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EXPLORING THE DETERMINANTS OF ECOLOGICAL FOOTPRINT IN SELECTED SOUTH ASIAN ASSOCIATION FOR REGIONAL COOPERATION ECONOMIES: INDIA, BANGLADESH, AND PAKISTAN

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ABSTRACT

South Asian countries are developing rapidly, and this development is increasing environmental stress, highlighting the need to examine the key determinants of the ecological footprints. Therefore, this study aims to analyze the impact of total population, natural resource rent, industrialization, renewable energy consumption, and GDP per person employed on the ecological footprint in the selected SAARC countries, Bangladesh, India, and Pakistan (BIP) by using panel data from 1990 to 2023. The study employed panel data techniques and applied a fixed effects model with Driscoll-Kraay standard errors to address issues of heteroscedasticity, autocorrelation, and cross-sectional dependence. Furthermore, the Westerlund test is utilized to check the long-run relationship. The findings reveal that natural resource rent and industrialization significantly increase ecological pressure, whereas renewable energy consumption helps to reduce environmental degradation. Population exhibits a positive but insignificant relationship with ecological footprint, while GDP per person has a negative and significant relationship with ecological footprint. In addition, the results show a long-term cointegrating relationship among the concerned variables. The results highlight the need for region-specific environmental policies that promote sustainable development without compromising economic progress. This study contributes to the growing literature on environmental sustainability in South Asia and provides empirical evidence for effective policy formulation aimed at achieving ecological balance.

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INTRODUCTION

Environmental degradation has become a universal challenge, not only for developed nations but also for underdeveloped nations. Environmental degradation has become one of the most debatable issues in the 21st century (Ul Haq et al., 2021). One of the world's most serious issues is climate change (Tariq et al., 2022). The ecological footprint measures the environmental impacts of human activities by calculating the biological productive land and water needed to measure the sustainable resource consumption and absorb the waste (Wackernagel and Galli, 2007). It is a key indicator used for sustainability, reflecting the balance between economic development and environmental preservation. Over the years, environmental degradation has become a global challenge, so a comprehensive measure is needed to assess environmental quality (Yousaf et al., 2022). Mathis Wackernagel and William Rees developed the idea of environmental accounting in the 1990s. The concept of ecological footprint evaluates the impact of human activities on the environment (Hanafiah et al., 2012). Ecological footprint means the natural resources we need and the waste we create. Simply, we are harming our environment in two ways at the same time. First, by extracting more resources beyond the limit, and second, by depositing more waste than the earth's capacity to handle it. It is measured in hectares, denoted by (ha) (Wackernagel and Galli, 2007). The ecological footprint is the land area required to provide resources for people and absorb their emissions, measured in global hectares (gha) (Hanafiah et al., 2012).

Ecological footprint Earth Overshoot Day

Overshoot day is the date in a year when humans have used up all the natural resources the earth can regenerate for that year. So, if ecological footprint < Bio-capacity (sustainable case surplus), and if ecological footprint > Bio-capacity (ecological deficit overshoot). This image shows (Figure 1), for each country in 2024, the calendar date when Earth Overshoot Day would happen if everyone in the world consumed resources at the same rate as people in that country.

South Asia is recognized as a highly populated region globally (Sultana et al., 2023). Furthermore, this region is producing carbon due to economic and population growth (Sultana et al., 2023). This area is highly vulnerable to climate change due to excessive carbon buildup. That is attributed to countries' significant economic and population growth. India, Bangladesh, and Pakistan are the most populous countries in the SAARC region. Pakistan is an ecologically deficient country in the World, being the 6th largest economy (population-wise) (Yousaf et al., 2022). This region is producing carbon due to economic and population growth (Sultana et al., 2023). Economic expansion has an impact on the environment as a result of scale and technology impacts (Tariq et al., 2022). Rapid industrialization and modernization have significantly aggravated the world's carbon emissions, leading to increased climate change adversities (Li et al., 2021).

