environmental degradation), Y denotes the dependent variable (average), and X designates the essential elements such as PVR, PPG, GDP,

Table 7 Statistical findings of CS-ARDL

Model

$EFP_{it}, = f(GDP_{it}, GDP_{it}^{2}, EPU_{it}\ PVR_{it}, ENG_{it}, TEC_{it}, PPG_{it})$

Variables	Short-run analysis		Long-run analysis	
East Asian panel	Co-efficient	SD	Co-efficient	SD
$LEFP_{it}$	0.958***	0.019	0.885***	0.066
$LGDP_{it}$	0.468**	0.261	0.204***	2.986
$LGDP_{it}^{2}$	−0.070***	0.579	−0.726***	−2.185
$LEPU_{it}$	0.040***	0.004	0.055***	0.003
$LPVR_{it}$	0.034**	0.144	0.164***	0.784
$LENG_{it}$	1.324**	0.273	1.506**	2.606
$LTEC_{it}$	−0.081***	0.067	−0.094***	−1.98
$LPPG_{it}$	0.049*	10.995	23.197***	0.046
South Asian panel	Co-efficient	Standard deviation	Co-efficient	Standard deviation
$LEFP_{it}$	0.691***	0.03	0.785***	0.015
$LGDP_{it}$	0.518***	0.04	0.404***	2.574
$LGDP_{it}^{2}$	−0.085**	−0.053	−1.726***	−2.267
$LEPU_{it}$	0.061***	−0.037	0.063***	0.040
$LPVR_{it}$	0.431***	0.173	0.642***	0.274
$LENG_{it}$	0.150**	0.273	0.186**	3.79
$LTEC_{it}$	−0.058**	−0.027	−0.034***	−0.594
$LPPG_{it}$	0.082**	0.078	20.172***	0.764
Full developing Asian panel	Coefficient	Standard deviation	Co-efficient	Standard deviation
$LEFP_{it}$	0.113	0.064	0.885***	0.066
$LGDP_{it}$	2.227***	3.583	2.874***	2.184
$LGDP_{it}^{2}$	−0.817***	0.579	−0.726***	−3.267
$LEPU_{it}$	0.078***	0.008	0.070***	0.001
$LPVR_{it}$	0.236**	0.144	1.264***	0.894
$LENG_{it}$	1.324**	0.273	1.506**	2.816
$LTEC_{it}$	−0.038***	0.067	−0.068***	−0.307
$LPPG_{it}$	0.071**	0.068	0.098***	0.125
ECM(−1)	−0.20***	0.013		
R^{2}	0.91			

***represents the level of significance at 1%, ** and ***indicate the significance level at 5 and 10 percent, respectively

ENG, TEC, EPU and GDP square, l, and m associated to the lag values of the independent variables.

The CS-ARDL test is applied to determine the statistical findings of the environment–poverty nexus with some control variables for developing Asian countries. Table 7 reports the CS-ARDL's result that poverty significantly contributes to increasing EFP in Asian economies. This study includes the 12 developing Asian countries, including East

