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Associating Economic Growth and Ecological Footprints through Human Capital and Biocapacity in South Asia

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Abstract: The ecological footprint (EF) has been used as an environmental indicator in most of the past research. Due to the complex linkages between economic growth and human development, EF has been inadequately understood in policy making. This research attempts to investigate the impacts of economic growth, human capital, biocapacity, and urbanization on the factors affecting the ecological footprint (EF) of five South Asian countries. To provide empirical evidence, this study utilizes the annual data from 1990 to 2022 for Pakistan, India, Bangladesh, Nepal, and Sri Lanka. The findings confirm the positive contribution of GDP, human capital, biocapacity, and urbanization to EF. The causality analysis shows feedback association between GDP and EF, human capital and EF, and biocapacity and EF.

Keywords: ecological footprints; biocapacity; human development; South Asia



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1. Introduction

For any field or in any project, a significant aspect is its ecological characteristics. Climate change significantly impacts every aspect around the globe in various forms like devastations of wildlife, the fluctuation and rise in sea levels, unpredictable precipitations, a rise in the air and oceanic temperatures, the rapid melting of glaciers, the reduction in the production of agriculture, and even the incompetency of manpower [1–3]. Policymakers and ecological economists should be on the same page for the issue of climate change, which needs to be addressed to reduce the escalating threats associated with it. The immense attention to climate change enriches the insights of economists and policymakers into economic growth's possible effects on the environment, shifting their prototypes from the simple detection of economic growth to concern about ecologically (environmentally) friendly economic growth [4].

Undoubtedly, economic growth can diminish poverty, facilitate the development of essential infrastructure, and enhance the overall quality of life. Nevertheless, the development process has its drawbacks, particularly when prioritizing wealth and prosperity at the expense of the natural environment [5]. The considerable economic progress in the South Asian region has resulted in notable transformations in the overall standard of living. Nevertheless, it is essential to acknowledge that South Asia, despite its pursuit of development, stands as one of the primary contributors to carbon emissions on a global scale. The ecological footprint is a metric used to quantify the impact of human activities on the environment, specifically concerning grazing land, ocean resources, croplands, forest products, built-up land (infrastructure), and carbon emissions. The measurement of land and water required for producing goods and waste assimilation is quantified in global hectares [6]. The ecological footprint is widely regarded in contemporary literature as a comprehensive and holistic measure for assessing the impact of human activities on the natural environment [7,8]. The present study examines the impact of natural resources, human capital, and urbanization on the ecological footprint in the South Asian region

while also considering the influence of economic growth. The study focuses on the time frame spanning from 1990 to 2022. Natural resources encompass valuable assets such as gas, oil, coal, minerals, and forests. These resources are quantified by the percentage of total resources as a function of the Gross Domestic Product (GDP). The topic of natural resources and environmental degradation elicits divergent perspectives and conflicting arguments. One perspective suggests that economic growth, urbanization, and industrialization increase demand for national resource extraction and consumption, leading to environmental unsustainability [9]. The purpose of this study is to provide thorough knowledge of the complex interaction between economic development and ecological footprints in the context of South Asia, concentrating on the crucial roles that human capital and biocapacity play. By evaluating these elements, the study seeks to provide light on the interaction between economic growth and environmental sustainability, giving policymakers, academics, and stakeholders useful information to use in making decisions that strike a balance between local development and ecological preservation. Modern society depends on economic development to raise living standards, spur technical advances, and promote general prosperity. However, given the importance of economic growth in a time of escalating environmental concerns, thorough knowledge of its effects on ecological sustainability is required. The idea of ecological footprints emerges as a key framework for analyzing the environmental cost of economic activity. Ecological footprints offer a measurable indicator of environmental impact by measuring the demand placed on ecosystems and natural resources to support human lifestyles and consumption habits. This metric goes beyond the limited focus on carbon emissions and extends to incorporate more ecological factors, therefore enabling a complete assessment of the ecological burden inherent in economic growth. Human capital, including the collective knowledge, talents, and skills possessed by people, serves as a significant driver of economic progress. Investments in people's education, health, and skill development enable them to make valuable contributions to economic activity, which promotes innovation and productivity improvements. Beyond its financial effects, human capital plays a crucial role in establishing sustainable practices. Populations who have received an education and have acquired new skills are better able to embrace environmentally friendly practices, create and use eco-friendly technology, and promote the shift to resource-efficient sectors. Therefore, human capital serves as a motivator for promoting environmentally conscious attitudes and behaviors in addition to being an engine of economic growth [10].