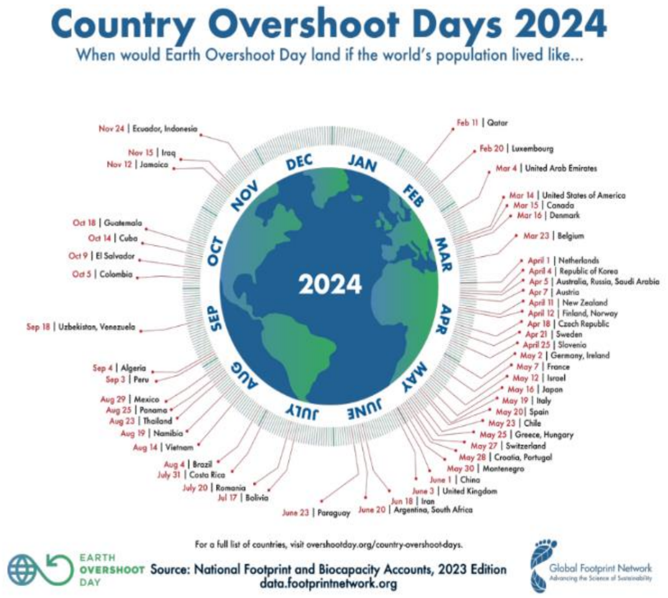

Figure 1. Country overshoot day Source: Ecological Footprint Network (2025).

A sustainable environment (SE) is significantly beneficial to an economy. A sustainable environment (SE) preserves the natural resources, supports healthy living beings, and ensures active human resources for the present and future economic and social activities (Hieu, 2022). Economic activities are a key cause of environmental damage, which has prompted researchers to investigate the driving factors in various economies (Sadiq et al., 2022). This degradation in the environment has a long- term effect on human life. Ecological footprints are considered a suitable measure for the assessment of environmental degradation (Ul Haq et al., 2021).

High population levels and continuous economic growth in South Asia contribute to rising carbon emissions (Sultana et al., 2023). Economic expansion has an impact on the environment as a result of scale and technology impacts (Tariq et al., 2022). Climate change is affecting human activities. It negatively affects the land ecosystem, food supply, land quality, and human well-being (Abid et al., 2021). This research aims to identify the key economic and environmental variables that influence India, Bangladesh, and Pakistan's environmental degradation. Besides, this research provides a policy to mitigate the ecological footprint issue in the economies of selected countries. Furthermore, to identify the impact of the GDP per person employed on the ecological footprint in three economies during the given period.

A comparative assessment of the ecological footprint for Pakistan, Bangladesh, and India between the initial period and the recent period reveals a substantial increase in environmental pressure in all three economies, as shown in Figure 2. India recorded the most pronounced expansion, with its footprint rising from 592.1 million in 1990 to 1470.5 million in 2022.

Pakistan's ecological footprint expanded from 88.9 million global hectares in 1990 to 172.1 million in 2022, reflecting a high environmental pressure due to population growth and industrial activities. Bangladesh also showed a significant upward trend, rising from 40.0 million global hectares in 1990 to 116.2 million global hectares in 2021. Besides, in 2023, 76.7 million global hectares experienced a temporary decline due to energy resource management.