Asia (China, Malaysia, Indonesia, Philippines, Cambodia, and Vietnam) and South Asia (Bhutan, Pakistan, Sri Lanka, India, Bangladesh, and Nepal). A positive association was found between EF and GDP, PVR, ENG, and PPG; these variables significantly ended EFP. This analysis confirmed the presence of EKC for the South, East, and complete panel of Asian countries. These findings align with Le and Quah (2018) and Saleem et al. (2020). The statistical findings demonstrate that GDP increases EFP in East Asian, South Asian, and Full Asian regions. The statistical conclusions based on East Asian economies indicate that a 1 percent change in GDP growth will significantly bring 0.47 and 0.2 percentage change in EF in the short and long run. This analysis exposed an adverse association between GDP square and EFP, representing that a rise in GDP square substantially affects EFP, and showed that a 1 unit change in GDP squares would -0.07 and -0.73 unit minimize in EFP in the short and long run. These estimations are aligned with the conclusion of (Ahmad & Raza, 2020; Khan et al., 2020a; Liddle, 2018). The negative impact of GDP square and the affirmative role of GDP on EFP confirm the existence of EKC. The poverty–environment nexus indicates that a 1% change in poverty shows a 0.16 and 0.03 unit change in EFP significantly in the long and short run. The association between GDP and EFP is statistically positive and significant. Specifically, in the comprehensive model, if there is a 1 unit change in economic growth, it would be 2.22 units (in a short period) and a 2.28 unit upsurge in environmental destruction in the long term. This specifies that as the economic growth rate in these Asian economies increases, the destruction of an ecosystem. In essence, this suggestion recommends that following higher GDP growth in the Asian region has the positive consequence of decreasing poverty but also carries the destructive result of a rise in environmental degradation. Our conclusions support prior research accompanied by (Behera & Dash, 2017, Naz et al., 2019 and Zhang & Zhang, 2018). Moreover, comprising the GDP*2 exposes a statistically and negatively substantial effect on EFP. This confirmed the EKC hypothesis, which postulates that growth primarily leads to the destruction of the environment but ultimately leads to a more ecologically sustainable connection as GDP growth extends to a certain level. Our outcomes are aligned with the EKC scheme. They are extra sustained by prior analysis, comprising those examined by Baek (2016) for the USA, Usman et al. (2019) for India, and Chen et al. (2019) for Pakistan; all studies confirmed the validation of the EKC.

The statistical findings of the environment–EPU nexus indicate that the 1% change in EPU shows a 0.04 and 0.05 unit change in EFP in the short and long term. The EPU is positively related to the EFP and uncertain economic situation, not enlightening improvement in air pollution in East Asian economies. The finding is in line with the work of Esmaeili et al. (2022). The influence of EPU on EFP is more destructive than its affirmative effect, resulting in a reduction in EFP as economic policy uncertainty rises. These results relate to the conclusions of Adedoyin and Zakari (2020), which indicate that EPU significantly impacts ecological damage, which aligns with the analysis of Pirgaip and Dinçergök (2020a). In contrast, the coefficient for EPU is adverse and highly significant at the 1% level. This indicates that improved EPU considerably diminishes regional ecological deterioration. These consequences are consistent with the findings concluded by Anser et al. (2021).Moreover, exposes that a high growth of population substantially increases air pollution. Thus, this designates that a rise in the population growth rate will result in greater energy use, thereby leading to a higher rate of ecological damage. Numerous studies concluded inconclusive findings in this regard, as the findings of Pirgaip and Dinçergök (2020) and Zahra and Badeeb (2022) concluded that EPU improves environmental quality in the long run; in contrast, the findings of Liu and Zhang (2022) found different results. Based on the short and long run, a negative association between EFP and EPU was found in this analysis. The outcome revealed that a 1% increase in technology led to a 0.08 and 0.09 decline in EFP in the short and long run. The environment–non-renewable nexus indicates that if there is a 1% change in energy use, it shows a significant 1.51 and 1.32 unit change in EFP in the long and short-term analysis; conclusions are aligned with the results of Chen et al., (2021) and Shahbaz et al., (2020). Population growth is significantly increasing the level of EFP in East Asian economies. A 1 percent change in PPG will significantly lead to a 0.05 percent change in EF in East Asian economies in the short run.

The outcomes based on South Asian economies indicate that a 1% rise in GDP will significantly bring a 0.4 in the short run and a 0.51% increase in EFP in the long run, respectively. The GDP square was negative and showed that a 1 percent change in GDP square would be a -1.7 and -0.08 percent diminution in EFP in the long and short run. The positive impact of GDP growth and adverse effects of GDP square on EFP effusively support the existence of the EKC curve. The environment poverty relationship showed that a 1 percent change in poverty would lead to a significant 0.64 and 0.43 percent change in EFP in the long and short run. Poverty and EFP are positively associated with each other. These outcomes highlight the urgent requirement for concrete activities to minimize extreme poverty, a noteworthy contributor to ecological destruction in numerous emerging Asian nations. Similarly, increasing poverty levels lead to ecological deterioration.

