https://doi.org/10.52131/joe.2024.0602.0226

iRASD Journal of Economics

Volume 6, Number 2, 2024, Pages 598 – 619

Journal Home Page:
https://journals.internationalrasd.org/index.php/joe

Analyzing the Intricate Nexus of Ecological Footprint, Urbanization & Economic Growth in South Asia: A Panel 2SLS Analysis

Qurat ul Ain[1], Asma Awan[2], Furrukh Bashir[3]

[1] Research Scholar, School of Economics, University of the Punjab, Lahore, Pakistan.
Email: quratulaneshoaib@gmail.com
[2] Assistant Professor, School of Economics, University of the Punjab, Lahore, Pakistan. Email: asma.eco@edu.pk
[3] Assistant Professor, School of Economics, Bahauddin Zakariya University, Multan, Pakistan.
Email: furrukh@bzu.edu.pk

ARTICLE INFO

Article History:
Received: March 22, 2024
Revised: June 27, 2024
Accepted: June 28, 2024
Available Online: June 30, 2024

Keywords:
Ecological Footprint
Urbanization
Economic Growth
South Asia
Panel 2SLS

JEL Classification Codes:
C23, F64, O18, O40, O53

Funding:
This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

ABSTRACT

The depletion of natural resources, environmental degradation, and climate change are critical global concerns. In South Asia, rapid urbanization and economic growth have improved living standards, but they have also exerted significant pressure on the environment. It is crucial to determine interconnectedness and common determinants of these factors to address the environmental challenges effectively and promote sustainable development. This study explores the relationship between environmental degradation, urbanization, and economic growth in five South Asian countries—Bangladesh, Nepal, Pakistan, Sri Lanka, and India, over the period 1994 to 2022. To analyze these connections, this study develops indices for infrastructure and governance using Principal Component Analysis (PCA). Several tests, including the Im, Pesaran, and Shin test and the Fisher and Pesaran Augmented Dickey-Fuller unit root test, are applied to ensure the stationarity of the variables. The Variance Inflation Factor is used to check for multicollinearity, and the Wald coefficient restriction test confirms the presence of simultaneity. Findings from the Panel Two-Stage Least Squares (2SLS) regression indicate a significant one-way positive relationship between economic growth and ecological footprint, suggesting that economic growth leads to an increased environmental impact. Additionally, urbanization shows a direct positive link to both ecological footprint and economic growth, although the reverse effects are not statistically significant. The study also finds that industrialization and infrastructure development significantly contribute to urbanization and environmental degradation. Infrastructure, however, negatively impacts economic growth, while globalization encourages urbanization and reduces environmental harm. Education is found to have a strong negative relationship with urbanization. The study concludes that achieving environmentally conscious economic growth in South Asia requires focusing on sustainable development goals, investing in green infrastructure, adopting eco-friendly industrial practices, and improving the education system in the region.

OPEN ACCESS

Corresponding Author's Email: furrukh@bzu.edu.pk
Citation: Ain, Q. ul, Awan, A., & Bashir, F. (2024). Analyzing the Intricate Nexus of Ecological Footprint, Urbanization & Economic Growth in South Asia: A Panel 2SLS Analysis. *IRASD Journal of Economics*, *6*(2), 598 – 619. https://doi.org/10.52131/joe.2024.0602.0226

1. Introduction

Environmental degradation, urbanization, and economic growth are critical areas of study for understanding the dynamics of modern societies. Ecological footprint, as a measure environmental degradation, indicates the demand placed on natural resources and ecosystem by a population. It calculates the total biologically productive area required to support the consumption pattern of population and absorb their waste. It is metric that measures how much nature we have and how much nature we use (Network, 2020). According to United Nations Habitat report, urbanization refers to the increasing proportion of a population residing in urban areas, leading to expansion and growth of cities. This involves migration of people from rural regions to urban centers, resulting in increased density and development in cities (Report, 2016). Economic growth is defined as the increase in the production of goods and services in an economy over a period. It is typically measured by change in Gross Domestic Product (GDP) at constant price, reflecting the economic expansion and improvement in living standards.

Climate change and environmental degradation, driven by rising pollution, smog, depletion of natural resources, and extreme weather conditions, are critical issues impacting developing and developed nations. These challenges highlight the urgent need for sustainable development practices. The region is highly susceptible to climate change, with rising average temperatures and increasingly erratic rainfall patterns expected to worsen (Mani, Bandyopadhyay, Chonabayashi, & Markandya, 2018). Nations are now adopting policies that minimize environmental harm, promoting sustainability by using eco-friendly equipment and adhering to Sustainable Development Goals to accommodate the growing population's demand while conserving natural resources. For instance, Punjab and Sindh provinces in Pakistan experience intense pollution from large-scale farming (Azhar, Zeeshan, & Fatima, 2019). Research shows that pollution effects often transcend borders; for instance, burning crop residues in India impacts air quality in Pakistan (Yousaf et al., 2021). The ecological footprint, a measure developed by Wackernagel and Rees (1998), provides insight into ecological degradation. India and Pakistan have high ecological footprints, indicating significant environmental impact and strain on natural resources (Sabir, Qayyum, & Majeed, 2020). South Asia's diverse and vulnerable ecosystems, high population density, and rapid urbanization and industrialization exert intense pressure on natural resources, contributing to environmental degradation. The zone's sensitivity to weather alterations and its role in global biodiversity make it critical for studying environmental challenges and their implications. The selected countries are classified as lower-middle-income by the World Development Indicators. Economic growth fuels urbanization, increasing the ecological footprint. However, environmental degradation can hinder economic growth by limiting resources and affecting public health. While economic growth in South Asia has improved living standards, it has also increased global carbon emissions (Mehmood, Aslam, & Javed, 2023). In China, economic growth has improved living standards but also made it the world's largest carbon-emitting economy (Guo, Hu, & Yu, 2019). Environmental degradation and economic growth interrelation include initial degradation due to intense economic activity (scale effect) followed by positive impacts as growth promotes sustainable practices (composition effect) (Qayyum, Sabir, & Anjum, 2021). South Asia's urbanization, driven by factors like modern housing, varying family size, industrial restructuring, urban distribution, and government infrastructure investments, transforms agricultural areas into urban centers. These centers demand substantial energy, essential for maintaining living standards and supporting economic growth (Alam, Murad, Noman, & Ozturk, 2016). The region's reliance on non-renewable energy and its growing population, which makes up a quarter of the world's total, puts immense pressure on natural ecosystems. Intensifying urbanization exacerbates this issue, increasing the ecological footprint (Yousaf et al., 2021).

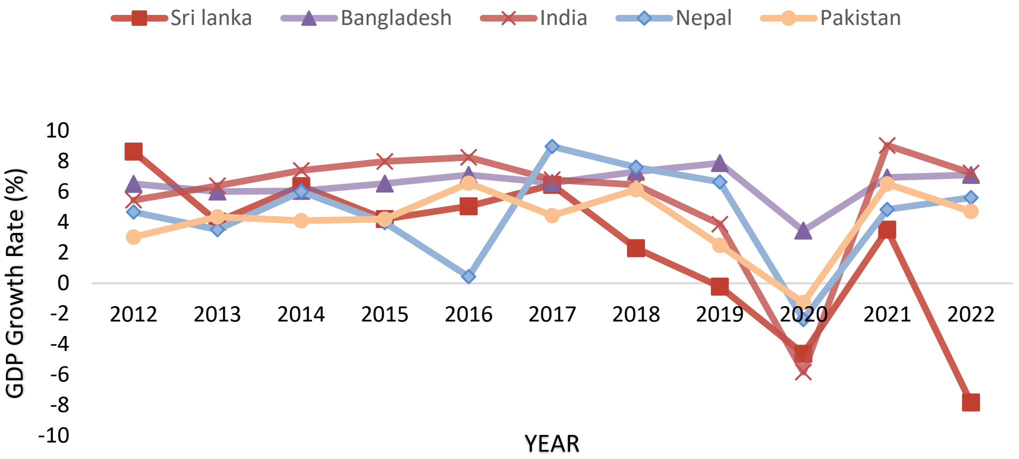

Figure 1: Annual GDP Growth Rates by Country (2012-2022)

The graph in figure 1 depicts the annual GDP growth rates of 5 South Asian countries from 2012 - 2022, highlighting the economic trajectories of these countries. Bangladesh consistently demonstrates strong and stable growth, with rates ranging from around 6% to 8%, peaking at approximately 8.2% in 2016 and 8.2% again in 2019. India follows a similar pattern, with growth rates between 5% and 8%, though it experienced a significant dip to -7.3% in the year 2020 on account of the COVID-19 pandemic, after there was a robust revival to 9.1% in 2021. Nepal's growth fluctuates between 4% and 7%, with a sharp decline to -2.4% in 2020, and a recovery to 4.2% in 2021. Pakistan shows an erratic growth pattern, with rates varying from 1.6% to 5.8%, and a noticeable drop to -0.9% in 2020, followed by a slight recovery to 5.7% in 2021. Sri Lanka, however, exhibits the most volatility, particularly after 2018, with growth falling from around 5% to -3.6% in 2020 and further in 2022 plummeting to -7.8%. The consequences of the COVID-19 pandemic are evident in sharp declines across all countries in 2020, though the recovery in 2021 varies, with Bangladesh and India showing the most significant rebounds. By 2022, Bangladesh and India continue to grow positively, while Sri Lanka faces a severe economic contraction, reflecting divergent economic outcomes within the region.