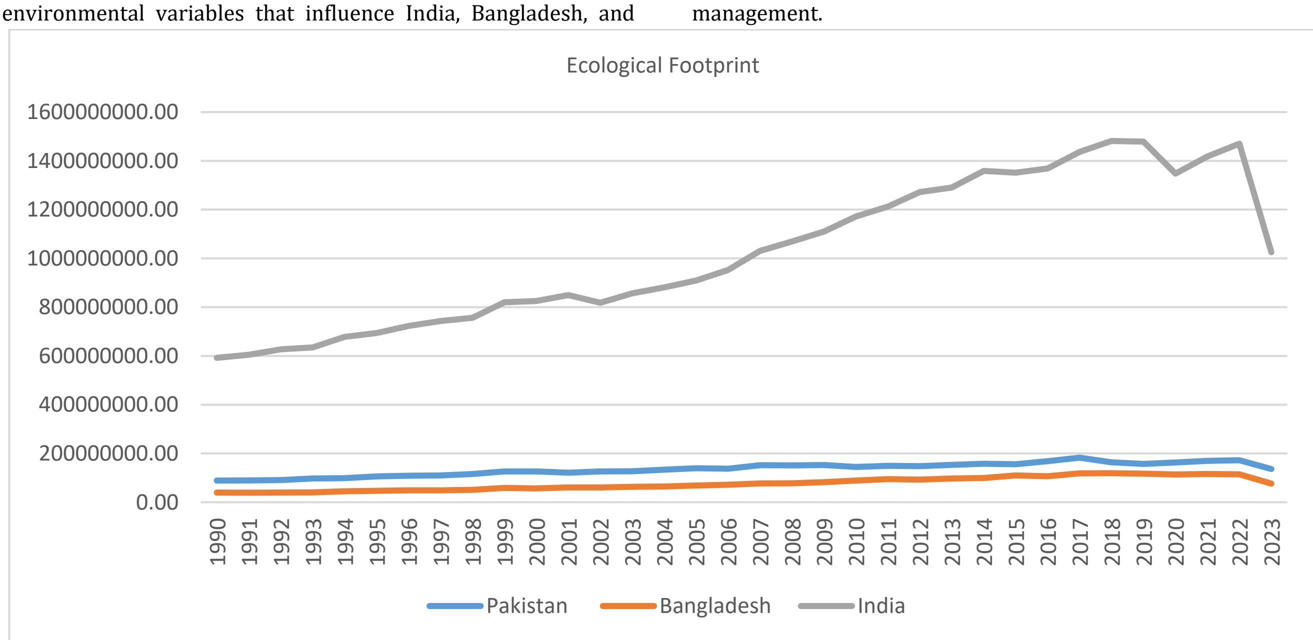

Figure 2. Ecological footprint of economies from 1990 to 2022; Source: (Global Footprint Network, 2025)

Significance

Ecological footprint evaluates the impact of human activities on the environment. Empirical evidence is provided for selected economies (BIP-Bangladesh, India, and Pakistan) on how renewable energy consumption, natural resource rent, population, GDP per person employed, and industrialization impact the ecological footprint. This analysis will be not only helpful for economists and businessmen but also for environmental policymakers to design strategies for sustainable resource management in these countries. The key determinants of ecological footprint degradation are highlighted in the case of the economies of selected countries (India, Bangladesh, and Pakistan). Besides, to identify the environmental quality and inclusive growth. Furthermore, this study will also help and suggest policy recommendations to balance economic development and environmental sustainability in these economies.

Research problem

A number of studies have been done on the determinants of the ecological footprint since the 1990s. In these studies, urbanization, total population, industrialization, digitalization, renewable energy consumption, financial development, and natural resource rent are found as key determinants of ecological footprint in different economies. For instance, Hacıimamoğlu and Cengiz (2024) investigate the impacts of the use of renewable energy and natural resources rents on environmental degradation in the economy of ASEAN-5 countries. Similarly, Ullah et al. (2023) explore the link between financial structure, energy use, and depletion, and their impacts on environmental quality and ecological footprints in the economy of Pakistan.

The literature discussed above makes it clear the importance of the ecological footprint and environmental issues in the selected SAARC countries. According to the World Air Quality Report, this region has the most polluted cities. For example, Delhi (India), Lahore (Pakistan), and Dhaka (Bangladesh) often reported poor air quality levels. Climate change is a global phenomenon, and the serious impact of this phenomenon is encouraging the national as well as international community to address the cause and to anticipate the consequences (Putri et al., 2016). The economies of selected countries (India, Bangladesh, and Pakistan) are facing environmental issues due to population growth, industrial growth, and increasing demand for resources. These environmental issues are also affecting economic activities, particularly in the winter season (Smog). However, researchers' best knowledge is limited, as research exists on the specific determinants of the ecological footprint in the country, creating a gap in policy formulation. Furthermore, the research on the given three countries is also not available. There is a need to develop a model and find the determinants of ecological footprints in the economies of selected SAARC countries (India, Bangladesh, and Pakistan). Furthermore, policy should be designed on the basis of results.

Research Objectives

This study aims to examine the determinants of environmental degradation in the context of the economies of the selected SAARC countries, including Bangladesh, India, and Pakistan (BIP), by focusing on the ecological footprint as the primary indicator. Furthermore, this study aims to examine the long-run relationship among these variables. Specifically, it examines the impact of key demographic, economic, and environmental factors on ecological footprint, including renewable energy consumption, natural resource rent, industrialization, population, and GDP per person employed.