The positive connection between environmental pollution and poverty can be described in some ways. Firstly, the chase of industrialization and GDP growth to fight against poverty can damage the environment. Highlighting local industries, which are important for poverty reduction and GDP growth, often comes at the cost of destroying the milieu, as confirmed by Jin et al., and 's (2018) study. Addressing poverty and its ecological effect is a persistent concern that demands an elusive balance between environmental sustainability and economic development for permanent enhancements. Secondly, it is essential to note that the affirmative connection between ecological destruction and poverty is probable, mostly within the various Asian countries. This statement is reinforced by substantial underprivileged populations in these areas who often utilize natural resources and their unmanageable exploitation, including vital elements such as water, raw food, and energy. The importance of this excessive resource exploitation is damaging to the quality of the environment. Broad and Cavanagh (2015) highlight the pivotal role of high poverty levels in subsidizing air pollution, particularly in the least developed economies. This situation can be attributed to many reasons, with the inadequate accessibility of basic facilities of education and the comparatively less awareness concerning ecological protection among poor populations. Subsequently, persons tackling poverty tend to persistently exploit and waste natural resources in unsustainable ways. This unsustainable attitude finally results in an appreciation of ecological pollution within Asian areas.

Furthermore, it is essential to identify that poverty significantly influences ecological effluence due to the requirement of making economic concerns to address environmental concerns. These concerns usually employ contacts to control elements such as industrialization and urbanization, acknowledged as substantial contributors to ecological destruction. Unfortunately, applying such procedures can hamper growth and inclusive economic endeavors to sustain the determination of poverty in this region (Dhrifi et al., 2020). The empirical conclusions are aligned with earlier research accompanied by Khan et al. (2020a), Masron and Subramaniam (2019), Azam et al. (2019), and Baloch et al., (2020a, 2020b). Conversely, it is critical to understand that our outcomes divert from those examined by Islam and Ghani (2018) and Dhrifi et al. (2020).

The elasticity of EPU indicates that one unit change in EPU leads to 0.061 (for a short run) and 0.063 unit changes in the long and short run. The EPU is positively associated with the ecological footprint, and weak economic conditions could not improve the environmental quality in South Asian nations. The elasticity of fossil fuel energy use illustrates that one unit change in ENG leads to 0.18 and 0.15 unit change in the long and short run. The conclusion of innovation shows that one unit change in TEC will significantly diminish EFP in 0.03 and 0.05 unit changes. Population growth is considerably increasing the level of EF in South Asian economies in the short and long run if a 1% change in PPG will bring a 20.1 and 0.08% change in EFP in East Asian economies in the long and short term.

The statistical findings based on a full panel of Asian economies indicate that a 1 unit change in GDP growth will significantly bring 2.8 and 2.2 unit changes in EFP. GDP Square shows a -0.73 and −0.82 percent drop in EFP in the short and long run, respectively. The positive impact of GDP growth and adverse effects of GDP square on EFP fully support the EKC curve. These decrees are effusively supported by (Ahmad et al., 2020; Can & Gozgor, 2017; Khan et al., 2020a; Shahbaz et al., 2020). The EPU is positively associated with the EFP-developing Asian nations (full panel analysis). The results show that a 1% change in EPU brings a 0.078 and 0.07% change in ecological footprint in the short and long run, respectively. The environment poverty relationship showed that if a 1% change is found in poverty, it will lead to a significant 1.26 and 0.23% change in EFP in the short and long run, respectively. The different studies (Awad & Warsame, 2022; Barbier, 2000; Chen et al., 2021; Cheng et al., 2018; Duraiappah, 1998) endorsed these outcomes. The estimation showed a direct connection between EPU and EFP, so a 1 percent rise in EPU led to a 0.07 increase in EFP in the short and long run. There is a positive association found between energy consumption and EFP. The elasticity of non-renewable energy consumption illustrates that one unit change in ENG leads to a 1.32 and 1.5 unit change in EFP in the short and long run, respectively. Technological innovation results indicate that one unit change in TEC will significantly lead to −0.03 and? −0.06 unit changes in EFP in the short and long run, respectively. The population growth is ominously increasing the level of EFP in a full panel of Asian economies. A 1 unit change in PPG will lead to a 0.09 and 0.07 unit change in EFP in the long and short run, respectively. The value of the error correction method (ECM) was found substantial at a 1% significance level, as statistical findings revealed that a 20% adjustment is mandatory to move toward the equilibrium position of the analysis.