Conversely, the presence of abundant natural resources has the potential to discourage the consumption of fossil fuels through the reduction in their imports [11]. Moreover, ref. [12] posits that various human activities, such as mining, deforestation, and chainsaw operations, are significant contributors to the degradation of natural resources and the pollution of water, soil, and air. In line with these assertions, the empirical inquiry about the impact of natural resources on environmental sustainability has yet to achieve consensus. Hassan et al. (2018) documented that natural resources have a positive correlation with ecological footprint, although contrasting findings have been reported by [9,13]. The literature concerning the correlation between natural resources and a comprehensive environmental metric such as the ecological footprint is undeniably inadequate. Further research is imperative to advance our understanding and progress toward achieving a sustainable environment.

For centuries, mankind has been bounded by the environment, with their activities like fishing, industry, international trade, and, most importantly agriculture significantly affecting the sea and land. There are conflicting ideologies to address these issues [14]. By not catering to the environmental quality of the country, financial expansion is a major hindrance to income sets and population expansion. The anthropological environmental footprints give us a detailed view of how anthropogenic activities have a communal impact, of how to calculate it using the area of bio-productive land, of the water needed to produce the goods consumed, and of the resulting waste generated. To be precise, it is the effect on the environment due to the anthropogenic activities required for our

living [15]. The ecological footprint describes how anthropogenic activities are affecting the territory [8]. As per the recent literature, the ecological footprint points toward ecological deprivation [7,16–19]. It gives us a detailed view of how the fabrication and depletion of human sources affect ecology [20]. In developing countries like Pakistan, ecological expansion is a major publicized and conventional concern. Many corporations and private organizations in Pakistan do not take seriously how their sources are affecting the ecology and how harmful and dangerous their effects are. Biodiversity is decreasing rapidly due to the increasing population, and the per-capita consumption has increased the ecological footprint of Pakistan. It is an alarming situation for human beings and their habitats that are losing biodiversity, which is causing a growth in ecological footprint. To sustain the ecological footprint, we need to produce a good amount of natural resources. According to an estimation, it will take 1.5 Earths to produce the required number of natural resources. Global climate change, ecological deprivation, hunting and fishing, and loss of habitat are the major concerns that are affecting biodiversity. South Asia is dealing with a major environmental discrepancy, which means it preserves less and consumes more [21]. Biocapacity and population are related to the economy and its ecological footprint [22,23]. It would be helpful to know what the major factors are that are affecting the ecological footprint in Asian countries. These countries have signed the Kyoto agreement with the United Nations and, as per the agreement, it must reduce its pollution to the required levels. A large population is exerting pressure on the land, which means that forests and agricultural land are being urbanized for the sake of living, causing major deforestation in the last two decades [8,24]. Figure 1 shows the trend of EF in South Asian nations.