Literature Review

Increasing carbon emissions have become a major concern for all economies, especially countries promoting and investing in clean energy. Therefore, Saqib and Dincă (2024) explore the impacts of shocks in the economic complexity index (ECI), direct foreign investment (DFI), Green technology (GT), and renewable energy resources (RER) on carbon emissions. The data from 1995 to 2020 is taken for this exploration. Panel NARDL methodology is used to investigate the asymmetrical connection between carbon emissions and relevant independent variables. Besides, AMG, CCEMG are also applied. As per the result, positive shocks in economic complexity, foreign direct investment (FDI), environmental technology, and renewable energy resources reduce carbon emissions, while negative shocks will increase pollution in the long run. Renewable energy is used in many economies. Therefore, Hacıimamoğlu and Cengiz (2024) investigate the impact of renewable energy consumption and income from natural resources on environmental quality in the economy of ASEAN-5 countries. This study uses Method of Moments Quantile Regression (MMQR), an advanced technique for panel data analysis. All estimation results reveal that both renewable energy consumption and natural resources rents reduce environmental degradation. This result demonstrates the validity of the environmental Kuznets curve (EKC) hypothesis, which means that a decrease in environmental pressure is expected when the income level in ASEAN-5 countries surpasses a certain threshold. Similarly, Ullah et al. (2023) investigate the relationship between financial structure and energy depletion with environmental degradation and ecological footprints in Pakistan. In this study, the researcher applied Augmented Autoregressive Distributed Lag (AARDL) for analysis. According to findings, it has been revealed that financial structure, urban population, and energy depletion decrease ecological footprints. At the same time, trade openness increases ecological footprints in Pakistan's economy while decreasing ecological footprints. Both developed and underdeveloped countries are facing environmental issues. Therefore, Cutcu et al. (2023) examine the relationship between foreign trade (exports and imports) and ecological footprint using two different models. The researcher found an inverse relationship between exports, renewable energy consumption, and ecological footprint, while a positive relationship between economic growth and ecological footprint. A sustainable environment has become a global requirement. So, Hieu (2022) investigates the role of green investment and environmental taxes in promoting a sustainable environment across ASEAN countries. The data from 1981 to 2020 is taken for this examination. A panel pooled mean group model is applied. Furthermore, this test is also used to examine the association between the constructs. The findings indicate that the green investment (GI) and environmental taxes (ET) are associated with a reduction in CO_2 emissions. In contrast, economic growth and population growth contribute to higher CO_2 emissions, which adversely affect environmental sustainability in ASEAN countries. The rapid industrialization has significantly aggravated the World's carbon (CO_2) emissions, leading to increased climate change adversities. So, Li et al. (2021) analyse the role of green investment and found green investment reduces the CO_2 emissions in the short run as well as in the long run, while natural resources, financial sector, and energy investment increase the carbon emission in the short run as well as in the long run. The MINT countries-Mexico, Indonesia, Nigeria, and Turkey- have practised significant levels of economic growth over the year, but these countries have not managed to improve environmental quality. Therefore, Li et al. (2022) observe that non-renewable energy (NRE) significantly increase environmental degradation and green investment (GI) significantly reduce it in the long run in MINT countries. China's economy is growing rapidly; however, environmental concerns are overlooked in the process. Therefore, Ren et al. (2022) examine the green investment effects in the economy of China, using panel data and the Durbin model, and a dynamic threshold model is used for this analysis. Green investment (GI) helps reduce environmental pollution by enhancing energy efficiency, promoting emission reduction, encouraging technological innovation, and supporting industrial upgrading. South Asia is a populous region in the world. Similarly, Shen et al. (2021) investigate the role of green investment (GI), natural resources rent (NRR), financial development (FD), and energy consumption (EC) in the mitigation of carbon emissions. The results indicate that increases in the natural resources rent, financial development, and energy use are associated with higher carbon emissions. In contrast, green investment is inversely related to carbon emissions and helps to control the downsides of carbon emissions

Therefore, Sadiq et al. (2022) examine the green growth using Ordinary Least Squares (OLS). The data of South Asia from 1995 to 2018 is taken. As per overall findings, clean energy (CE), green finance (GF), and sustainable economic growth (SEG) are all important and positive indicators of a composite assessment of sustainable practices. Environmental sustainability is important to achieve for survival. Therefore, South Asia (SA), South-East Asia (SEA), China, Middle Eastern countries, and European countries are investigated by many researchers. So, Khan et al. (2022) examine the impact of green finance on environmental sustainability. As per findings, the greater renewable energy investment, the higher will be environmental sustainability. The share of 40% of the world economy is related to BRICS. Therefore, Rout et al. (2022) examine the impact of renewable and non-renewable energy use on the ecological footprints in the economy of BRICS. The Kuznets framework is used. Non-renewable energy consumption creates a negative impact on the environment in the long run, while renewable energy has a positive impact on environmental sustainability.