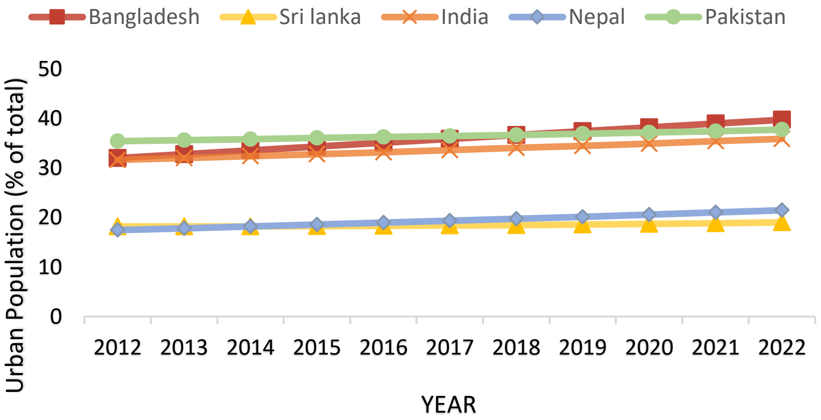

Figure 2: Urbanization by country (2012-2022)

The graph in figure 2 depicts the urbanization trends in Bangladesh, Sri Lanka, India, Nepal, and Pakistan from 2012 to 2022. Pakistan consistently leads in urbanization, with its urban population increasing from around 36% in 2012 to approximately 39% by 2022. Bangladesh shows a significant rise in urbanization, growing from about 29% to nearly 38% over the same period. India also experiences steady urban growth, with its urban population rising from around 31% to 35%. In contrast, Nepal and Sri Lanka display lower levels of urbanization, with Nepal’s rate increasing gradually from about 17% to 20%, while Sri Lanka’s urbanization remains relatively static, hovering around 18% throughout the decade. These trends reflect varying rates of urban growth across the region, with Pakistan and Bangladesh showing the most pronounced increases.

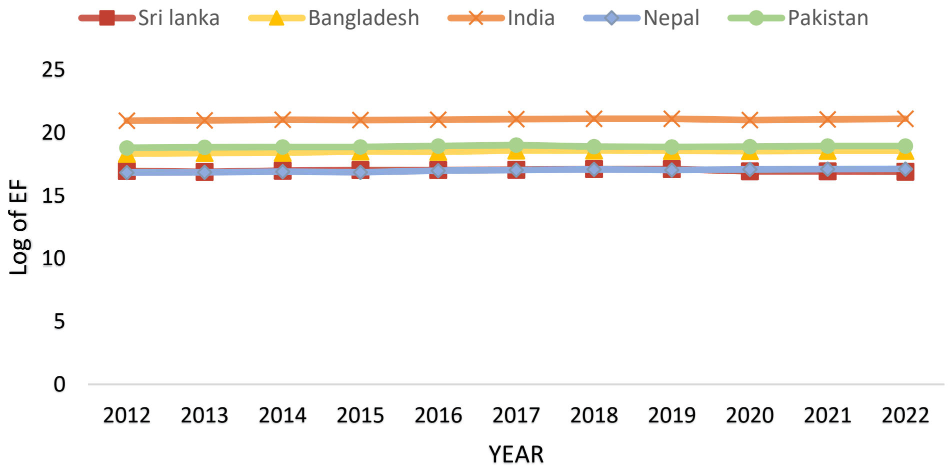

Figure 3: Ecological Footprint by Country (2012-2022)

The graph in figure 3 shows the ecological footprint pattern expressed in logarithmic terms for selected South Asian countries from 2012 to 2022. India exhibits the highest ecological footprint with an index value of around 20 consistently over the period. Other countries (Bangladesh, Sri Lanka, Nepal, and Pakistan) have similar and lower Ecological Footprints; all logarithmically from 15 to 17. The data shows that ecological footprint of these countries is stable over a decade without any major variations, indicating that their environmental impact remained constant during this period.

The significance of this research is the fresh empirical evidence regarding nexus among ecological footprint, urbanization, and economic growth in South Asia. Given that economic growth and urbanization often result in environmental degradation, this research highlights the delicate balance needed to achieve these macroeconomic objectives while minimizing ecological harm. By employing the Panel 2SLS technique, this regional analysis fills a critical gap in existing literature, providing valuable insights for policymakers in the context of South Asia's rapid urbanization and significant environmental challenges.

This study aims to investigate the simultaneous association among economic growth, urbanization, and ecological footprint in South Asian countries from 1994 to 2022. This empirical analysis focuses on bidirectional and feedback relationships.

The research is organized in seven sections. Following the introduction, Section 2 offers a comprehensive review of the theoretical and empirical literature on the subject matter, identifying key findings and research gaps. Section 3 discusses the theoretical and conceptual framework, illustrating the connections among ecological footprint, urbanization, and economic growth. Section 4 covers data, models, and methodology. Section 5 presents findings and discussions using comprehensive tables. The last section provides conclusions and policy suggestions.

2. Literature Review

2.1. Urbanization and Environmental Degradation

Urbanization is a significant driver of environmental pollution, particularly in low- and middle-income countries. Zhao et al. (2006) pointed out that urbanization contributes to environmental problems on a global scale. In low- and middle-income countries, rapid urban population growth presents a major challenge, as it requires significant infrastructure investments and puts a strain on available resources (Henderson, 2010). Urbanization, while driving economic growth and industrialization, has varying impacts based on the quality of infrastructure and institutions in the area (Turok & McGranahan, 2013). It generally exacerbates environmental pollution, particularly in secondary industries, although the tertiary sector may help to mitigate these effects (Hao et al., 2020; Liang & Yang, 2019). In Pakistan, Khan, Teng, Khan, and Khan (2019) observed that urbanization has contrasting effects on CO_2 emissions. Conversely, Hao et al. (2020) demonstrated that urbanization consistently increases pollution in China. Abbasi, Parveen, Khan, and Kamal (2020) identified energy consumption and urbanization as drivers of CO_2 emissions in Asia. Khan and Majeed (2023) identified urbanization and industrialization as key contributors to environmental degradation in Pakistan. Voumik, Mimi, and Raihan (2023) found that urbanization increases CO_2 emissions in the region.

2.2. Economic Growth and Environmental Degradation

Economic growth typically demands increased production, thereby causing higher consumption of fossil fuels and a rise in carbon dioxide emissions (De Vita, Katircioglu, Altinay, Fethi, & Mercan, 2015; Lee & Brahmasrene, 2013). Shahbaz, Sbia, Hamdi, and Ozturk (2014) showed a direct relation between urbanization and CO_2 emissions in the UAE from 1975 to 2011.Salahuddin, Alam, Ozturk, and Sohag (2018) confirmed that economic growth, electricity consumption, and FDI were drivers of CO_2 emissions in Kuwait. In Pakistan, economic growth and industrialization have been found to indirectly harm environmental quality (Ali, Bakhsh, & Yasin, 2019). In South Asia, economic growth frequently occurs at the cost of environmental degradation (Zakaria & Bibi, 2019). Anwar, Younis, and Ullah (2020) found that economic growth and financial development are associated with high CO_2 emissions. Khan, Saleem, Shabbir, and Huobao (2022) found a causal relationship between GDP growth and carbon emissions in South Asia.

2.3. The Role of Ecological Footprint in Measuring Environmental Degradation

CO_2 emission is a commonly used indicator of environmental degradation. It may not fully capture the extent of environmental impact, as it excludes solid waste and depletion of resources, etc. Many studies have used CO_2, SO_2, and NO_X emissions as indicators of pollution (Ali et al., 2019; Anwar et al., 2020; Hao et al., 2020). Keho (2023) suggests that the ecological footprint offers a broader perspective on environmental degradation, as it deals with various dimensions of resource consumption and waste generation Xiang and Chen (2019) projected a rise in the global per capita ecological footprint under business-as-usual scenarios. Xue, Haseeb, Mahmood, Alkhateeb, and Murshed (2021) confirmed that renewable energy reduces ecological footprints in the region. Zhou, Abbasi, Salem, Almulhim, and Alvarado (2022) reported that urbanization was linked to reduced ecological footprints in Pakistan. Keho (2023) identified a sustained relationship in Côte d’Ivoire between urbanization, income, and ecological footprint.

2.4. Relationships among Urbanization, Economic Growth, and Environmental Degradation

Urbanization and economic growth are crucial for development, yet they often bring about significant environmental pollution challenges. The study by Tao, Zheng, and Lianjun (2008) analyzing data from 29 Chinese provinces between 1985 and 2005 identified an inverse U-shaped relationship between GDPs per capita and pollutants such as waste gas, water waste, and solid waste. Similarly, Fodha and Zaghdoud (2010) examined Tunisia's data from 1961 to

2004 and found a non-linear association between GDP and SO_2 discharge, forming an inverted U-shaped curve, while CO_2 emissions continued to rise with GDP. (Jiang, Lin, & Zhuang, 2011) confirmed this Environmental Kuznets Curve (EKC) for Chinese provinces, where pollution declined after GDP per capita reached specific thresholds, with higher thresholds observed in more developed coastal regions. Liang and Yang (2019) identified an inverted U-shaped relationship between urbanization, economic growth, and environmental pollution in China. Ahmed, Asghar, Malik, and Nawaz (2020) suggested that urbanization and human capital could alleviate environmental degradation in China. Anwar et al. (2020) found that urbanization significantly impacts CO_2 emissions in Far East Asian countries. Sharma, Sinha, and Kautish (2021) linked economic activities to ecological footprints in developing Asian nations. Mughal et al. (2022) connected technological innovation to increased environmental degradation in South Asia.

Numerous studies have examined the individual factors of ecological footprint, urbanization, and economic growth across different regions using various econometric methodologies. While CO_2 emission is a common measure of environmental degradation, that may not fully capture its extent, leading some researchers to adopt ecological footprint as an alternative metric. In South Asia, there has been relatively limited research utilizing the ecological footprint. Moreover, a comprehensive framework analyzing the bidirectional relationship among ecological footprint, urbanization, and economic growth in South Asia is notably lacking. This research seeks to fill that gap by exploring these interconnections using three structural equations, thereby contributing to the existing literature.

3. Theoretical and Conceptual Framework

The theoretical foundation of this research is based on renowned economic theories that interpret the interconnected relationship among environmental degradation, urbanization and economic growth, providing rationale for the conceptual framework. First theory that posit relationship between economic growth and environmental degradation is Environmental Kuznets Curve (EKC) Hypothesis. According to EKC hypothesis, as economy grows, the environmental degradation increases but to certain limit, and economic growth leads to technological advancement, shift towards cleaner industries, thus decreasing the ecological harm. This theory underpins the bidirectional relationship between economic growth and ecological footprint.