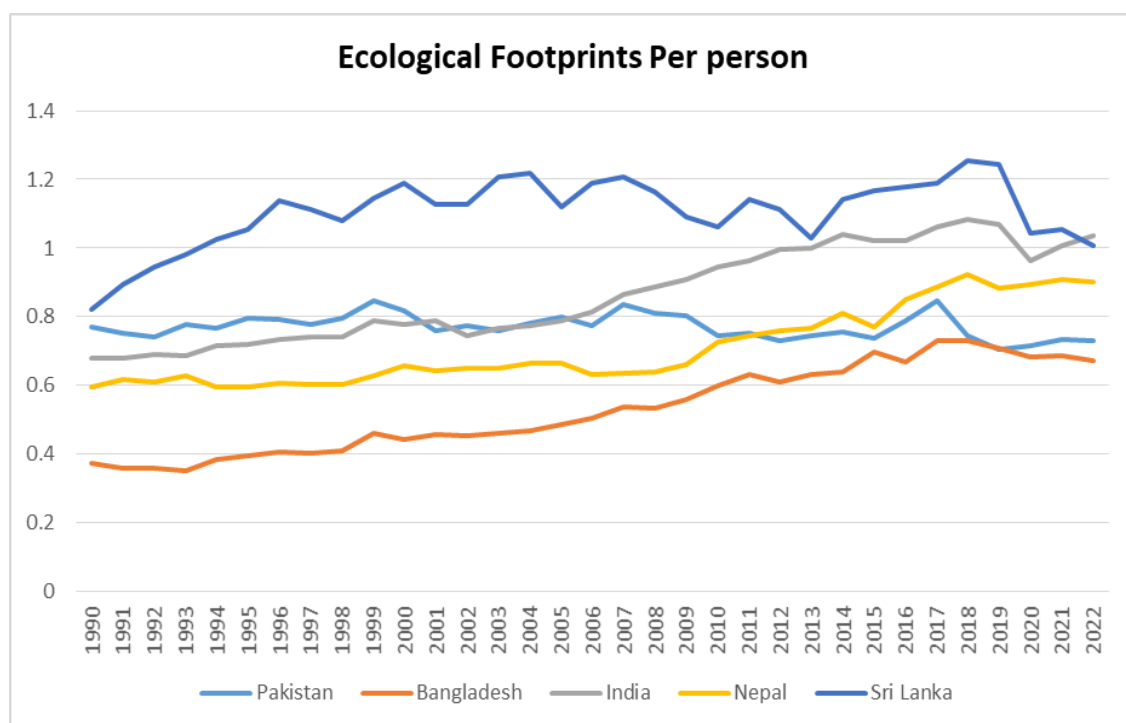


Figure 1. Map of ecological footprints in South Asian countries. (Authors compilation).

This analysis will help in understanding the factors that are affecting South Asia's ecological footprint, it may help in policy implications to diminish the ecological discrepancy of the countries, and it can improve the quality of life. Further, we investigate how much the estimation of the human footprint can be improved by including the variables of economic growth, human capital, biocapacity, and urbanization. The next section of the research is structured as follows. Following the introduction in the first portion, the

literature review is presented in the second section, the results and discussion are presented in the third section, and the study's result is presented in the final section.

2. Literature Review

This section gives us an overview of what has been researched so far and what are the factors that are affecting EF. In the last three decades, numerous research has been conducted on how ecological pollution relates to energy consumption and economic growth. Various factors have been involved in explaining their relationship, which has led to a heated argument among policymakers and ecological economists. In a revolutionary approach, the former found a relation between environmental pollution and economic growth [25], while the Environmental Kuznets Curve (EKC) was first used by [26]. Over the last three decades, extensive work has been performed using the EKC in different countries using time series data analysis and panel data. The ecological growth was next analyzed by [2,27] in Pakistan, it was analyzed in OECD countries by [28,29], while it was analyzed by [30,31] in Singapore and Malaysia, respectively. The interrelationships between human capital, green energy use, and load capacity among the ASEAN nations were investigated by [32]. Parallel to this, the focus of our recent study is on comparable factors in the context of South Asian countries. In addition, Yongchang et al. confirmed the link between ecological footprints and biocapacity among G20 member states. Our research aims to delve into the complex relationship between economic growth and ecological footprints, paying special attention to the roles played by human capital and biocapacity within the South Asian region, a region that has remained comparatively underexplored in recent scholarship.

To indicate ecological pollution, CO₂ emissions are used as a parameter in former studies [1,33–36]. Given the pervasiveness of urbanization and environmental challenges, most research use panel data as their samples, discovering how urbanization influences CO₂ emissions. The impact of a rising population under different income levels on environmental pollution is consistent, while the effect of urbanization on CO₂ emissions is dramatically varied among income groups. The current ecological footprint has caused a new parameter to be used to interpret ecological deprivation [2,12,37–39] just because it gives a better understanding than CO₂ emissions. To measure the degree of sustainability for development, ecological footprint analysis is a more suitable method of the ecological economy [40]. Upon further investigation, it is noted that EF has long-lasting effects on high- and low-middle-revenue countries [41]. Later on, a convergence analysis was conducted on EF and their parameters by [35,42] for OCED countries and multiple countries, respectively. The studies suggested that by using ecological footprint, we can detect the EKC. The ref. [43] found how EF is linked with economic progression. The results of this study suggest that economic progression intensifies the ecological footprint. Previous studies have suggested that income relates to the ecological footprint through the EKC hypothesis [7,17,18,20,44]. But according to [8,16,45], EKC does not exist using the ecological footprint for ecological pressure. To conclude the effect of the ecological footprint, the foreign direct investment on CO₂ emissions and the carbon footprint empirical estimation panel were used by [46]. They found that they are independent of each other. The EKC hypothesis signifies that in many revenue countries, ecological footprint is affected by tourism [17]. This has been confirmed in high-income and upper-middle-income countries. The impact of tourism has been examined as well, and how it affects the ecological footprint and, for that matter, the top ten tourism destinations countries have been studied [47]. A contradictory result has been observed, agreeing with the panel data analysis in that tourism negatively impacts ecological footprint. To determine the effect of Foreign Direct Investment (FDI) on ecological footprint, and considering its negative effect, a dataset of 20 countries was used by [46] for their study. In recent times, for newly industrialized countries, several parameters of ecological footprint have been investigated [12]. A U-shaped relation has been found between ecological footprint and income. In Belt and Road Initiative (BRI) countries, a rise in ecological footprint has been witnessed with the increase in economic expansion [48]. By forming the EKC, how ecological footprint increases naturally has been studied by [49].