Urbanization is one of the key factors affecting the ecological footprint. Therefore, Abid et al. (2021) investigate the determinants of ecological footprint (EFP). A panel of 118 countries is designed for this analysis. The results reveal that economic growth contributes to a lower ecological footprint in general, but in lower-middle-income countries, it leads to higher ecological degradation. Financial development, Globalization, Human capital, Energy use, and Urbanization increase ecological footprints, while Natural resources exert a positive influence on ecological footprint. South Asia is the most populous region. Therefore, Safdar et al. (2022) explore the role of governance and natural resources rent in the economy of selected South Asian countries. The data from 1996 to 2020 is taken for this analysis. Results indicate that greenhouse gas emissions (GGE) can be decreased with the help of good governance and the use of natural resources.

The world's top 15 renewable energy-consuming economies are striving to achieve sustainable economic development. Therefore, Ullah et al. (2021) examine the non-linear relationship between renewable energy consumption (REC), natural resource rent (NRR), and ecological footprint (EFP). The results indicate that higher renewable energy use reduces the ecological footprint, whereas greater natural resources rent increases it in both low and high regimes among 15 economies.

Latin America is characterized by relatively low industrialization and a significant advantage in biodiversity. Therefore, Alvarado et al. (2021) explore the environmental degradation associated with the ecological footprint in this region. Quantile regression method is used based on a theoretical framework, EKC. The impact of economic complexity (EC) and the natural resources rents (NRR) has been observed to be heterogeneous throughout the distribution on the ecological footprint (EFP).

The significant economic growth is observed in China. Therefore, Ahmed et al. (2020) investigate the determinants of ecological footprint (EFP) in the economy of China. The data from 1970 to 2016, is used in a cointegration test for this analysis. Natural resources, GDP per capita, and urbanization increase while urbanization (URB) decreases environmental degradation and the ecological footprint.

The Environmental Inclusive Growth Kuznets curve is utilised by Kamah et al. (2021) to explore the link between inclusive growth and the environment. For this exploration, the researcher took environmental sustainability, inclusive growth, and institutional quality as variables from 2001 to 2018 and found that environmental quality improves with inclusive growth. Furthermore, a new phenomenon has been developed called the environmental inclusive growth Kuznets curve, on the basis of the result. Organisation for Economic Co-operation and Development (OECD) countries are trying to control environmental degradation. Therefore, Ulucak and Ozcan (2020) investigate the relationship between the use of energy and environmental sustainability in OECD countries during the period of 1980 to 2016. The analysis shows an inverted U-shaped link between per capita income and environmental degradation. While renewable energy does not significantly affect CO2 emissions, it helps reduce ecological and carbon footprints. Conversely, natural resource extraction raises CO2 emissions but shows no significant impact on the ecological footprint.

The literature shows that renewable energy use, natural resource rents, population growth, industrialization, and labour productivity affect environmental outcomes. So, total natural resource rent and GDP per person employed can increase economic output but may also affect the ecological footprint. Therefore, it should be examined how the impact of renewable energy use, population growth in general, industrialisation, natural resource rents, and labour productivity affect environmental outcomes in particular. Furthermore, this study aims to examine the long-run relationship among these variables.

METHODOLOGY

This section explains the selection of variables, theoretical framework, and countries used to investigate the effects of independent variables (IV) on ecological footprint. Ecological footprint is dependent, while Green investment (Renewable energy consumption (REC)), Natural resource rent (NRE), industrialization (Industry (including construction), value added (% of GDP)) (IND), Total population (TP), and GDP per person employed (GPPE) are taken as independent variables.

Theoretical framework

Ecological footprints quantify the environmental impact of human activities on the lives of people, particularly. Besides, it can be explained as ecological footprints measure how much nature we use compared to how much nature is available. This study is underpinned by rational choice theory, which assumes that individuals, businessmen, and governments act logically to maximize benefits and minimize costs. In the context of ecological footprint (EFP), countries like Bangladesh, India, and Pakistan (BIP) often prioritize economic growth, improve living standards, industrialization, and urbanization to achieve development goals—reflecting rational decisions based on immediate socio-economic needs. However, such decisions can lead to environmental degradation when sustainability is not valued equally. Rationalism also supports the Environmental Kuznets Curve hypothesis, which suggests that as income rises, societies rationally shift toward cleaner technologies and sustainable practices. Thus, rationalism helps explain both the causes and potential solutions to ecological overshoot in BIP countries. There are many theories related to the ecological footprint. One of the most important and relevant theories is the Environmental Kuznets curve. This theory suggests an inverse U-shaped curve. The relationship between economic growth and environmental degradation was confirmed as an inverted U-shaped relationship investigated by Dinda (2005) and Kaika and Zervas (2013).