Urbanization is closely linked with economic growth and environmental impact. Modernization theory provide foundation to the relation between urbanization and economic growth. According to this theory, a nations ability to transition between rural and urban areas is solely determined by their economic development. It is major cause of increased industrial activities and infrastructure development, which can boost ecological footprint, increasing dependence upon natural resources.

Solow Growth model propose that economic growth rate is increased by the accumulation of labor force and capital. Urban areas are the hub of physical capital, human capital in the form of labor and intellectual capital. So, urbanization is driver of the economic growth within this model. However, the unchecked use of resources for the capital formation in urban areas, drive significant environmental implications through increased ecological footprint.

The theoretical framework provides solid foundation for the conceptual framework. The conceptual framework in figure 4 present a visual map of the core dependent variables, their interdependence, and various key determinants. It indicates bidirectional association between economic growth and ecological footprint as per literature on the subject matter. Similarly, there is a bidirectional causal relation between urbanization and ecological footprint and same is reported in case of urbanization and economic growth.

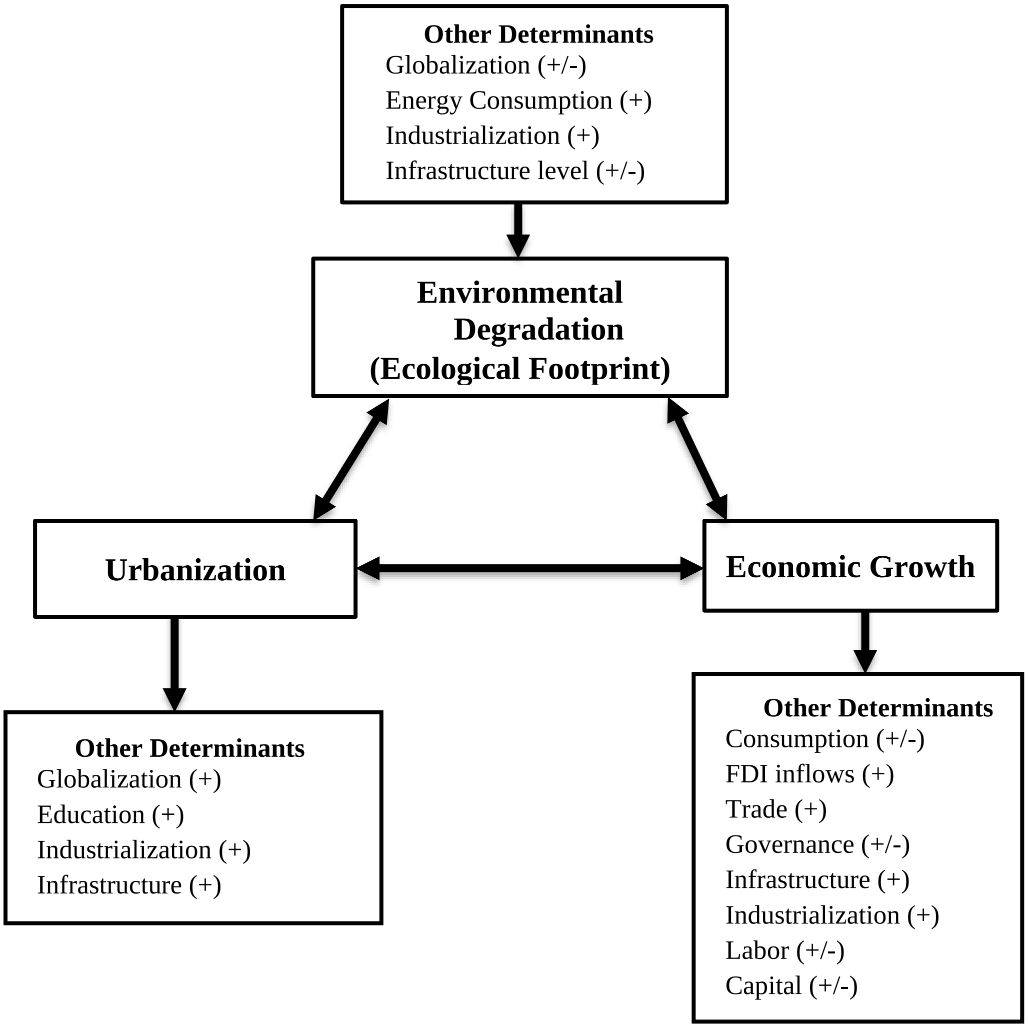

Figure 4: Ecological Footprint, Urbanization and Economic Growth Interlinkages

The figure 4 illustrates the relation of ecological footprint with its key determinants drive from the literature. Industry, infrastructure, and energy use positively effects the ecological footprint, but globalization can promote or mitigate it (Alam, 2010). Naeem, Appiah, Karim, and Yarovaya (2023); Primbetova, Sharipov, Allayarov, and Haq (2022); Shahzadi, Yaseen, and Anwar (2019) and Eweade, Akadiri, Olusoga, and Bamidele (2024) found that economic growth, urban population, international trade, infrastructure, and energy use contributes to ecological footprint. Infrastructure can mitigate the ecological footprint, having a constructive effect on the environment Munaf and Amar (2024), but Awad, Mallek, Ozturk, and Abdalla (2023) claimed that infrastructure development might have adverse effects on environmental quality.

Urbanization through modernization cause low economic growth in developing countries in contrast to developed countries (Shabu, 2010). Economic growth is closely related to infrastructure (Sharif & Tauqir, 2021). These industries have undergone a major transformation from rural industries to trade and services, which have become the key driver of economic growth. Increasing industrialization poses a threat to environmental quality. Per capita expenditure contributes positively to economic growth (Liang & Yang, 2019). Corruption reduces the confidence of entrepreneurs and the balance between resources and income, thus more or less hindering economic growth (d’Agostino, Dunne, & Pieroni, 2016). Labor shows varying effect on the economic growth. Labor force participation negatively affects economic growth in South Asia, whereas it has a positive effect in West Asia (Amna Intisar, Yaseen, Kousar, Usman, & Makhdum, 2020). Haque, Kibria, Selim, and Smrity (2019) found that both labor and capital have a detrimental impact on economic development. Wahyudi (2024) assessed the effectiveness of employment in the construction sector. Research by Wiranatakusuma and Zakaria (2024) and Hashim, Shahlan, and Rambeli (2024) indicated that capital formation and trade positively influence economic growth. Foreign direct investment boosts GDP per capita (Amna Intisar et al., 2020). Azam, Uddin, Khan, and Tariq (2022) showed that industrialization and globalization drive urbanization. According to Choy and Li (2017), higher education accelerates growth. Hence, all the factors considered contribute positively to urban development.

4. Data, Simultaneous Model and Methodology

4.1. Data

This study empirically evaluates the simultaneous association among ecological footprint, urbanization and economic growth across five South Asian countries from 1994-2022 (annually). The countries included in the analysis are Bangladesh, India, Nepal, Pakistan and Sri Lanka. The period from 1994 to 2022 is selected due to availability of consistent data across variables of interest. It provides a sufficient span of nearly three decades for long term analysis.

Table 1
Description of Variables

	Variables	Symbols	Proxies	Units	Sources
Dependent Variables	Environmental Degradation	Inef_{it}	Ecological Footprint	Gha (log value)	GFN
	Urbanization	URB_{it}	Urban population as % of total population	Percentage	WDI
	Economic Growth	GDP_{it}	Real GDP (Constant 2015) growth	Percentage	WDI
Explanatory Variables	Industrialization	INDM_{it}	Manufacturing, value added	(% of GDP)	WDI
	Infrastructure level	INFRA_{it}	Index constructed using PCA based on four dimensions.	(-1.5 to 2.5)	WDI
	Energy Consumption	ENG_{it}	Energy use	(Metric tons per capita)	WDI
	Globalization Index	Inglob_{it}	Dreher’s globalization	Scale of 100	Dreher’s Dataset
	Education	EDU_{it}	Secondary school enrollment	(% gross)	WDI
	FDI inflows	FDI_{it}	Foreign direct investment, net inflows	(% of GDP)	WDI
	Trade	TRD_{it}	Sum of imports and exports	(% of GDP)	WDI
	Labor	LAB_{it}	Labor Force Participation rate	Percentage	WDI
	Capital	CAP_{it}	Gross Fixed capital formation	(% of GDP)	WDI
	Consumption	CONSU_{it}	Sum of private and government consumption	(% of GDP)	WDI
	Governance Index	GOV_{it}	Index constructed using PCA based on six dimensions	(-2.6 to 2.2)	WGI

Note: A scale of 10 has been added to all index values to account for negative values when taking logs. Dreher's globalization index includes political, economic, and social globalization.

The infrastructure index is based on access to electricity, total natural resource rents, high-technology exports, and mobile cellular subscriptions.

The governance index is constructed using the six dimensions from the WGI: control of corruption, government effectiveness, regulatory quality, rule of law, political stability, and absence of violence/terrorism, and voice and accountability. Both the infrastructure and governance indices are constructed using the PCA technique.

The table 1 provides comprehensive description of all variables in the three structural equations, including their symbols, proxies, units and data sources. The table includes dependent variables such as environmental degradation measured by the ecological footprint in log form, urbanization measured as the urban population as a percentage of the total population and economic growth measured by real GDP growth, constant 2015. Explanatory variables include industrialization, infrastructure level, and energy consumption, labor, capital, consumption among others. Notably, both the infrastructure and governance indices were constructed using the PCA technique.