3.5 Robustness check analysis by FMOLS

For the robustness of the CS-ARDL, the FMOLS test was employed. To find out the long-run association among the variables (dependent and independent), this analysis used FMOLS, designed by Phillips and Hansen (1990). The estimation of CS-ARDL is checked (Table 8) by the FMOLS method for robustness.

For the robustness of the CS-ARDL, the FMOLS approach was used for developing Asian economies. This analysis confirmed the EKC's existence period in the developing countries of Asia. The FMOLS results indicate that environmental destruction can be minimized by significantly improving the use of technological innovation in Asian economies from 1996 to 2018. The FMOLS output presented the same results with a slight difference. Table 8 indicates the consequences for robust Asian economies: ecological footprint (EFP) is significantly increased by energy use, GDP, population, and Poverty. The issues of ecological deterioration and poverty must be handled by adopting effective, sustainable environmental policies (Cao et al., 2009; Zhong et al., 2013).

Table 8 The results of the FMOLS method

Model		
$EF_{it} = f(GDP_{it}, GDP_{it}^2, PVR_{it}, ENG_{it}, TEC_{it}, PPG_{it})$		
Types of developing Economies/Variable names		
East Asian panel	Co-efficient	Standard deviation
$LEFP_{it}$	0.878**	0.020
$LGDP_{it}$	0.454***	0.001
$LGDP_{it}^2$	− 0.056***	0.675
$LEPU_{it}$	0.048***	0.003
$LPVR_{it}$	0.046**	0.123
$LENG_{it}$	1.254**	0.453
$LTEC_{it}$	− 0.061***	0.085
$LPPG_{it}$	0.050**	0.046
South Asian panel		
$LEFP_{it}$	0.691***	0.010
$LGDP_{it}$	0.613***	0.040
$LGDP_{it}^2$	− 0.061**	− 0.035
$LEPU_{it}$	0.058***	0.006
$LPVR_{it}$	0.552**	0.673
$LENG_{it}$	0.201**	0.165
$LTEC_{it}$	− 0.050**	− 0.030
$LPPG_{it}$	0.086**	0.087
Full developing Asian panel		
$LEFP_{it}$	0.125**	0.074
$LGDP_{it}$	1.897**	0.053
$LGDP_{it}^2$	− 0.767***	0.678
$LEPU_{it}$	0.070***	0.010
$LPVR_{it}$	0.256**	0.154
$LENG_{it}$	1.465**	0.235
$LTEC_{it}$	− 0.048***	0.057
$LPPG_{it}$	0.082**	0.077
R^2	0.90	

***represents the level of signiicance at 1%, ** and ***indicate the signiicance level at 5 and 10 percent, respectively

3.6 Heterogeneous panel causality test

This analysis tries to identify the association among ecological footprint, poverty, and other control variables through Dumitrescu and Hurlin's (2012) test. The mentioned method was applied to find out the causality between these variables and the efficient properties (the issue of CSD can be solved with this test). The heterogeneous test non-causality (alternative hypothesis and homogenous non-causality (null hypothesis) is used to identify the causality. Dumitrescu and Hurlin's (2012) test results are testified in Table 9.