Data collection

The Data is collected from Global Footprint Network (GFN) and World Development Indicators (WDI). Different sources are used for the collection of data. Besides, WDI is a reliable source because this organisation provides data around the world and has been collecting data since the inception of the digital world. Table 1 presents the list and symbols of variables used in the study, along with data sources and measurements.

Data Sampling and Design

The World Development Indicators (WDI) and Global Footprint Network are used for data collection. The data from 1990 to 2023 is taken. A quantitative approach is applied to investigate the links between green investment, natural resource rent (NRE), industrialization (IND), total population (TP), and ecological footprint (EFP).

Econometric Model

This panel data study utilises five independent variables and one dependent variable. Furthermore, in this study, panel data of three countries (India, Bangladesh, and Pakistan) from 1995 to 2023 is developed. This model uses time variation in panel data. A general form of your panel data model:

$$EFP_{\{it\}} = \alpha + \beta_{\{1\}}\, X_{\{1it\}} + \beta_{\{2\}}\, X_{\{2it\}} + \beta_{\{3\}}\, X_{\{3it\}} + \cdots\ \mu_{\{it\}} \quad (1)$$

Where:
i = country
t = time period
α = constant term
μi = country-specific effects (fixed or random) ϵit = error term

$$EFP_{\{it\}} = \alpha + \beta_{\{1\}}\, REC_{\{it\}} + \beta_{\{2\}}\, NRE_{\{it\}} + \beta_{\{3\}}\, IND_{\{it\}} + \beta_{\{4\}}\, TP_{\{it\}} + \beta_{\{5\}}\, GPPE_{\{it\}} + \mu_{\{it\}} \quad (2)$$

i=1,2,...,N (countries); t=1,2,...,T (years)

Model Justification

In the literature, it is observed fixed model was applied in many studies. Furthermore, pooled OLS, random effect, and fixed effect approaches were applied, and the Hausman test was used to decide the suitable model. The test statistics were (Table 9: p-value = 0.0000) significant, indicating that the Fixed Effects model is more appropriate. This study used panel data of three countries (India, Bangladesh, and Pakistan) from 1990 to 2023.

Table 2 presents the list, variable name, measurement, data sources, and justification of variables used in the study. Furthermore, the variables used in the model are based on the studies conducted by various scholars.

RESULTS AND DISCUSSION

To select the most appropriate panel data model, Pooled OLS, Fixed Effects (FE), and Random Effects (RE) are applied, and the Hausman test was used to decide the suitable model. The test statistics were significant, indicating that the Fixed Effects model is more appropriate. The results of the Hausman Test are presented in Table 3.

Table 1. Summary of variables.

Variables	Symbol	Measurement
Ecological footprints	EFP	GHA
Renewable energy consumption	REC	Percentage share of total final energy consumption
Natural resource rent	NRE	Percentage of GDP
Total population	TP	Total Population in million
GDP per person employed	GPPE	Dollar per person employed
Industrialization	IND	Percentage of GDP

Table 2. Variables and justification.

Variables	Measurement	Data sources	Used in literature
Ecological footprint	GHA	Global Footprint Network	Qayyum et al. (2024)
Renewable energy consumption	Percentage share of total final energy consumption	World Development Indicators	Hacıimamoğlu and Cengiz (2024)
Natural resource rent	Percentage of GDP	World Development Indicators	Abid et al. (2021), Hacıimamoğlu and Cengiz (2024)
Total population	Total	World Development Indicators	Hieu (2022), Anser et al. (2020)
GDP per person employed	Dollar per person employed	World Development Indicators)	Ge et al. (2020), Jiang et al. (2022)
Industrialization	value added (% of GDP)	World Development Indicators)	Ullah et al. (2021)

Table 3. Hausman test.

Test	Value	df	p-Value	Interpretation
Hausman	41.688	5	6.81e-08	Use Fixed Effects model

Table 4. Levin–Lin–Chu (LLC) Panel Unit Root Test and Order of Integration

Variable	Level (P-Values)	First difference (P-Values)	Order of Integration
ln_efp	-0.404 (0.343)	-4.724 (0.000)	I(1)
ln_rec	-0.038 (0.485)	-2.208 (0.014)	I(1)
ln_nre	-1.397 (0.081)	-8.813 (0.000)	I(1)
ln_urb	2.041 (0.979)	0.612 (0.730)	Non-stationary
ln_ind	1.241 (0.893)	-9.160 (0.000)	I(1)
ln_tp	6.559 (1.000)	-6.353 (0.000)	I(1)
ln_gppe	7.179 (1.000)	-28.729 (0.000)	I(1)