4.2. Simultaneous Model

To the study the simultaneous interaction among ecological footprint, urbanization and economic growth, three structural equations have been formulated. In this study, environmental degradation, urbanization, and economic growth are dependent variables. The three structural equations are:

$$\mathrm{lnef}_{1it} = \alpha_1 + \alpha_2\mathrm{URB}_{it} + \alpha_3\mathrm{GDP}_{it} + \beta_1\mathrm{INDM}_{it} + \beta_2\mathrm{INFRA}_{it} + \beta_3\mathrm{ENG}_{it} + \beta_4\mathrm{lnglob}_{it} + \varepsilon_{1it} \tag{1}$$

$$\mathrm{URB}_{2it} = \alpha_2 + \alpha_1\mathrm{lnef}_{it} + \alpha_3\mathrm{GDP}_{it} + \beta_1\mathrm{INDM}_{it} + \beta_2\mathrm{INFRA}_{it} + \beta_4\mathrm{lnglob}_{it} + \beta_5\mathrm{EDU}_{it} + \varepsilon_{2it} \tag{2}$$

$$\begin{aligned}\mathrm{GDP}_{3it} = {} & \alpha_3 + \alpha_1\mathrm{lnef}_{it} + \alpha_2\mathrm{URB}_{it} + \beta_1\mathrm{INDM}_{it} + \beta_2\mathrm{INFRA}_{it} + \beta_6\mathrm{FDI}_{it} + \beta_7\mathrm{TRD}_{it} + \beta_8\mathrm{LAB}_{it} + \beta_9\mathrm{CAP}_{it} + \\ & \beta_{10}\mathrm{CONSU}_{it} + \beta_{11}\mathrm{GOV}_{it} + \varepsilon_{3it}\end{aligned} \tag{3}$$

In the above equations, $\alpha_1, \alpha_2\ and\ \alpha_3$ are intercepts of the equation of ecological footprint, urbanization, and economic growth respectively. ε_{it} represents the error term, α's are the coefficients of endogenous variables. $\beta's$ are coefficients of independent variables. ln shows the natural log. The subscript *it* indicates that the variable varies across cross-sectional units *i* and periods *t*. This study includes five cross-sectional units over 28 years.

The first structural equation focuses on the ecological footprint, using it as a surrogate for environmental degradation, reflecting resource consumption and waste production. Industrialization, infrastructure, energy consumption, and globalization have mixed effects, as per the literature. Urbanization is expressed as the urban population percentage. Macroeconomic factors like industrialization, infrastructure, globalization, and education positively impact urbanization. Real GDP growth, is influenced by industrialization, infrastructure, FDI, trade, labor, capital, consumption, and governance. Labor and capital show mixed effects on economic growth while all other variables contribute positively. The infrastructure index and Governance index are constructed using the PCA technique.

4.3. Econometric Methodology

This research employs several pre-estimation tests to ensure data and model reliability. Initially, the Pesaran cross-section dependence test is applied to determine whether the observations within the dataset exhibit dependency, which in turn guides the choice between first-generation and second-generation unit root tests. The Im, Pesaran, and Shin test, along with the Fisher-Augmented Dickey-Fuller test, are used to check the stationarity of the variables. Correlation analysis examines relationships between endogenous variables and their determinants, while the VIF addresses multicollinearity. Hausman specification test detects simultaneity, which is further validated through the Wald restriction test, ensuring the robustness of the model against simultaneity bias, and identification tests confirm unique parameter estimation. In this study, a three-equation simultaneous model is employed to capture the interdependencies among the variables. The Ordinary Least Squares (OLS) method is unsuitable due to the presence of simultaneity, where explanatory variables are endogenous and correlated with the error term. This leads to biased and inconsistent estimates. To address this, the Panel Two-Stage Least Squares (2SLS) method is used, which provides consistent estimates by using instrumental variables to account for endogeneity (Liang & Yang, 2019). The weak identification test validates the strength of the instruments using the Cragg-Donald Wald F statistic against Stock-Yogo critical values. In constructing the indices for governance and infrastructure, the Principal Component Analysis (PCA) technique is employed. This method reduces the dimensionality of the data while preserving most of its variability. By converting the original variables into a new set of uncorrelated variables called principal components, PCA simplifies the complexity of high-dimensional data, ensuring that the indices accurately reflect the underlying dimensions of governance and infrastructure within the selected South Asian countries.

5. Results and Discussion

This section presents and thoroughly discusses the empirical results of the simultaneous equation model involving Ecological Footprint, Urbanization, and Economic Growth. The results reported include descriptive statistics, unit root test, correlation test, test of simultaneity, 2SLS estimation, and diagnostic tests.

Table 2
Descriptive Statistics for Key Variables

Variables	Observations	Mean	Std. dev	Min	Max
lnef_{it}	145	18.277	1.477	16.377	21.116
URB_{it}	145	25.817	7.985	10.433	39.711
GDP_{it}	145	4.952	2.666	-7.823	9.050
INDM_{it}	145	13.731	4.229	4.474	21.764
INFRA_{it}	145	5	1.000	4.0156	7.153
ENG_{it}	145	395.133	131.820	126.404	695.759
lnglob_{it}	145	3.871	.191	3.383	4.223
EDU_{it}	145	58.052	23.933	13.853	96.296
FDI_{it}	145	0.910	.689	-.098	3.620
TRD_{it}	145	42.887	15.555	20.078	88.636
LAB_{it}	145	54.345	23.276	-26.69	93
CAP_{it}	145	23.907	5.988	12.824	35.812
CONSU_{it}	145	81.623	8.206	65.622	96.357
GOV_{it}	145	4.996	.980	2.322	7.246

Note: Author's own estimates using STATA 17.0

Table 2 presents the descriptive statistics for the variables examined. The mean of ecological footprint is 18.277 gha with a standard deviation of 1.477 gha, reflecting a relatively high and consistent environmental impact across the dataset. Urbanization has a mean of 25.817% and a standard deviation of 7.985%, reflecting substantial variability in urbanization levels among regions. The mean of economic growth is 4.952% with a standard deviation of 2.666%, suggesting moderate average growth with considerable variation across observations. These statistics underscore the significant disparities in ecological footprint, urbanization, and economic growth across South Asia.

Table 3 reveals correlation results across three equations. In the environmental degradation equation, the ecological footprint has a strong positive correlation with GDP (0.2310) and urbanization (0.7484), and a moderate positive correlation with industrialization (0.3), energy consumption (0.3), and globalization (0.4488). Infrastructure has a weak negative correlation (-0.0101). None of the correlations exceed 0.8, indicating no severe multicollinearity. In the urbanization equation, urbanization is strongly correlated with economic growth (0.121) and ecological footprint (0.7484), and moderately with globalization (0.4683). Education negatively correlates with urbanization (-0.3988). In the economic growth equation, GDP has strong correlations with ecological footprint (0.2310) and urbanization (0.1218), and positive correlations with FDI (0.0977), trade (0.048), labor (0.0402), and capital (0.2746). Consumption shows a strong correlation with GDP (0.2145). There is a nonlinear relationship with governance (0.0706). Infrastructure and globalization positively correlate (0.5701), while trade and labor force negatively correlate (-0.5740). Despite some significant correlations, multicollinearity is not a severe issue, as confirmed by Variance Inflation Factor (VIF) values, all of which are below 10. The authors can provide the results upon request.

Table 3A
Correlation Results Across Three Equations

Equation 1: Environmental Degradation							
Variables	**lnef**	**URB**	**GDP**	**INDM**	**INFRA**	**ENG**	**lnglob**
lnef_{it}	1.000						
URB_{it}	0.748	1.000					
GDP_{it}	0.231	0.121	1.000				
INDM_{it}	0.341	0.346	0.184	1.000			
INFRA_{it}	-0.010	0.153	-0.145	0.045	1.0000		
ENG_{it}	0.3679	0.1189	-0.097	0.009	0.4175	1.0000	
lnglob_{it}	0.4488	0.4683	0.060	0.457	0.5701	0.6888	1.0000

Table 3B
Equation 2: Urbanization

	URB	lnef	GDP	INDM	INFRA	lnglob	UPG	EDU
URB_{it}	1.0000							
lnef_{it}	0.7484	1.000						
GDP_{it}	0.121	0.231	1.000					
INDM_{it}	0.3463	0.3410	0.184	1.0000				
INFRA_{it}	0.1535	-0.010	-0.145	0.0453	1.0000			
lnglob_{it}	0.4683	0.4488	0.060	0.4579	0.5701	1.0000		
EDU_{it}	-0.398	-0.2594	0.017	0.2853	0.5216	0.4621	-0.621	1.000

Table 3C
Equation 3: Economic Growth

	GDP	lnef	URB	INDM	INFRA	FDI	TRD	LAB	CAP	CONSU	GOV
GDP_{it}	1.000										
lnef_{it}	0.231	1.000									
URB_{it}	0.121	0.748	1.000								
INDM_{it}	0.184	0.341	0.346	1.000							
INFRA_{it}	-0.14	-0.01	0.153	0.045	1.000						
FDI_{it}	0.097	0.427	0.315	0.414	0.121	1.000					
TRD_{it}	0.048	-0.44	-0.57	0.057	-0.012	0.255	1.000				
LAB_{it}	0.040	-0.38	-0.63	-0.32	0.095	-0.37	0.310	1.000			
CAP_{it}	0.274	0.229	-0.08	0.274	0.371	0.267	0.258	0.415	1.000		
CONSU_{it}	0.214	-0.54	-0.20	-0.63	-0.137	-0.42	-0.04	0.022	-0.725	1.000	
GOV_{it}	0.070	0.032	0.158	0.011	0.107	0.150	0.254	-0.10	0.1929	-0.0703	1.000

Note: Author's own estimates using STATA 17.0. Correlations greater than 0.8 would indicate severe multicollinearity, but none of the correlations in this table reach that threshold. VIF values are all below 10, indicating that multicollinearity is not a significant issue.

From the results in table 4, Unit root tests ensure that variables are stationary. The Pesaran CD test assesses cross-sectional dependency, guiding the choice between first- and second-generation unit root tests. Im, Pesaran, and Shin tests and the Fisher-Augmented Dickey-Fuller tests are applied to industrialization, trade, governance index, and capital, while second-generation tests, including Pesaran's Cross-sectional Dependence and Augmented Dickey-Fuller tests, are used for other variables. The maximum number of lags is taken as one. Schwarz information criterion and Hannan-Quinn information criterion are considered for lag length. The unit root tests' results from table 4 indicate that all the variables are either stationary at level I(0) or at the first difference I(1) validating the application of the panel 2SLS technique in the presence of simultaneity.