Thus, the present analysis applied the Dumitrescu–Hurlin panel technique to identify the causality between all the plausible determinants. Table 9 reports the cause-and-effect

Table 9 The statistical estimation of the Heterogeneous panel causality test

	Hypothesis	*W*-stat	*Z*-stat	*p*-value	Statistical results	Decision
1	EFPϕGDP	2.877	0.806	0.009	Yes	Bidirectional causality
	GDPϕEFP	3.983	2.104	0.035	Yes	
2	EFPϕGDP2	3.767	0.77	0.671	No	Unidirectional causality
	GDP2ϕEFP	4.831	3.043	0.041	Yes	
3	EFPϕEPU	3.504	0.95	0.842	No	Unidirectional causality
	EPUϕEFP	3.431	2.093	0.011	Yes	
	EFPϕPVR	3.098	2.125	0.012	Yes	Bidirectional causality
	PVRϕEFP	3.356	2.725	0.012	Yes	
4	EFPϕENG	4.456	3.511	0.006	Yes	Bidirectional causality
	ENGϕEFP	3.909	2.125	0.01	Yes	
5	EFPϕTEC	5.912	4.769	0.04	Yes	Bidirectional causality
	TECϕEFP	3.267	2.657	0.003	Yes	
6	EFPϕPPG	3.779	1.761	0.789	No	Unidirectional causality
	PPGϕEFP	4.985	3.092	0.001	Yes	
7	PVRϕGDP	1.728	0.542	0.587	No	Unidirectional causality
	GDPϕPVR	7.025	6.025	0.000	Yes	
8	ENGϕGDP	4.075	3.075	0.002	Yes	Bidirectional causality
	GDPϕENG	3.436	2.288	0.02	Yes	
	EPUϕGDP	7.075	6.075	0.000	Yes	Bidirectional causality
	GDPϕEPU	6.406	5.280	0.000	Yes	
9	TECϕLGDP	4.474	3.878	0.007	Yes	Bidirectional causality
	GDPϕTEC	5.693	3.915	0.012	Yes	
10	PPGϕGDP	4.889	3.677	0.004	Yes	Bidirectional causality
	GDPΦPPG	3.768	2.548	0.006	Yes	
11	GDP2ϕGDP	11.887	10.887	0.000	Yes	Bidirectional causality
	GDPϕ GDP2	7.104	6.236	0.000	Yes	
12	GDP2ϕPVR	3.145	2.66	0.001	Yes	Bidirectional causality
	PVRϕGDP2	3.923	2.92	0.001	Yes	
13	EPUϕGDP2	4.075	5.075	0.000	Yes	Bidirectional causality
	GDP2ϕEPU	5.406	6.280	0.000	Yes	
14	ENGϕPVR	7.483	0.023	0.769	No	Unidirectional causality
	PVRϕENG	3.567	2.967	0.333	Yes	
15	ENGϕTEC	7.096	6.782	0.002	Yes	Bidirectional causality
	TECϕENG	5.516	4.795	0.008	Yes	
16	PPGϕENG	4.657	2.891	0.001	Yes	Bidirectional causality
	ENGϕPPG	5.673	6.091	0.001	Yes	
17	ENGϕEPU	5.090	4.042	0.000	Yes	Bidirectional causality
	EPUϕENG	6.519	4.095	0.000	Yes	
18	PVRϕPPG	2.667	1.761	0.001	Yes	Bidirectional causality
	PPGϕPVR	6.657	5.791	0	Yes	
19	PPGϕTEC	6.983	0.073	0.819	No	Neutrality
	TECΦPPG	3.567	0.967	0.226	No	

association between EF_{it}, GDP_{it}, EPU_{it}, GDP_{it}^{2}, PVR_{it}, ENG_{it}, $TEC_{it,}$ and PPG_{it}. The causality between environmental quality and poverty is bidirectional in developing Asian economies. The findings of the Dumitrescu–Hurlin panel test also showed that the two-way causality was found between GDPϕEFP, EFPϕTEC, EFPϕPVR, ENGϕEPU, EPUϕGDP, and PPGϕEFP. Henceforth, statistical findings showed that the ecological footprint could be reduced through effective policy shock to the GDP, ENG, TEC, and PVR. The one-way causality is established between GDP2ϕEFP, EFPϕEPU, PPGϕEFP, PVRϕGDP2, and PVRϕENG. Thus, the effects of GDP, GDP2, and PVR strategy shock on EFP will be practical.