To check if the data is suitable for regression, we performed panel unit root tests (Levin-Lin-Chu and Im-Pesaran-Shin). The result in Table 4 showed mixed orders of integration. Some variables, like Ecological Footprint (EFP) and GDP per person employed, were stationary at level (I(0)), while other variables, such as Renewable Energy Consumption (REC), Natural Resources (NRE), industrialization (IND), and Total Population (TP), were stationary after first differencing (I(1)).
In Table 5, the correlation matrix shows that ecological footprints are positively correlated with natural resource rent (NRE), industrialization (IND), GDP per person employed (GPPE), and total population (TP), while negatively correlated with renewable energy consumption (REC). Other variables have weak to moderate links.
Variance Inflation Factor (VIF) tests (Table 6) were used to check the multicollinearity issues. It was revealed no serious multicollinearity issues. All VIF values were below 5, confirming that the independent variables are not highly correlated with each other. The reported value range from 2.17 to 4.18, confirming that multicollinearity is not a concern in the model. Besides, Tests revealed that the residuals from the Fixed Effect model showed signs of autocorrelation and heteroskedasticity. To handle this issue, we applied Driscoll-Kraay Standard Errors in the final model to ensure robust and reliable results.

Table 5. Correlation matrix.

Variables	ln_efp	ln_rec	ln_nre	ln_ind	ln_tp	ln_gppe
ln_efp	1.000	-0.466	0.740	0.467	0.981	0.237
ln_rec	-0.466	1.000	-0.203	-0.514	-0.380	-0.557
ln_nre	0.740	-0.203	1.000	0.135	0.702	0.196
ln_ind	0.467	-0.514	0.135	1.000	0.509	0.013
ln_tp	0.981	-0.380	0.702	0.509	1.000	0.122
ln_gppe	0.237	-0.557	0.196	0.013	0.122	1.000

Table 6.Variance Inflation Factor (VIF) .

Variable	VIF
ln_rec	3.90
ln_nre	2.72
ln_urb	4.18
ln_ind	2.17
ln_tp	3.50
ln_gppe	2.39

*Above 5 Moderate multicollinearity, ** Above 10 severe multicollinearity

Table 7. Cointegration test (Westerlund).

Statistics	Value	Z-value	P-0value	Robust P-value	decision
Gt	-6.116	-5.911	0.000	0.008	Cointegration
Ga	-14.349	0.529	0.702	0.070	No Cointegration
Pt	-12.953	-7.887	0.000	0.010	Cointegration
Pa	-33.596	-3.902	0.000	0.005	Cointegration

The Westerlund test was employed to investigate the presence of long-run relationships between the variables. In Table 7, cointegration is observed as per the Gt statistics and robust p-value (0.008). Furthermore, the null hypothesis of no cointegration cannot be rejected for this statistic, as a robust p-value (0.07) in the Ga statistic. The panel-t statistic is highly significant with a robust p-value of 0.010, confirming the existence of a long-run cointegrating relationship for the panel as a whole. Pa statistic is also statistically significant at the 1% level, as indicated by the robust p-value of 0.005, further supporting panel cointegration.

Despite the Ga statistic indicating no cointegration, the significant results of Gt, Pt, and Pa statistics provide strong evidence of a long-run equilibrium relationship among the variables in the panel. Since the majority of the Westerlund test statistics reject the null hypothesis, it is concluded that the variables are cointegrated in the long run.

Final Model Interpretation (Fixed Effects with Driscoll-Kraay SEs)

The final model used Environmental Footprint (EFP) as the dependent variable, while Renewable Energy Consumption (REC), Natural Resources Rent (NRE), Industrialisation (IND), Total Population, and GDP per person employed (GPPE) as independent variables. The results from the Fixed Effects model (with Driscoll-Kraay SEs) are summarized in Table 8. This estimator, proposed by Driscoll and Kraay, is particularly suitable for macro panels (large T, small N), which is consistent with the structure of this study. Driscoll-Kraay standard errors provide robust estimates even when residuals are correlated across countries and over time, thus ensuring valid statistical inference. The Fixed Effects (FE) model with Driscoll-Kraay standard errors was identified as the most reliable approach. This method effectively accounts for cross-sectional dependence, heteroskedasticity, and serial correlation in the panel data structure, making the findings robust and credible.