Table 4
Panel Unit Root Test Results

Variables	CD (p)	CD	First-Generation Test				Second-Generation Test			
			IPS		FADF		CIPS		CADF	
			I (0)	I (1)	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
Inef$_{it}$	0.000	D					-2.51**		-0.44	-5.252*
URB$_{it}$	0.000	D					-3.265*		-4.33*	
GDP$_{it}$	0.000	D					-3.134*		-1.40	-7.460*
INDM$_{it}$	0.061	I	0.275	-3.75*	1.081	-5.68*				
INFRA$_{it}$	0.000	D					-2.295	-3.32*	-4.06*	
ENG$_{it}$	0.000	D					-2.49**		-2.58*	
Inglob$_{it}$	0.000	D					-1.976	-4.20*	-1.89*	
EDU$_{it}$	0.000	D					-2.822*		-1.95*	
FDI$_{it}$	0.035	D					-2.960*		-2.24*	
TRD$_{it}$	0.531	I	0.148	-4.809*	-0.408	-6.56*				
LAB$_{it}$	0.001	D					-1.404	-5.49*	1.259	-6.268*
CAP$_{it}$	0.190	I	-1.276	-3.078*	-0.873	-4.92*				
CONSU$_{it}$	0.013	D					-1.519	-5.31*	1.237	-4.404*
GOV$_{it}$	0.708	I	1.207	-7.805*	1.241	-7.08*				

Note: Author's own estimations using STATA 17.0 and D and I shows dependent and independent, respectively. *, **, *** show significance level at 1%, 5% and 10% respectively. CD (p) denotes the probability value of the cross-sectional dependency test.

Table 5
Simultaneity Test Results

Test Statistics	Value	df	P value
Wu-Hausman F-statistic	27.56824	(2, 136)	0.0000
Durbin Chi-square	55.13649	2	0.0000

Note: Author's own estimates using EViews

The Hausman simultaneity test and Wald restriction test is utilized to assess simultaneity and the significance of residuals. As shown in Table 5, the Wu-Hausman F-statistics and Durbin chi-square p-values are below 0.05, indicating significant simultaneity in the model.

Table 6 demonstrates the simultaneous model, estimated using panel two-stage least squares, which includes three equations with reported coefficients, p-values, F values, R-squared, and adjusted R-squared. Results reveal a significant positive one-way relationship between urbanization and the ecological footprint consistent with Ahmed et al. (2020) while the reverse is not significant. Economic growth and the ecological footprint exhibit an asymmetric positive relationship aligns with Uddin, Salahuddin, Alam, and Gow (2017) and Ahmed, Wang, Mahmood, Hafeez, and Ali (2019) and urbanization positively affects economic growth, but not vice versa. In the environmental degradation and urbanization equation, four out of six determinants are significant and six out of ten variables in the equation of economic growth have significant coefficients.

In the environmental degradation equation, the positive significant coefficient of urbanization (0.1448, p = 0.000) at ɑ equal to 5% suggests that higher levels of urbanization are linked to an increased ecological footprint, consistent with (Voumik et al., 2023). However, Rafiq, Rafiq, Salim, and Nielsen (2016), supported by Zhou et al. (2022) for Pakistan, found urbanization's impact on emissions to be insignificant. The results differ from those reported by Danish et al. (2020), who suggested that urbanization in South Asia could improve the environment through enhanced technology and infrastructure. The significant positive coefficient for economic growth (0.4287, p = 0.000) indicates that as GDP rises, the ecological footprint also increases, highlighting the environmental costs of economic expansion, aligns with Quito, del Río-Rama, Álvarez-García, and Durán-Sánchez (2023) and Mughal et al. (2022), who report same conclusion for South Asia. Industrialization shows a significant positive effect (0.0614, p = 0.052) on the ecological footprint, suggesting that advancements in industrial processes or regulations increase environmental deterioration, which aligns with the findings of (Yang & Usman, 2021). Infrastructure development also has an insignificant positive impact (0.0390, p = 0.794) on the ecological footprint, in contrast to (Hussain, Ye, Ye, & Wang, 2021; Hussain, Pal, & Villanthenkodath, 2023). Energy consumption, with a small but significant positive coefficient (0.0081, p = 0.000), indicates that increased energy use marginally increases the ecological footprint, leading to exploitation of natural resources at a higher rate, supports the conclusion of Nathaniel (2021); Rehman et al. (2021) and contrast with (Sharma et al., 2021). Lastly, globalization shows a significant negative effect (-4.3211, p = 0.001) on the ecological footprint, suggesting that global integration may lead to more environmentally friendly practices or technologies being adopted, in contrast with the findings of (Rehman et al., 2021; Yang & Usman, 2021). The constant term is also significant, indicating a substantial baseline level of the ecological footprint when all other factors are controlled for.

The regression results for urbanization reveal several key relationships. The ecological footprint has a statistically insignificant positive relationship (0.5050, p = 0.164) with urbanization, in contrast with the findings of (Liang & Yang, 2019). GDP shows a positive association with urbanization (0.4700, p = 0.072), but at 7% significance level. Industrialization has a significant positive relation (0.583, p = 0.000), implying that higher levels of industrialization are linked with increased urbanization, aligning with the results of (Wong, Lee, Zhao, & Tai, 2022). Infrastructure shows a significant positive relation with urbanization (3.0646, p = 0.000), indicating a strong link between infrastructure development and urban growth. The better infrastructure attracts the population towards the urban cities for better facilities and opportunities. The globalization index has a substantial positive effect on urbanization (18.150, p = 0.000), highlighting the role of globalization in driving urban growth, findings align with those of (Narayana, 2010). Education has a significant negative relationship with urbanization, (-0.2658, p = 0.000), indicating that secondary education attainment lowers urbanization rates but Wan and Min (2023) claimed that investment in education promotes urbanization. The constant term is significantly negative (-63.737, p = 0.000), reflecting underlying factors not captured by the model.

In the equation of economic growth, estimation results show the following key findings. There exists an insignificant positive relation in ecological footprint and economic growth (0.4108, p = 0.328) at selected α = 5%. This implies that, within the scope of this analysis, economic growth can occur independently of the ecological footprint’s size, conforms to the results of (Rahman, Bindu, & Islam, 2018; Uddin, Alam, & Gow, 2016). Urbanization has a significant positive impact on economic growth (0.2139, p = 0.028) consistent with results of (Nguyen & Nguyen, 2018). The urban cities are the hub of economic activities, industries, job opportunities, and business infrastructure. Industrialization shows an insignificant positive effect (0.0658, p = 0.431) on economic growth, aligns with the work of (Ndiaya & Lv, 2018). Infrastructure development also has a negative significant coefficient (-1.3502, p = 0.000), indicating that investments in infrastructure can reduce economic activities, in contrast with the findings of Palei (2015) and (Pradhan & Bagchi, 2013). Foreign direct investment (-0.7048, p = 0.125) has an insignificant negative effect on economic growth. Trade (0.069, p = 0.009) positively and significantly affects economic growth. Labor has an insignificant positive (0.0122, p = 0.444) coefficient for economic growth. Capital has a significant positive coefficient (0.2940, p = 0.000) for economic growth, the higher the investment in physical capital higher the economic growth aligned with the results of (Akpolat, 2014). The coefficient for consumption is positive and significant (0.1563, p = 0.014) suggesting that an increase in consumption increases economic growth. Conversely, governance shows a negative and insignificant effect (-0.4330, p = 0.104) on economic growth, in contrast with the results of (Huang & Ho, 2017).

Table 6
Panel 2SLS Results

Variable	Simultaneous Equation Model Equation 1 lnef	 Equation 2 URB	 Equation 3 GDP
$lnef_{it}$		0.505 (0.164)	0.410 (0.328)
URB_{it}	0.144* (0.000)		0.213* (0.023)
GDP_{it}	0.428* (0.000)	0.470 (0.070)	
$INDM_{it}$	0.061 (0.052)	0.583* (0.000)	0.065 (0.431)
$INFRA_{it}$	0.039 (0.794)	3.064* (0.000)	-1.350* (0.000)
ENG_{it}	0.008* (0.000)		
$lnglob_{it}$	-4.321* (0.001)	18.150* (0.000)	
FDI_{it}			-0.704 (0.125)
TRD_{it}			0.069* (0.009)
EDU_{it}		-0.2658* (0.000)	
LAB_{it}			0.012 (0.444)
CAP_{it}			0.294* (0.000)
$CONSU_{it}$			0.156* (0.017)
GOV_{it}			-0.433 (0.104)
Constant	24.903* (0.000)	-63.737* (0.000)	-22.923* (0.000)
Summary Statistics			
R^2	0.390	0.831	0.265
Adj R^2	0.363	0.823	0.210
F Prob	0.000	0.000	0.000

Source: Author's own estimates using STATA 17.0
Note: *p* < .05. The coefficient of the variable is given first, with the p-value enclosed in parentheses.

Table 7
Weak Identification Test Results

	lnef	URB	GDP
Cragg-Donald Wald F statistics	14.417	14.470	67.414
Stock-Yogo weak ID test critical values			
10% maximal IV size	7.03	7.03	7.03
15% maximal IV size	4.58	4.58	4.58
20% maximal IV size	3.95	3.95	3.95
25% maximal IV size	3.63	3.63	3.63

Note: Author's own estimation using STATA 17.0

According to the results in Table 7, the Cragg-Donald Wald F statistic significantly exceeds the Skeels and Windmeijer (2018) critical values across all three structural equations. So, the instruments in the model are strong.