3.7 Discussion

This study aims to survey the consequence of economic, social, and technological variables on the ecological footprint as a proxy of environmental conditions. The author, using the Asian countries (a full panel of East and South Asian countries) data from 1996 to 2018 and the CS-ARDL approach, showed that the environmental quality is diminished due to uncertain economic conditions. The weak economic conditions are creating hazards to achieving sustainable environment targets. Due to existing uncertainties, less attention from the government (due to existing uncertainties) to promoting green energy (renewables) sectors can significantly encourage manufacturers' demand for fossil fuel energy sources. Due to the decline in the externalities of fossil fuel energy consumption, there is no other way than to promote the production and consumption of renewable energy, because renewable energies (green energies) minimize environmental devastation (Sharif et al., 2019). A policy such as using energy-efficient vehicles and selecting specific economic strategies to regulate polluting industries to cut emissions will be very effective. This research proves the connection between poverty and ecological footprint among different groups of countries. The findings concluded that poverty positively and substantially affects EFP in the full panel of economies and the East and South Asian groups. These outcomes climax the concerning connotation between environmental impact and poverty, highlighting the need for targeted involvement to address this problem in these population segments. The damaging sway of poverty on EFP, as acknowledged in the current study, is aligned with results from other research (Baloch et al., 2020a, 2020b), strengthening the significance of addressing poverty as a critical aspect of extenuating EFP and nurturing sustainability.

In addition, stresses the importance of understanding the interaction between poverty and EFP across South-East Asia and delivers valuable intuitions for policymakers pursuing effective plans to fight against climate change. Poverty's effect on pollution harms all groups of countries, and conclusions are consistent with Masron and Subramaniam (2019), who concluded that poverty can be targeted by comprehensive environmental policies to ensure environmental sustainability. In the context of ASEAN, it has been perceived that poverty aggravates the quality of the environment. This association is recognized because penurious societies tend to be involved in unverifiable practices, i.e., extraction of natural resources, unskilled workers, and heightening pollution and deforestation) to meet their basic subsistence requirements. Consequently, these practices contribute to an upsurge in pollution and ecological harm.

The research findings revealed that environmental quality significantly worsens due to increased poverty levels in Asian countries. These findings suggested that Asian economies should take serious steps to overcome these issues. The direct impact of poverty on environmental destruction has many reasons; the intensity of ecological destruction can be increased due to poverty reduction programs and industrialization to boost GDP growth and lessen the strength of poverty (Khan et al., 2020a). Many developing countries face poverty, leading to climate change's cause and effect. Environment degradation and population growth are interrelated; the findings are supported by Cleaver and Schreiber (1994). These findings align with those (Bhujabal et al., 2021; Shobande & Ogbeifun, 2022). Based on the statistical results, it is concluded that this region's environmental quality is deteriorating because of the increasing population. The increase in population can significantly require more resources, and Asia is the most populous region of the world; natural resources are rapidly depleting. The negative impact of the depletion of resources is in terms of biodiversity loss and deforestation. The findings concluded that there is a direct association between poverty and ecological footprint and GDP growth in this region, also significantly deteriorating the environment.

The results implied that ecological degradation affects the vulnerability and the health of poor people in developing Asian economies. Similarly, the high poverty rate also affects environmental quality in various ways. At the expense of environmental quality, multiple countries are trying to uplift their economies from poverty with increasing GDP growth. Thus, various societies downgraded environmental protection concerns, and such situations to protect natural resources are failing. The findings are based on the descending spiral hypothesis, implying that deprived people and environmental damage are always found in a downward spiral. Poverty is deepening due to worse ecological quality, and at the same time, poverty is the foremost hurdle to improving environmental quality. The depletion of natural resources by the poor people for survival and such environmental degradation further increases Poverty (Jehan & Umana, 2003; Ostrom et al., 1999). Overall, the findings suggested that the EFP level can be compacted by control over uncertain economic policies, poverty reduction, eco-friendly technology innovation, less dependence on fossil fuels, and control of the population growth rate. However, GDP Square can improve environmental quality by employing eco-friendly technological change.