In Table 8, the results show that Renewable energy consumption (REC) has a negative and significant relationship in these countries. The results indicate that Renewable energy consumption (REC) is a 0.2% cause of environmental degradation reduction in these countries. So, when countries increase their Renewable energy usage, their environmental footprint decreases (Sarkodie et al., 2020). This suggests causal support for the idea that clearer energy sources directly contribute to environmental protection (Iorember et al., 2021). Natural resources rent has a positive and highly significant connection with ecological footprint. The results demonstrate that natural resource rent is a 0.4% cause of environmental degradation in these countries. Its positive coefficient shows that more dependence on natural resource extraction (like oil, minerals, and deforestation) causes environmental harm (Ahmad et al., 2020). This supports the theory of resource depletion causing ecological degradation in the region. Industrialization has a significant and direct relation with environmental degradation. The results demonstrate that industrialization is a 0.3% cause of environmental degradation in these countries. It means that industrial activity contributes to environmental pollution, especially when regulations are weak or energy use is non-renewable. This supports the pollution haven hypothesis in developing economies.

Population is directly related to the ecological footprint. Population have insignificant and positive link with the ecological footprint. The results indicate that population is a 0.1% cause of environmental degradation in these countries. In simple words, if the ecological footprint of a population (country, region, or nation) exceeds the biocapacity of the area (country, region, or nation), it can lead to environmental degradation and other negative consequences. A positive relationship is found between ecological footprint and total population in BIP countries (Ahmed et al., 2020; Chen et al., 2022). It is not statistically insignificant. Therefore, it implies that population size alone does not have a strong direct causal effect on environmental footprints.

GDP per person employed has a significant and inverse relation with ecological footprint. The result demonstrates that GDP per person employed is a 0.1% cause of environmental degradation reduction in these countries. A negative and mildly significant coefficient indicates that more productive and efficient economies tend to reduce environmental impact, possibly by using advanced, less-polluting technologies. This suggests that economic productivity can help achieve green growth.

Table 8. Fixed effects model (with Driscoll-Kraay SEs).

Variable	Coefficient	Significance	Interpretation
ln_REC	-0.282**	Significant	An increase in REC reduces EFP
ln_NRE	0.421***	Highly significant	More resource use increases EFP
ln_IND	0.301**	Significant	Industrial growth increases EFP
ln_TP	0.112	Not significant	Population effect is weak
ln_GPPE	-0.198*	Mildly significant	More productive economies reduce EFP

(Significance levels: ***p<0.01, **p<0.05, *p<0.1)

CONCLUSION AND POLICY IMPLICATIONS

Climate change is a critical issue around the world. This study explored the effect of Renewable Energy Consumption, Total Natural Resources, Industry (including construction), Total Population, GDP per person employed, on ecological footprint in the economies of three SAARC countries BIP. As a result, renewable energy consumption is negative. If these economies use more renewable energy sources, the ecological footprint will be decreased. The estimated results indicate that renewable energy consumption and GDP per person employed are causes of environmental degradation reduction in Pakistan, India, and Bangladesh. This study identified the most important climate change problems and possibilities for environmental policy makers to consider. The primary objective was to identify how economic and demographic factors influence environmental pressure, and whether sustainable policy shifts could be informed through empirical insights. The results strongly support the idea that renewable energy adoption and economic productivity reduce environmental harm, while resource extraction and industrial growth worsen it (Sarkodie et al., 2020). A positive and highly significant coefficient shows that more dependence on natural resource extraction (like oil, minerals, and deforestation) causes environmental harm. So, we can say that more dependence on natural resource extraction and industrial growth is a major cause of environmental issues in these countries.

Population pressure alone is not a strong determinant in these countries unless coupled with other factors like urban planning or technology (Ahmed et al., 2020; Chen et al., 2022). Furthermore, as per the findings, investing in green energy and improving labour productivity are important steps towards sustainable development in these countries. GDP per person employed has a significant and negative connection with the ecological footprint. Means inclusive growth can help to reduce environmental issues (Kamah et al., 2021).

The findings of this study provide important guidance for the regional policy makers as well as government officials. There is strong evidence that increasing renewable energy consumption (REC) can significantly reduce ecological footprint (EFP). Public and private investment in solar, wind, and hydropower should be prioritized. Besides, the Unsustainable use of natural resources is directly increasing environmental harm. Therefore, regulation and monitoring mechanisms must be strengthened. Lastly, clean technologies and eco-efficient industrial policies should be adopted to decouple industrial growth from environmental damage. It will not only save the environment but also improve the living standard at the same time.

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