Table 8
Robustness Check

Equation 1: Environmental Degradation

Variables	Model 1	Model 2	Model 3	Model 4
lnef_{it}	dv	dv	-	-
lncf_{it}	-	-	dv	dv
URB_{it}	0.144*	0.1804*	0.165*	0.202*
GDP_{it}	0.428*	-	0.435*	
GDPC_{it}	-	0.4649*		0.477*
INDM_{it}	0.061**	0.056***	0.078**	0.073**
INFRA_{it}	0.039	-0.091	0.04	-0.088
ENG_{it}	0.008*	0.009*	0.008*	0.009*
lnglob_{it}	-4.321*	-5.722*	-3.435**	-4.902**
Constant	24.903*	30.224*	19.358	24.875*

Equation 2: Urbanization

Variables	Model 1	Model 2	Model 3	Model 4
URB_{it}	dv	dv	dv	dv
lnef_{it}	0.505	0.676**	-	-
lncf_{it}	-	-	0.569***	0.704**
GDP_{it}	0.470***	-	0.448***	-
GDPC_{it}	-	0.1834	-	0.175
INDM_{it}	0.583*	0.596*	0.566*	0.578*
INFRA_{it}	3.064*	2.865*	3.032*	2.836*
lnglob_{it}	18.150*	17.843*	16.901*	16.521*
EDU_{it}	-0.2658*	-0.2632*	-0.2604*	-0.258*
Constant	-63.737*	-63.337*	-59.284*	-57.835*

Equation 3: Economic Growth

Variables	Model 1	Model 2	Model 3	Model 4
GDP_{it}	dv	-	dv	-
GDPC_{it}	-	dv	-	dv
lnef_{it}	0.410	0.263	-	-
lncf_{it}	-	-	0.3606	0.327
URB_{it}	0.213*	0.200*	0.217**	0.1864**
INDM_{it}	0.065	0.080	0.057	0.084
INFRA_{it}	-1.350*	-0.976*	-1.413*	-1.001*
FDI_{it}	-0.704	-0.603	-0.720	-0.662
TRD_{it}	0.069*	0.077*	0.069*	0.078*
LAB_{it}	0.012	0.018	0.014	0.018
CAP_{it}	0.294*	0.297*	0.291*	0.296*
CONSU_{it}	0.156*	0.135**	0.155**	0.145**
GOV_{it}	-0.433	-0.558**	-0.423	-0.531**
Constant	-22.923*	-21.900	-21.32**	-23.28**

Note: Author's own estimation using STATA 17.0. "dv" define the dependent variable in the respective equation.
Model 1 includes GDP growth and Ecological Footprint (Primary model).
Model 2 includes GDP per capita growth and Ecological Footprint.
Model 3 includes GDP growth and Carbon Footprint.
Model 4 includes GDP per capita growth and Carbon Footprint.

5.1. Robustness Check

To ensure the robustness of our findings, we conducted additional estimations by substituting different proxies for the dependent variables. Specifically, we replaced the original measure of economic growth, GDP growth, with GDP per capita growth to capture a more refined perspective of economic performance. Additionally, the Ecological Footprint was substituted with the Carbon Footprint to provide a more direct assessment of environmental impact through carbon emissions. These robustness checks were assessed across three key dimensions—magnitude, significance, and the sign of the coefficients. The consistency observed across these dimensions strengthens the reliability of our primary results, thereby confirming the validity of the relationships identified in our analysis. The data of GDP per capita growth is taken from WDI and Carbon Footprint is taken from Global Footprint Network.

The table 8 outlines the robustness check performed by substituting proxies for key variables across four models. The models are organized to show how changes in GDP measurement (from GDP growth to GDP per capita growth) and environmental degradation metrics (from Ecological Footprint to Carbon Footprint) impact the significance, magnitude, and signs of the coefficients for the variables across the three equations.

The robustness checks for Equation 1 reveal that the key variables urbanization, economic growth, industrialization, energy consumption, and globalization exhibit strong robustness. These variables consistently maintain the same sign, magnitude, and significance across all model specifications, indicating reliable relationships with environmental degradation. In contrast, the variable for infrastructure development shows weak robustness, with inconsistent signs and lack of statistical significance, suggesting its impact on environmental degradation is less stable and may vary depending on the model used.

The robustness checks for Equation 2 demonstrate that the variables urbanization, industrialization, infrastructure, globalization, and education are strongly robust. These variables consistently show the same sign, magnitude, and significance across all models, indicating a stable and reliable relationship with urbanization. The economic growth variables exhibit moderate robustness, with consistent signs but some variation in significance, reflecting a slightly less stable influence on urbanization. Both ecological footprint and carbon footprint are also moderately robust, maintaining consistent signs with some variation in significance, indicating that the choice between these proxies slightly affects the strength of their relationship with urbanization.

The robustness checks for Equation 3 indicate that the variables urbanization, infrastructure, trade openness, capital formation, and consumption are strongly robust, consistently showing the same sign, magnitude, and significance across all models. This highlights their reliable influence on economic growth. The variables for ecological footprint, carbon footprint, and labor demonstrate moderate robustness, maintaining consistent signs but with some variations in significance, suggesting a stable yet slightly variable relationship with economic growth. The variables for government expenditure and foreign direct investment show weak robustness, with inconsistent significance, indicating a less reliable impact on economic growth.

6. Conclusion and Policy Suggestions

This research analyzes the long-term relationships among the ecological footprint, urbanization, and economic growth in Bangladesh, India, Nepal, Pakistan, and Sri Lanka from 1994 to 2022 using annual panel data. By formulating a model based on an extensive literature review, we identified key variables and conducted identification tests and panel unit root tests to verify data robustness. The analysis, conducted through the panel 2SLS technique, reveals that economic growth significantly influences the ecological footprint, while the reverse effect is insignificant. Urbanization notably impacts the environment but has only a marginal effect on economic growth. Additionally, industrialization strongly drives urbanization and environmental degradation, whereas infrastructure enhances urbanization but negatively affects economic growth. Globalization fosters urbanization and reduces environmental impact, while education has a negative relationship with urbanization.

South Asian countries considering the rapidly increasing environmental crisis, pollution, and adverse climatic fluctuations should adopt some policies to make the region livable for the coming generations. The policy implications in the light of significant empirical findings underscore the necessity for a balanced strategy that promotes sustainable urbanization, safeguards the environment, and fosters economic growth. This requires coordinated efforts across various sectors, including education, infrastructure, industry, and governance to ensure sustainable development.

1. Implement measures to manage urban growth sustainably. This could include investing in efficient, low-emission public transportation systems to reduce reliance on private vehicles., increasing green spaces, and invest in smart city initiatives that use technology to optimize resource use, reduce energy consumption, and improve the quality of life for residents.
2. Promote sustainable economic development that balances growth with environmental protection. Enforce strict environmental regulations on industries that limit pollution and incentivize businesses to adopt cleaner technologies and provide tax incentives and subsidies for green technologies and sustainable practices in urban development.
3. Implement advanced waste management systems, including recycling and composting, to minimize the environmental impact of urban areas.

While this study offers valuable insights into the relationships among ecological footprint, urbanization, and economic growth in South Asia, certain limitations must be acknowledged. One significant limitation is the constraint of data availability, which restricted the analysis to only a subset of South Asian countries. Additionally, the lack of more than 30 years of data for the selected countries prevents a more comprehensive comparative analysis across countries. Secondly, this study employs a static model for the analysis. The static model provides a snapshot of relationships among variables, it may not fully capture temporal dynamics and evolving interactions. In terms of future research, dynamic models such as panel Vector Autoregression or dynamic panel data models could be employed which could provide more concrete inferences and deeper insights into causality and long-term effects. There is an opportunity to expand the scope by including additional South Asian countries and extending the study period if more data becomes available, allowing a more thorough comparative analysis within South Asia and with other regions globally. Future research can incorporate potential external shocks, to better understand how these shocks impact ecological footprint, economic growth and urbanization in the region.

Author’s Contribution:

Qurat ul Ain: Qurat ul Ain conceptualized the study, developed the research framework, and was actively involved in data collection.

Asma Awan: contributed to the literature review and theoretical grounding of the research.

Furrukh Bashir: provided expertise in econometric modeling and assisted in refining the 2SLS analysis.

Conflict of interest/ Disclosures:

The authors declared no potential conflicts of interest regarding this article's research, authorship and/or publication.

References

Abbasi, M. A., Parveen, S., Khan, S., & Kamal, M. A. (2020). Urbanization and Energy Consumption Effects on Carbon Dioxide Emissions: Evidence from Asian-8 Countries Using Panel Data Analysis. *Environmental Science and Pollution Research, 27*(5), 18029-18043. doi:https://doi.org/10.1007/s11356-020-08262-w

Ahmed, Z., Asghar, M. M., Malik, M. N., & Nawaz, K. (2020). Moving Towards a Sustainable Environment: The Dynamic Linkage between Natural Resources, Human Capital, Urbanization, Economic Growth, and Ecological Footprint in China. *Resources Policy, 67*(8), 101677. doi:https://doi.org/10.1016/j.resourpol.2020.101677

Ahmed, Z., Wang, Z., Mahmood, F., Hafeez, M., & Ali, N. (2019). Does Globalization Increase the Ecological Footprint? Empirical Evidence from Malaysia. *Environmental Science and Pollution Research, 26*(6), 18565-18582. doi:https://doi.org/10.1007/s11356-019-05224-9

Akpolat, A. G. (2014). The Long-Term Impact of Human Capital Investment on Gdp: A Panel Cointegrated Regression Analysis. *Economics Research International, 2014*(1), . doi: https://doi.org/10.1155/2014/646518

Alam, M. M., Murad, M. W., Noman, A. H. M., & Ozturk, I. (2016). Relationships among Carbon Emissions, Economic Growth, Energy Consumption and Population Growth: Testing Environmental Kuznets Curve Hypothesis for Brazil, China, India and Indonesia. *Ecological Indicators, 70*(11), 466-479. doi:https://doi.org/10.1016/j.ecolind.2016.06.043

Alam, S. (2010). Globalization, Poverty and Environmental Degradation: Sustainable Development in Pakistan. *Journal of Sustainable Development, 3*(3), 103.