After examining past research, it is evident that no study has been conducted so far that investigated the effects of human capital and biocapacity on EF in South Asian countries. Therefore, this research fills this gap in the literature to present some important policy implications to achieve sustainable development in South Asian countries.

3. Data and Estimated Model

The term “Ecological Footprint” (EF) refers to the amount of land and water needed to meet the energy and material needs of a given population forever. This includes both the land area and the water area needed to treat the waste produced by that population. The measurement of ecological footprints is also connected to biocapacity or biologically productive area. While biocapacity relates to endless supply, ecological footprints represent ongoing need. Depending on factors like population, per-capita consumption, production efficiency, and productivity, ecological footprint and biocapacity estimates change from year to year. This research utilizes annual data from 1990 to 2022 for five South Asian countries. EF is an attractive term to people, measured through land yield recommendations. Land and sea yields are recommended as biocapacity. The data of EF and biocapacity are obtained from Global Footprint networks. Economic growth is in constant 2010 USD, obtained from world data indicators. Human capital data are obtained from Penn world tables.

1. The data for the biocapacity variable are derived from the “Global Footprint Network”.
2. The data for Ecological Footprints are sourced from “WDI” world data indicators.
3. Economic Growth data are also derived from “WDI”.
4. Data for the human capital variable are sourced from “Pen World Tables”.
5. Urbanization data are derived from “WDI” world data indicators.

This is the variable data justification and source from where the data are derived (see Table 1).

Table 1. Variable and sources.

Parameters	Symbol	Sources
Ecological footprint	EF	Global footprint network
Biocapacity	BIO	Global footprint network
Economic Growth	G	World Bank
Human capital	HC	Penn World Tables
Urbanization	URB	World Bank

3.1. Model Specifications

This work attempts to investigate the impacts of human capital, GDP, and biocapacity on EF in five South Asian countries. The empirical representation of the equation is as follows:

$$\ln EF_t = \beta_0 + \beta_1 BIOC_t + \beta_2 HC_t + \beta_3 G_t + \beta_4 G_t^2 + \beta_5 URB_t \epsilon_t \quad (1)$$

where refers to $\ln EF_t$; $\ln BIOC_t$ refers to biocapacity, which is a proxy to measure environmental degradation; $\ln HC_t$ represents human capital; $\ln G_t$ represents economic growth; t is the time frame; and ϵ_t shows stochastic error term.

By following [50], this research took the income-ecological nexus for many reasons. EF not only measures environmental pollution due to economic activities but also considers resource depletion due to economic growth. Because activities in manufacturing may not be the most harmful, footprint measures consider both the direct consumption and production effect. Humans are the most threatening creatures for the degradation of environmental quality [50]. The index of human capital provides information about the enrolment in education, which provides information regarding human capital. The attainment of education is important for people if they are undergoing environmental

problems [20]. The insertion of biocapacity is important because it provides information about the total productivity of the available land, which is important to measure EF. If the EF exceeds the available biocapacity, it will create sustainability problems [51]. Biocapacity can sway the association of economic growth and EF. Therefore, structural change in any sector will affect the other sectors and can create sustainable problems for any country [52].