4 Conclusion and policy implications

The environmental degradation and poverty trade-off in developing countries is discussed empirically and found disappointing and bad news in prior literature. The results indicate that these developing Asian countries could attain sustainable development goals (SDG-1) (No poverty) and SDG-13 (climate action). These objectives can be accomplished by redesigning the policies for demographic factors (population). Moreover, poverty reduction and goals of sustainable growth with improved environmental quality can be achieved through producing various goods and services with new technology. Our study aims to analyze the nexus between environmental degradation and poverty with some plausible variables for developing Asian economies from 1996 to 2018. The STIRPAT framework enlightened the environmental quality–poverty nexus with various plausible variables such as technological innovation change, GDP growth, population growth, and energy consumption through its multiple mechanisms. Besides, numerous empirical and theoretical research analyses described that these variables (increase in per capita GDP and technological change) could be crucial in the population's welfare. We applied the panel cointegration test (Westerlund, 2008) to identify the long-term link between EFP and its fundamental factors. Methodologically, the CS-ARDL and the FMOLS techniques were applied for the robustness analysis to detect the sway of diverse determinants on EFP. The CS-ARDL and FMOLS statistical results supported the presence of EKC in East Asia and South Asia and a Full panel of Asian nations. These findings align with the works of (Le & Quah, 2018 and Saleem et al., 2020), and EKC is confirmed for Asian economies. Our study found a positive relationship among poverty, energy use, growth in population, and environmental quality. CS-ARDL and the FMOLS's estimation results indicate that technological change specifies a negatively significant correlation with an ecological footprint in South and East Asian nations. This study used the second-generation econometric method that considers the heterogeneity between economies and cross section components reliance.

Consequently, our study accomplished solid and accurate findings. Similarly, this analysis examined the poverty's impact on the environment. It calculated the contradictory effect, so a heterogeneous panel causality test (Dumitrescu and Hurlin, 2012) was implemented to determine the causal implications between ecological footprint and poverty. This analysis applied ecological footprint instead of CO_2 emission to determine the causal connection among the variables simultaneously; the EFP is advantageous in providing attention to consumption and production, describing the EFP's impact on ecological quality, direct or indirect. We offer an inclusive investigation of EFP's effect on poverty with some crucial variables for East Asian, South Asian, and full panel developing Asian economies. The results of the panel test of Dumitrescu–Hurlin showed that the bidirectional causality was found in the relationship between GDP and EPC, EFP and technological change, EFP and poverty, and population growth and EFP. Hence, SDGs are expected to be achieved in developing Asian countries, although the statistical findings brought good news for these countries. The research carries significant strategy implications. The findings expose that high poverty contributes to ecological destruction in selected Asian economies. Consequently, planning growth rules that simultaneously diminish extreme poverty while safeguarding the environment's quality is essential.

Regarding strategy suggestions, Asian least developed economies should not exclusively trust enhancing GDP growth. Instead, they should implement a multidimensional method to address their composite challenges of the economy. This comprises providing instant social relief through growing micro-financial funding activities, creating employment opportunities, and establishing social safety nets. These strategies can help alleviate poverty without exacerbating income inequality or causing harm to the environment. Targeted nations can address environmental destruction issues by implementing strategies preventing developed economies from transferring their wealth into ecologically destructive practices. Instead, they should stimulate sustainable innovations like clean energy for these individuals. Combating poverty, economic policy uncertainty, and ecological destruction need a long-term economic plan in developing Asian regions. These policies should highlight sustainable development, economic growth, and environmental protection. This region's Policymakers, facing high population growth rates, industrialization, and rapid economic growth, should balance economic progress with environmental quality. They should promote eco-friendly energy sources and impose ecological regulations to reduce environmental pollution and drive eco-friendly innovation.