Ali, R., Bakhsh, K., & Yasin, M. A. (2019). Impact of Urbanization on Co2 Emissions in Emerging Economy: Evidence from Pakistan. *Sustainable Cities and Society, 48*(7), . doi:https://doi.org/10.1016/j.scs.2019.101553

Amna Intisar, R., Yaseen, M. R., Kousar, R., Usman, M., & Makhdum, M. S. A. (2020). Impact of Trade Openness and Human Capital on Economic Growth: A Comparative Investigation of Asian Countries. *Sustainability, 12*(7), 2930. doi:https://doi.org/10.3390/su12072930

Anwar, A., Younis, M., & Ullah, I. (2020). Impact of Urbanization and Economic Growth on Co2 Emission: A Case of Far East Asian Countries. *International Journal of Environmental Research and Public Health, 17*(7), . doi:https://doi.org/10.3390/ijerph17072531

Awad, A., Mallek, R. S., Ozturk, I., & Abdalla, Y. A. (2023). Infrastructure Development's Role in Environmental Degradation in Sub-Saharan Africa: Impacts and Transmission Channels. *Journal of Cleaner Production, 414*(8), 137622. doi:https://doi.org/10.1016/j.jclepro.2023.137622

Azam, M., Uddin, I., Khan, S., & Tariq, M. (2022). Are Globalization, Urbanization, and Energy Consumption Cause Carbon Emissions in Saarc Region? New Evidence from Cs-Ardl Approach. *Environmental Science and Pollution Research, 29*(58), 87746-87763. doi:https://doi.org/10.1007/s11356-022-21835-1

Azhar, R., Zeeshan, M., & Fatima, K. (2019). Crop Residue Open Field Burning in Pakistan; Multi-Year High Spatial Resolution Emission Inventory for 2000–2014. *Atmospheric Environment, 208*(7), 20-33. doi:https://doi.org/10.1016/j.atmosenv.2019.03.031

Choy, L. H., & Li, V. J. (2017). The Role of Higher Education in China's Inclusive Urbanization. *Cities, 60*(2), 504-510. doi:https://doi.org/10.1016/j.cities.2016.04.008

d'Agostino, G., Dunne, J. P., & Pieroni, L. (2016). Government Spending, Corruption and Economic Growth. *World development, 84*(8), 190-205. doi:https://doi.org/10.1016/j.worlddev.2016.03.011

Danish, M. S. S., Bhattacharya, A., Stepanova, D., Mikhaylov, A., Grilli, M. L., Khosravy, M., & Senjyu, T. (2020). A Systematic Review of Metal Oxide Applications for Energy and Environmental Sustainability. *Metals, 10*(12), . doi:https://doi.org/10.3390/met10121604

De Vita, G., Katircioglu, S., Altinay, L., Fethi, S., & Mercan, M. (2015). Revisiting the Environmental Kuznets Curve Hypothesis in a Tourism Development Context. *Environmental Science and Pollution Research, 22*(11), 16652-16663. doi:https://doi.org/10.1007/s11356-015-4861-4

Eweade, B. S., Akadiri, A. C., Olusoga, K. O., & Bamidele, R. O. (2024). *The Symbiotic Effects of Energy Consumption, Globalization, and Combustible Renewables and Waste on Ecological Footprint in the United Kingdom.* Paper presented at the Natural resources forum.

Fodha, M., & Zaghdoud, O. (2010). Economic Growth and Pollutant Emissions in Tunisia: An Empirical Analysis of the Environmental Kuznets Curve. *Energy policy, 38*(2), 1150-1156. doi:https://doi.org/10.1016/j.enpol.2009.11.002

Guo, M., Hu, Y., & Yu, J. (2019). The Role of Financial Development in the Process of Climate Change: Evidence from Different Panel Models in China. *Atmospheric Pollution Research, 10*(5), 1375-1382. doi:https://doi.org/10.1016/j.apr.2019.03.006

Hao, Y., Zheng, S., Zhao, M., Wu, H., Guo, Y., & Li, Y. (2020). Reexamining the Relationships among Urbanization, Industrial Structure, and Environmental Pollution in China—New Evidence Using the Dynamic Threshold Panel Model. *Energy Reports, 6*(11), 28-39. doi:https://doi.org/10.1016/j.egyr.2019.11.029

Haque, A. U., Kibria, G., Selim, M. I., & Smrity, D. Y. (2019). Labor Force Participation Rate and Economic Growth: Observations for Bangladesh. *International Journal of Economics and Financial Research, 5*(9), 209-213. doi:https://doi.org/10.32861/ijefr.59.209.213

Hashim, A., Shahlan, N. A. I., & Rambeli, N. (2024). Trade Openness and Other Selected Macroeconomic Effects on Economic Growth in Malaysia. *International Business Education Journal, 17*(1), 38-48. doi:https://doi.org/10.37134/ibej.Vol17.1.4.2024

Henderson, J. V. (2010). Cities and Development. *Journal of regional science, 50*(1), 515-540. doi:https://doi.org/10.1111/j.1467-9787.2009.00636.x

Huang, C.-J., & Ho, Y.-H. (2017). Governance and Economic Growth in Asia. *The North American journal of economics and finance, 39*(1), 260-272.

Hussain, M., Ye, C., Ye, C., & Wang, Y. (2021). Impact of Financial Inclusion and Infrastructure on Ecological Footprint in Oecd Economies. *Environmental Science and Pollution Research, 29*(3), 1-8. doi:https://doi.org/10.1007/s11356-021-17429-y

Hussain, M. M., Pal, S., & Villanthenkodath, M. A. (2023). Towards Sustainable Development: The Impact of Transport Infrastructure Expenditure on the Ecological Footprint in India. *Innovation and Green Development, 2*(2), 100037. doi:https://doi.org/10.1016/j.igd.2023.100037

Jiang, Y., Lin, T., & Zhuang, J. (2011). Environmental Kuznets Curves in the People's Republic of China: Turning Points and Regional Differences. *Available at SSRN 1861568*(6), 1-25. doi:http://dx.doi.org/10.2139/ssrn.1861568

Keho, Y. (2023). Impact of Urbanization on the Ecological Footprint: Evidence from Cote D'ivoire. *Modern Economy, 14*(12), 1773-1801. doi:https://doi.org/10.4236/me.2023.1412093

Khan, M. B., Saleem, H., Shabbir, M. S., & Huobao, X. (2022). The Effects of Globalization, Energy Consumption and Economic Growth on Carbon Dioxide Emissions in South Asian Countries. *Energy & Environment, 33*(1), 107-134. doi:https://doi.org/10.1177/0958305X20986896

Khan, M. K., Teng, J.-Z., Khan, M. I., & Khan, M. O. (2019). Impact of Globalization, Economic Factors and Energy Consumption on Co2 Emissions in Pakistan. *Science of the total environment, 688*(10), 424-436. doi:https://doi.org/10.1016/j.scitotenv.2019.06.065

Khan, S., & Majeed, M. T. (2023). Toward Economic Growth without Emissions Growth: The Role of Urbanization & Industrialization in Pakistan. *Journal of Environmental Studies and Sciences, 13*(1), 43-58. doi:https://doi.org/10.1007/s13412-022-00797-3

Lee, J. W., & Brahmasrene, T. (2013). Investigating the Influence of Tourism on Economic Growth and Carbon Emissions: Evidence from Panel Analysis of the European Union. *Tourism management, 38*(10), 69-76. doi:https://doi.org/10.1016/j.tourman.2013.02.016

Liang, W., & Yang, M. (2019). Urbanization, Economic Growth and Environmental Pollution: Evidence from China. *Sustainable Computing: Informatics and Systems, 21*(3), 1-9. doi:https://doi.org/10.1016/j.suscom.2018.11.007

Mani, M., Bandyopadhyay, S., Chonabayashi, S., & Markandya, A. (2018). *South Asia's Hotspots: The Impact of Temperature and Precipitation Changes on Living Standards*: World Bank Publications.

Mehmood, U., Aslam, M. U., & Javed, M. A. (2023). Associating Economic Growth and Ecological Footprints through Human Capital and Biocapacity in South Asia. *World, 4*(3), 598-611. doi:https://doi.org/10.3390/world4030037

Mughal, N., Arif, A., Jain, V., Chupradit, S., Shabbir, M. S., Ramos-Meza, C. S., & Zhanbayev, R. (2022). The Role of Technological Innovation in Environmental Pollution, Energy Consumption and Sustainable Economic Growth: Evidence from South Asian Economies. *Energy Strategy Reviews, 39*(1), 100745. doi:https://doi.org/10.1016/j.esr.2021.100745

Munaf, E., & Amar, S. (2024). Infrastructure, Investment, and Environmental Degradation: A Study of Economic Development in West Sumatra. *International Journal of Sustainable Development & Planning, 19*(1). doi:https://doi.org/10.18280/ijsdp.190129

Naeem, M. A., Appiah, M., Karim, S., & Yarovaya, L. (2023). What Abates Environmental Efficiency in African Economies? Exploring the Influence of Infrastructure, Industrialization, and Innovation. *Technological Forecasting and Social Change, 186*(1), 122172. doi:https://doi.org/10.1016/j.techfore.2022.122172

Narayana, M. (2010). Impact of Economic Globalization on Urbanization: A Comparative Analysis of Indian and Select Global Experiences. *India Quarterly, 66*(1), 91-116. doi:https://doi.org/10.1177/097492841006600106

Nathaniel, S. P. (2021). Ecological Footprint, Energy Use, Trade, and Urbanization Linkage in Indonesia. *GeoJournal, 86*(5), 2057-2070. doi:https://doi.org/10.1007/s10708-020-10175-7

Ndiaya, C., & Lv, K. (2018). Role of Industrialization on Economic Growth: The Experience of Senegal (1960-2017). *American Journal of Industrial and Business Management, 8*(10), 2072-2085. doi:https://doi.org/10.4236/ajibm.2018.810137

Network, G. F. (2020). Ecological Footprint-Global Footprint Network. In: Tillgänglig: https://www. footprintnetwork. org/our-work/ecologicalfootprint ….