We also want to discover how urbanization affects the relationship between environmental footprint and human capital. As a result, we include the interaction term of urbanization and human capital in the basic model. It should be noted that the moderating influence of urbanization may also be non-linear. The urbanization interaction model is shown as follows:

$$\ln ef_{it} = \beta_0 + \beta_1 \ln hc_{it} + \beta_2 \ln hc_{it}^2 + \beta_3 \ln pgdp_{it} + \beta_4 \ln pgdp_{it}^2 + \beta_5 \ln urban_{it} + \beta_6 \ln eu_{it} + \beta_7 \ln fdi_{it} + \beta_8 \ln hc_{it} \times \ln URB_{it} + \varepsilon_{it} \quad (2)$$

where $\ln hc_{it}$ and $\ln urb_{it}$ denote the interaction term of human capital and urbanization, respectively, which has been decentralized. We can find the marginal influence of $\ln hc_{it}$ on $\ln ef_{it}$ by calculating the first-order partial derivative of Equation (2).

3.2. Methodology

The significance of biocapacity as a crucial variable within the complex framework of ecological footprints cannot be overemphasized. At its essence, biocapacity represents the limited capacity of the Earth to provide resources and assimilate waste resulting from human activities. It serves as an indicator of the sustainability of our evolutionary path. The relevance of this phenomenon is heightened as it becomes entwined with a range of dependent factors, hence enhancing its pivotal function as a cornerstone of environmental stewardship. The importance of human capital, when considered with ecological footprints, is a framework in which expenditures in education, skills, and knowledge extend beyond traditional economic benefits. The device in question plays a crucial role in guiding countries toward paths of enlightened progress, by harmonizing economic ambitions with ecological necessities. In the face of intricate environmental issues, the development of human resources arises as a significant factor in promoting advancement and facilitating the creation of a sustainable and balanced future. This future entails the coexistence of prosperity and the preservation of the Earth's fragile ecosystems. The impact of economic expansion on ecological footprints is mediated via its effect on consumption patterns and resource needs, ultimately leading to improvements in living standards and technological advancement. The significance of this nexus becomes more apparent when examining the shift toward more environmentally sustainable economies. An expanding economy facilitates the allocation of resources required for the exploration, advancement, and use of sustainable technologies, hence reducing ecological footprints via the promotion of cleaner industrial methods and the adoption of renewable energy sources. In addition, the rate and characteristics of economic development have a significant effect on the extent of environmental consequences. This underscores the significance of growth approaches that prioritize the efficient use of resources and the separation of economic expansion from excessive resource utilization. We choose to explore the relationship between ecological footprints by focusing on the significance of biocapacity, human capital, and economic development.

We use a six-stage analysis to check for a lasting connection. First, we look to see whether our panel data exhibit a cross-sectional dependency. The cross-sectional dependency test is helpful for avoiding skewed findings. The LM (Lagrange Multiplier) test proposed by [53] and the CD (cross-sectional dependency) test proposed by [54] are therefore used in this investigation. The equations for these tests are as follows:

$$LM = T \sum_{i=1}^{n-1} \sum_{j=i+1}^n \partial_{ij}^t$$

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{n-1} \sum_{j=i+1}^n \partial_{ij}^t \right)$$

where T is the time interval and N is the total number of X-rays. The pairwise error correlation between i and j is denoted by ∂_{ij}^t . We perform a slope homogeneity test to verify the slope phenomena after analyzing the cross-sectional dependency. Unreliable findings may be produced if there is data uniformity among the panel nations [55]. The equations for slope homogeneity tests of $\tilde{\Delta}$ and $\tilde{\Delta}_{adj}$ are as follows:

$$\tilde{\Delta} = \sqrt{N} \left(\frac{N^{-1}\tilde{S} - K}{\sqrt{2K}} \right)$$

$$\tilde{\Delta}_{adj} = \sqrt{N} \left(\frac{N^{-1}\tilde{S} - E(\tilde{Z}_{iT})}{\sqrt{\text{var}(\tilde{Z}_{iT})}} \right)$$

where $E(\tilde{Z}_{iT}) = K$ and $\text{var}(\tilde{Z}_{iT}) = 2K(T - K - 1)/(T + 1)$. The modified test of $\tilde{S}$ can be applied by following the equation as follows:

$$\tilde{S} = \sum_{i=1}^n \left(\hat{\gamma}_i - \tilde{\gamma}_{WFE} \right) \frac{Y_i' M_T X_i}{\tilde{\sigma}_i^2} \left(\hat{\gamma}_i - \tilde{\gamma}_{WFE} \right)$$

where $\hat{\gamma}_i$ represents the value of the pooled OLS test for the individual unit. $\tilde{\gamma}_{WFE}$ shows the weighted pooled estimator and M_T refers to the identity matrix. In this equation, S and K represent the number of years, while Z is the slope coefficient.