The outcomes of empirical research highlight the region's high dependency on fossil fuel energy. To discourse this, the Asian countries experiencing development through numerous economic corridors should highlight intensifying their energy assortment, emphasizing eco-friendly and clean energy sources. This modification should ensure less ecological harmful impact. Implementing the Emission Trading Approach (ETS) and carbon tax implementation can produce extra income and reduce poverty while restricting ecological destruction. Moreover, a combined struggle by this region's private and public sectors should contain strategies that provide financial encouragement, such as credits, to encourage the implementation of eco-friendly innovations like solar power. These policies and technological advancement discourse energy scarcities and subsidies to alleviate environmental destruction.

For detailed policy implications, it is suggested that: (i) The GDP rise is impossible without an increase in energy consumption. Energy consumption also has environmental consequences. Therefore, solving the dilemma increases production and maintains the environment, which can only be achieved with the help of green energy and new technologies. By using clean energies such as wind, solar, and geothermal, it is possible to increase production and welfare in the framework of sustainable development. (ii) Transparent economic strategies are prerequisites to control economic policy uncertainty; thus, economic policy deficiencies and illnesses should be diagnosed and adequately treated by transparent economic policies and economic stability by government authorities and officials. Numerous international organizations, e.g., the World Bank, International Monetary Fund, and World Trade Organization, can help reduce economic policy uncertainty by starting a campaign. Environmental sustainable goals can be achieved by identifying those factors that cause environmental pollution. (iii) The current study showed that the population harms the environment. Population control policies are essential to creating the ability to meet the increasing demand of the people and to establish strict environmental policies to deal with people's encroachment on the environment. Also, following policies associated with green growth and renewable energies can lead to the simultaneous growth of environmental quality, increase in production, and securing of population demand. (iv) Moreover, promoting environmental sustainability is a prerequisite to the reforms in the energy sector (e.g., renewable energy use, enabling effective and efficient energy consumption, and manufacturing practices should be modernized and environment friendly. (v) Poor people in developing countries rely heavily on natural resources for survival.

Considering poverty's negative effect on the environment, it is necessary that the studied countries, while enacting strict environmental laws, support the poor people in different ways so that while meeting the needs of people experiencing poverty, the environmental quality is also maintained. vi) It is necessary to empower the weak sections of society, transfer the necessary training to create employment, and provide support facilities to create employment and get out of poverty. Encouraging policies should be applied to use more environmentally friendly technologies to maintain environmental quality. Also, giving the necessary awareness about the importance of the environment and its conservation methods should be done in schools from a young age.

The findings of this study also suggested that adopting strict environmental policies, encouraging green growth projects, and practical strategies to decrease poverty are prerequisites for the environmental sustainability agenda. Due to data constraints, this work couldn't add numerous important indicators among the study variables. The future investigation could enlarge this by applying alternative variables, lengthening the analysis's scope and confirming the outcomes. This research analysis can assist as motivation and foundation for future examinations into the same associations in the world's developing countries. For future studies, the authors suggest that: (i) Due to the importance of climate change and its direct impact on various economic sectors, especially the agricultural sector, essential climate variables, for instance, temperature and precipitation, should be considered in poverty-environment modeling. (ii) Researchers can also strengthen the works by inspecting the relationship between institutional quality, research and development (R&D), health, and education. (iii) Further research can be estimated using financial inclusion's role in extenuating ecological degradation and poverty reduction by offering monetary aid to the industry to develop green products.

Appendix (A)

List of selected Asian countries

Panel 1	Panel 2
Developing South Asian Countries	Developing East Asian Countries
Bangladesh	Cambodia
Bhutan	China
India	Indonesia
Nepal	Malaysia
Pakistan	Philippines
Sri Lanka	Vietnam

Funding No funding was received from any source.

Availability of data and materials The datasets analyzed during the current study are available in the World Bank Data Bank Database repository (https://data.worldbank.org).

Declarations

Conflict of interests The authors declare no competing interest.

Ethical approval Not applicable.

Consent to participate Not applicable.

Consent for publishcation Not applicable.

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