Nguyen, H. M., & Nguyen, L. D. (2018). The Relationship between Urbanization and Economic Growth: An Empirical Study on Asean Countries. *International Journal of Social Economics, 45*(2), 316-339. doi:https://doi.org/10.1108/IJSE-12-2016-0358

Palei, T. (2015). Assessing the Impact of Infrastructure on Economic Growth and Global Competitiveness. *Procedia Economics and Finance, 23*, 168-175. doi:https://doi.org/10.1016/S2212-5671(15)00322-6

Pradhan, R. P., & Bagchi, T. P. (2013). Effect of Transportation Infrastructure on Economic Growth in India: The Vecm Approach. *Research in Transportation economics, 38*(1), 139-148. doi:https://doi.org/10.1016/j.retrec.2012.05.008

Primbetova, M., Sharipov, K., Allayarov, P., & Haq, I. u. (2022). Investigating the Impact of Globalization on Environmental Degradation in Kazakhstan. *Frontiers in Energy Research, 10*(6), 896652. doi: https://doi.org/10.3389/fenrg.2022.896652

Qayyum, U., Sabir, S., & Anjum, S. (2021). Urbanization, Informal Economy, and Ecological Footprint Quality in South Asia. *Environmental Science and Pollution Research, 28*(12), 67011-67021. doi:https://doi.org/10.1007/s11356-021-15111-x

Quito, B., del Río-Rama, M. d. l. C., Álvarez-García, J., & Durán-Sánchez, A. (2023). Impacts of Industrialization, Renewable Energy and Urbanization on the Global Ecological Footprint: A Quantile Regression Approach. *Business Strategy and the Environment, 32*(4), 1529-1541. doi:https://doi.org/10.1002/bse.3203

Rafiq, S., Salim, R., & Nielsen, I. (2016). Urbanization, Openness, Emissions, and Energy Intensity: A Study of Increasingly Urbanized Emerging Economies. *Energy Economics, 56*(5), 20-28. doi:https://doi.org/10.1016/j.eneco.2016.02.007

Rahman, M. M., Bindu, K. J., & Islam, M. K. (2018). Linking Per Capita Gdp to Energy Consumption, Ecological Footprint, and Carbon Dioxide Emission in a Developing Economy in the World: The Case of Bangladesh. *Journal of Banking and Financial Dynamics, 2*, 9-15. doi:https://doi.org/10.20448/journal.525.2018.21.9.15

Rehman, A., Radulescu, M., Ma, H., Dagar, V., Hussain, I., & Khan, M. K. (2021). The Impact of Globalization, Energy Use, and Trade on Ecological Footprint in Pakistan: Does

Environmental Sustainability Exist? *Energies, 14*(17), 5234. doi:https://doi.org/10.3390/en14175234

Report, W. C. (2016). *Urbanization and Development - Emerging Futures (Hs/038/16e)*. Retrieved from The city as a center for resources: https://unhabitat.org/world-cities-report-2016

Sabir, S., Qayyum, U., & Majeed, T. (2020). Fdi and Environmental Degradation: The Role of Political Institutions in South Asian Countries. *Environmental Science and Pollution Research, 27*(9), 32544-32553. doi:https://doi.org/10.1007/s11356-020-09464-y

Salahuddin, M., Alam, K., Ozturk, I., & Sohag, K. (2018). The Effects of Electricity Consumption, Economic Growth, Financial Development and Foreign Direct Investment on Co2 Emissions in Kuwait. *Renewable and sustainable energy reviews, 81*(2), 2002-2010. doi:https://doi.org/10.1016/j.rser.2017.06.009

Shabu, T. (2010). The Relationship between Urbanization and Economic Development in Developing Countries. *International Journal of Economic Development Research and Investment, 1*(2), 30-36.

Shahbaz, M., Sbia, R., Hamdi, H., & Ozturk, I. (2014). Economic Growth, Electricity Consumption, Urbanization and Environmental Degradation Relationship in United Arab Emirates. *Ecological Indicators, 45*(10), 622-631. doi:https://doi.org/10.1016/j.ecolind.2014.05.022

Shahzadi, A., Yaseen, M. R., & Anwar, S. (2019). Relationship between Globalization and Environmental Degradation in Low Income Countries: An Application of Kuznet Curve. *Indian Journal of Science and Technology, 12*(19), 1-13. doi:https://doi.org/10.17485/ijst/2019/v12i19/143994

Sharif, F., & Tauqir, A. (2021). The Effects of Infrastructure Development and Carbon Emissions on Economic Growth. *Environmental Science and Pollution Research, 28*(27), 36259-36273. doi:https://doi.org/10.1007/s11356-021-12936-4

Sharma, R., Sinha, A., & Kautish, P. (2021). Does Renewable Energy Consumption Reduce Ecological Footprint? Evidence from Eight Developing Countries of Asia. *Journal of Cleaner Production, 285*(2), 124867. doi:https://doi.org/10.1016/j.jclepro.2020.124867

Skeels, C. L., & Windmeijer, F. (2018). On the Stock–Yogo Tables. *Econometrics, 6*(4), 44. doi: https://doi.org/10.3390/econometrics6040044

Tao, S., Zheng, T., & Lianjun, T. (2008). An Empirical Test of the Environmental Kuznets Curve in China: A Panel Cointegration Approach. *China Economic Review, 19*(3), 381-392. doi:https://doi.org/10.1016/j.chieco.2007.10.001

Turok, I., & McGranahan, G. (2013). Urbanization and Economic Growth: The Arguments and Evidence for Africa and Asia. *Environment and urbanization, 25*(2), 465-482. doi:https://doi.org/10.1177/0956247813490908

Uddin, G. A., Alam, K., & Gow, J. (2016). Does Ecological Footprint Impede Economic Growth? An Empirical Analysis Based on the Environmental Kuznets Curve Hypothesis. *Australian Economic Papers, 55*(3), 301-316. doi:https://doi.org/10.1111/1467-8454.12061

Uddin, G. A., Salahuddin, M., Alam, K., & Gow, J. (2017). Ecological Footprint and Real Income: Panel Data Evidence from the 27 Highest Emitting Countries. *Ecological Indicators, 77*(6), 166-175. doi:https://doi.org/10.1016/j.ecolind.2017.01.003

Voumik, L. C., Mimi, M. B., & Raihan, A. (2023). Nexus between Urbanization, Industrialization, Natural Resources Rent, and Anthropogenic Carbon Emissions in South Asia: Cs-Ardl Approach. *Anthropocene Science, 2*(1), 48-61. doi:https://doi.org/10.1007/s44177-023-00047-3

Wackernagel, M., & Rees, W. (1998). *Our Ecological Footprint: Reducing Human Impact on the Earth* (Vol. 9): New society publishers.

Wahyudi, H. (2024). The Relationship between Electricity Consumption and Economic Growth in Brics Countries. *International Journal of Energy Economics and Policy, 14*(2), 349-356. doi:https://doi.org/10.32479/ijeep.15500.

Wan, B., & Min, W. (2023). An Empirical Study on the Role of Education in Promoting Urbanization. *Journal of East China Normal University (Educational Sciences), 41*(10), 40. doi:https://doi.org/10.16382/j.cnki.1000-5560.2023.10.004

Wiranatakusuma, D., & Zakaria, Y. (2024). *An Analysis the Influence of Mobile Cellular Subscription, Fixed Telephone Subscription, Gross Fixed Capital Formation, and Labor Force Participation Rate on Gross Domestic Product in Indonesia.* Paper presented at the Proceedings of the 1st International Conference on Economics and Business, ICEB 2023, 2-3 August 2023, Padang, Sumatera Barat, Indonesia.

Wong, D. W., Lee, H. F., Zhao, S. X., & Tai, A. C. (2022). Post-2008 Fiscal Stimulus Packages and the Driving Forces for China's Urbanization. *Land, 11*(12), 2303. doi:https://doi.org/10.3390/land11122303

Xiang, L., & Chen, C. (2019). Multiple Scenarios Simulation of Global Ecological Footprint Based on Empirical Mode Decomposition Method. *Open Journal of Ecology, 9*(11), 506. doi:https://doi.org/10.4236/oje.2019.911033

Xue, L., Haseeb, M., Mahmood, H., Alkhateeb, T., & Murshed, M. (2021). Renewable Energy Use and Ecological Footprints Mitigation: Evidence from Selected South Asian Economies. Sustainability 2021, 13, 1613. In.

Yang, B., & Usman, M. (2021). Do Industrialization, Economic Growth and Globalization Processes Influence the Ecological Footprint and Healthcare Expenditures? Fresh Insights Based on the Stirpat Model for Countries with the Highest Healthcare Expenditures. *Sustainable Production and Consumption, 28*(10), 893-910. doi:https://doi.org/10.1016/j.spc.2021.07.020

Yousaf, H., Shaikh, P. A., Khan, T. N., Shah, S. H., Shafiq, H., Muhammad, F., & Zardari, S. (2021). A Comparative Study on South Asian Countries' Biocapacity and Ecological Footprint: A Message Forward. *Linguistica Antverpiensia*(1), 1427-1444.

Zakaria, M., & Bibi, S. (2019). Financial Development and Environment in South Asia: The Role of Institutional Quality. *Environmental Science and Pollution Research, 26*(3), 7926-7937. doi:https://doi.org/10.1007/s11356-019-04284-1

Zhao, S., Da, L., Tang, Z., Fang, H., Song, K., & Fang, J. (2006). Ecological Consequences of Rapid Urban Expansion: Shanghai, China. *Frontiers in Ecology and the Environment, 4*(7), 341-346. doi:https://doi.org/10.1890/1540-9295(2006)004[0341:ECORUE]2.0.CO;2

Zhou, R., Abbasi, K. R., Salem, S., Almulhim, A. I., & Alvarado, R. (2022). Do Natural Resources, Economic Growth, Human Capital, and Urbanization Affect the Ecological Footprint? A Modified Dynamic Ardl and Krls Approach. *Resources Policy, 78*(9), 102782. doi:https://doi.org/10.1016/j.resourpol.2022.102782