Once the assessment of slope homogeneity has been completed, the subsequent step involves examining the order of integration among the variables. This is crucial as the presence of a unit root in the time series can lead to spurious outcomes. Two types of unit root tests are employed to assess the stationarity characteristics of the variables. Consequently, the data are subjected to a series of first-generation unit root tests [56,57], as well as a series of second-generation unit root tests. If the unit root tests indicate that the order of integration is at level $I(0)$, it is appropriate to use simple regression with ordinary least squares (OLS) [58–60]. However, if the variables are co-integrated at the first difference, it is necessary to examine the presence of co-integration among the variables. In this study, we employ the test from [61] as an alternative to the co-integration techniques utilized in previous research [58–60]. The [61] test takes into account the presence of cross-sectional dependence among the time series.

Following the establishment of co-integration among the estimated variables, we proceed to the estimation of the long-run coefficients. In order to achieve our objective, we implement the fully modified ordinary least square (FMOLS) and dynamic least square (DOLS) methodologies. The equations pertaining to these tests are as follows:

$$\hat{\gamma}_{FMOLS} = \left[N^{-1} \sum_{i=1}^N \left(\sum_{t=1}^T U_{it} - \bar{U}_i \right)^2 \right]^{-1} \times \left[\left(\sum_{t=1}^T U_{it} - \bar{U}_i \right) \hat{S}_{it} - T \Delta_{\epsilon\mu} \right]$$

$$\hat{\gamma}_{DOLS} = \left[N^{-1} \sum_{i=1}^N \left(\sum_{t=1}^T C_{it} C'_{it} \right) \right]^{-1} \left(\sum_{t=1}^T C_{it} C'_{it} \right)$$

In the given equation, U and C are both coefficients. This study employs the fully modified ordinary least squares (FMOLS) and ordinary least squares (DOLS) methodologies to estimate the long-run coefficients. The utilization of these tests in the field of literature is extensive due to their ability to address issues related to autocorrelations and endogeneity, thereby facilitating the identification of causal relationships between variables. Consequently, we employ these tests in our study. The efficiency of this test is attributed to its ability to eliminate the issue of confounding variables in the data (see Tables 2 and 3).

Table 2. LLC (Levin–Lin–Chu) and IPS (Im–Pesaran–Shin) unit root tests.

Variable	Levin–Lin–Chu Unit Root Test		Im–Pesaran–Shin	
	At Level	1st Difference	At Level	1st Difference
$\ln EF_t$	−2.18 **	−1.85 **	−0.57	−7.47 ***
$\ln BIOC_t$	14.40	−9.33 ***	−0.43	−2.43 ***
$\ln G_t$	10.13	−8.88 ***	−0.94	−3.74 ***
$\ln URB_t$	−0.99	−9.81 ***	−0.99	−4.08 ***
$\ln HC_t$	5.40	−12.59 ***	0.12	−8.90 ***

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

Table 3. CADF (covariate-augmented Dickey–Fuller test) and CIPS (cross-sectional augmented Im–Pesaran–Shin) unit root tests.

Variable	CADF Unit Root Test		CIPS Test	
	At Level	1st Difference	At Level	1st Difference
$\ln EF_t$	−1.87	−2.53 **	−2.50	−5.40 ***
$\ln BIOC_t$	−2.76	−4.52 ***	−3.31 ***	−5.72 ***
$\ln G_t$	−3.51 ***	−4.84 ***	−3.62 **	−5.40 ***
$\ln URB_t$	−3.12 **	−2.35 *	−1.41	−2.46 **
$\ln HC_t$	−1.45	−4.22 **	0.47	−2.53 **

***, **, and * show the significance level at 1%, 5%, and 10% respectively.

Multicollinearity can produce misleading outcomes by lowering dependable probability results and increasing assurance intervals. Therefore, this study examines how closely the independent variables are related. The variance inflation factors (VIFs), which are shown in Table 4, are used to test the multicollinearity. The findings show that our models do not significantly display multicollinearity, because the average VIF is below the cutoff of 5.

Table 4. VIF test results.

Variable	VIF	1/VIF
LEF	2.101	0.310
LURB	1.090	0.290
LG	2.653	0.401
LG2	2.216	0.201
Lbioc	2.906	0.402
Mean VIF	1.400	----

Next, the CD test, slope test, Westerlund test, FMOLS and DOLS tests, and causality tests are applied in Tables 5–9 respectively.

Table 5. Cross-sectional dependence test.

	lnEF	lnG	lnURB	lnBIOC	lnHC
LM test	289.91 *** (0.00)	289.88 *** (0.00)	290.84 *** (0.00)	289.91 *** (0.00)	251.04 *** (0.00)
CD test	17.02 *** (0.00)	17.04 *** (0.00)	17.01 *** (0.00)	17.02 *** (0.00)	15.81 *** (0.00)

*** show the significance level at 1%.

Table 6. Slope homogeneity.

Tests	LM Stats	Prob
$\tilde{\Delta}$	3.41 ***	0.001
$\Delta_{adj}^{\sim}$	1.74 ***	0.000

*** show the significance level at 1%.

Table 7. Westerlund test.

Stats	Values	Z-Value	Prob	Robust Prob
G_t	−1.33	3.003	0.000	0.700
G_a	−3.51 ***	3.033	0.000	0.000
P_t	−1.54	3.017	0.000	0.055
P_a	−0.67 ***	2.040	0.000	0.000

*** show the significance level at 1%.

Table 8. FMOLS and DOLS test results.

Variables	FMOLS	Prob	DOLS	Prob
lnBIOC	0.033 ***	0.000	0.031 ***	0.000
lnHC	0.041 ***	0.000	0.049 ***	0.003
lnG	−0.086 ***	0.000	−0.078 ***	0.000
lnG ²	0.008 ***	0.000	0.007 ***	0.000
lnURB	0.096 ***	0.000	0.096 ***	0.000

*** show the significance level at 1%.

Table 9. Causality test results.

Null Hypothesis	W-Stat.	Zbar-Stat.	Prob
BIOC → EF	5.64 ***	3.16	0.00
EF → BIOC	6.70 ***	4.13	0.00
G → EF	4.96 **	2.53	0.01
EF → G	5.59 ***	3.12	0.00
HC → EF	4.77 **	2.36	0.01
EF → HC	5.71 ***	3.23	0.00
URB → EF	3.17	0.89	0.36
EF → URB	3.65	1.34	0.17

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

4. Results and Discussion

In this section, we start by discussing the results of the cross-sectional dependence test. According to Table 4, the CD test and LM test results confirm the existence of cross-sectional dependence among the variables. To test the problem of slope homogeneity, we perform

the test using [62] in Table 6. The significant probability value rejects the null hypothesis of slope homogeneity in our panel data. We perform two sets of unit root tests to check stationarity among the time series. In this regard, first-generation and second-generation unit root tests are applied to verify the test results. The unit root tests show that most of the variables of EF, biocapacity, human capital, GDP, and urbanization are integrated at the first difference $I(1)$.

We apply the Westerlund co-integration test to check the existence of co-integration. The significant probability values reject the null hypothesis of no co-integration among the estimated variables. The existence of co-integration in our model allows us to perform further tests for long-run coefficients. It is important to mention that before our econometric calculations, we convert our time series to their logarithmic form for robust calculations. Table 8 shows the coefficient values of FMOLS and DOLS tests. It can be seen that both tests show similar results.

First, our findings invalidate the EKC in South Asian countries. More economic growth will enhance the EF in South Asian countries. These findings are explainable in the context of South Asia. South Asia consists of developing countries, which are expanding their industrial production. These countries may overlook environmental quality in expanding economic activities. In these countries, people's awareness of environmental quality is not so good. Therefore, after achieving a certain level of economic prosperity, people will not care about their environment. Our findings are consistent with [63,64] but inconsistent with [20,65].

The coefficient value of biocapacity is positively correlated with EF, suggesting that biocapacity is degrading the environment. This condition is suitable for any country whose sources are sufficient to improve EF. A high level of biocapacity can reduce natural resources, but when biocapacity exceeds EF in any area, that area's sources become sustainable. The proper management of production units to reduce resource depletion further improves the environment with more biocapacity. Human capital is positively affecting EF, suggesting that human capital is affecting environmental quality. This result indicates that high school education is not giving sufficient environmental awareness to people. According to the Paris agreement 2017, education is compulsory to mitigate environmental problems. The coefficient value of urbanization is also contributing to more environmental degradation. Urbanization leads to more utilization of land area with an additional infrastructure burden.

4.1. Granger Causality Test

The direction of causal effect will assist policymakers to formulate sound planning. Therefore, the next step is to analyze the causality among EF, biocapacity, human capital, GDP, and urbanization. The statement of a reciprocal relationship between biocapacity and ecological footprint (EF) represents a complex and essential paradigm within the field of sustainability dynamics. The bidirectional link mentioned above indicates that changes in the natural ability of ecosystems to provide resources and withstand human influences have a significant impact on the measurement of interactions between humans and the environment. Hence, every alteration, whether it is an increase or decrease, in biocapacity has a cascading impact that directly affects the related assessment of ecological footprint. When the biocapacity of the Earth is increased by activities such as reforestation, habitat restoration, or responsible resource management, it enhances the Earth's ability to regenerate, resulting in a reduction in the ecological footprint. The concept of positive synergy exemplifies a state of peaceful cohabitation in which the demands for resources are effectively balanced by the inherent resilience of nature.

Table 9 shows the results of [66] for South Asian countries. The causality test of ref. [66] provides the reliable direction of causal effect among the variables. There is two-way causality between biocapacity and EF, meaning that any change in biocapacity will affect EF. Moreover, feedback causality exists between economic growth and EF. This finding is in line with [67]. Human capital and EF also have two-way causal links.

4.2. Conclusion and Policy Recommendations

This study investigates the association of EF, biocapacity, human capital, economic growth, and urbanization in five South Asian countries over the period of 1990–2022. We apply several econometric techniques to present empirical evidence including unit root tests and co-integration analysis.

Economic analysis shows that economic growth, human capital, biocapacity, and urbanization have positive effects on EF. These findings confirm that available sources are not sufficient to increase EF in South Asian countries. Moreover, feedback causality exists between human capital and EF, biocapacity and EF, and economic growth, and EF. The economic study highlights a connection in which economic expansion, human capital, biocapacity, and urbanization all have a beneficial impact on the ecological footprint (EF). The convergence of these forces highlights the complex relationship between social progress and its effects on the environment. The presence of investments in human capital with economic expansion serves to augment the adoption of sustainable practices, thus leading to an enhancement in biocapacity. Urbanization, as a component of the process of development, has the potential to enhance resource efficiency and foster technological innovation, so contributing to the augmentation of environmental friendliness. The integration of many factors highlights the complex and multifaceted aspects of EF dynamics, highlighting the need for comprehensive strategies that balance economic development and environmental conservation. The confluence of favorable outcomes identified in the economic study, wherein economic development, human capital, biocapacity, and urbanization together lead to increased ecological footprints (EFs), underscores the need for specific policy actions. In light of the possible environmental stress caused by these variables, it is imperative for policymakers to embrace a comprehensive strategy that effectively reconciles economic growth with the principles of sustainable resource management. The integration of environmental education with investments in human capital is essential in promoting conscientious consumer behaviors. It is essential for urbanization policies to place a high priority on the implementation of environmentally friendly infrastructure and resource-efficient urban design in order to effectively address the possible exacerbation of ecological footprints. In addition, it is essential to prioritize the utilization of biocapacity advancements resulting from sustainable practices as a fundamental aspect of development agendas. This approach will facilitate the establishment of a balanced state between economic advancement and the preservation of ecological systems. The achievement of a balanced and sustainable development trajectory requires the implementation of a comprehensive policy framework that effectively links social ambitions with ecological imperatives.

Our results suggest that policymakers in South Asia have been engaged in increasing the economic growth of the respective countries. In light of our findings, the policymakers need to reform the economic policies of South Asian countries to reduce EF. The rising income in these countries has made the people invest more in properties, which creates an unequal distribution of resources. The population explosion has caused a wide area to be utilized, which has reduced the agricultural land considerably. South Asian countries need to introduce proper management for sustainable urban settlements. The use of agricultural land for urban settlements should be discouraged by implementing strict regulations. The positive effect of human capital and biocapacity on EF also presents some policy recommendations to stop the unsustainable use of resources.

The positive role of human capital on EF suggests that people are not aware of environmental education in South Asian countries. Governments need to start awareness programs to educate human resources about environmental pollution and its contributing factors. Human capital can be a strong weapon to mitigate climatic problems in the most vulnerable regions of the world.

Future Studies. Apart from the contribution of this work, there are some limitations that can be filled by future studies. Upcoming works can include other regions with similar variables for interesting results. Moreover, the interactional role of human capital with other variables can also be studied.

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