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Grow Now, Clean Later: Evidence from South Asian Countries

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Abstract

The environmental Kuznet curve (EKC) postulates an inverted U-shaped relationship between economic growth and environmental degradation, suggesting that as economies develop, environmental quality initially worsens before improving. The study aims to check whether South Asian countries follow the EKC hypothesis or not and also check the pattern of the EKC. Although this study confirms the traditional understanding of the EKC, it also identifies an alternative perspective suggesting an N-shaped trajectory for the EKC. Through an empirical analysis, this paper finds evidence supporting this N-shaped pattern, indicating a transition from degradation to improvement as economies progress. The findings have significant implications for policy makers and environmental advocates, highlighting the need for proactive measures to accelerate the transition toward sustainable development. Additionally, this emphasizes the importance of designing effective environmental policies, encouraging investments in clean technologies, and recognizing regional variations in the turning point of the N-shaped curve. Further research, including case studies and comparative analysis, is warranted to deepen our understanding of this relationship and facilitate informed decision-making towards a more sustainable and resilient future.

Keywords: *Environment and growth, Environmental Kuznets curve, Ecological footprint, N-shaped curve, Panel data models*
JEL Classification: *O44; Q56; Q57; C23*

Introduction

The twin challenges of economic growth and environmental quality are always constant. The constant economic growth will lead to an increase in both the supply and demand of consumer goods. Hence, more energy consumption is there, which is one of the major causes of environmental problems. Sustainable Development Goals (SDGs) of No. 7 and No. 13 also focus on clean and affordable energy, climate action, and economic growth. Hence, it is important

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to be concerned about the environment with economic growth. In this context, the EKC hypothesis was observed by Grossman and Krueger (1991), suggesting that certain indicators of environmental quality tend to deteriorate during the initial stages of economic growth in countries with low income per capita but then improve as income levels rise. The EKC suggested the inverted U-shaped relation between various indicators of environmental degradation and income per capita. While testing this hypothesis, Hao et al. (2018) found an N-shaped relation between environmental quality and income per capita. In most of the empirical studies like Ben Cheikh et al. (2021), G.C. & Adhikari (2021), Stern (2004), Selden & Song (1994), Lean & Smyth (2010), Balsalobre-Lorente et al. (2018) CO_2 emission is considered for the proxy of environmental quality. However, carbon emission only captures air pollution. Environmental quality is the composite of water, soil, and air pollution. So, a comprehensive criterion is needed to capture the overall environmental degradation. The concept of the 'Ecological Footprint' is introduced by Wackernagel & Rees (1998) to fill this gap. The computing of the ecological footprint includes natural human resources consumption and environmental degradation.

The ecological footprint is a developing approach within ecological economics that aims to assess the environmental impact caused by both economic and non-economic activities. It involves quantifying the pressure exerted on the environment through various factors such as grazing land, ocean use, crop cultivation, forest products, built-up land (infrastructure), and carbon emissions. Several studies like Hassan et al. (2011) and Lin (2011) have contributed to the understanding and measurement of the ecological footprint, with others like Danish et al. (2020) focusing on the specific assessment of the carbon footprint.

Thus, the objectives of this empirical investigation are to check whether South Asian countries follow the EKC hypothesis and to check the pattern of the curve. The study contributes to the literature by using ecological footprints to capture environmental quality as well.

Review of Literature

On the theoretical front, researchers have attempted to model the relationship between pollution and income. Models range from simple static frameworks to complex dynamic models incorporating overlapping generations and endogenous policy determination. Jaeger (1998) proposes a model for welfare-maximizing solutions that generate smooth inverted 'U-shaped' paths for pollution and income, while others involve discrete jumps between multiple equilibria. Jones and Manuelli (2001) developed the model, which exhibits multiple direction changes, forming 'N-shaped' or sideways-mirrored 'S-shaped' paths.

There are some theoretical models of the growth and the environment. John and Pecchenino (1994) switch abruptly from constrained 'corner solutions' to interior optima, representing an inverse 'V-shaped' path for pollution and income. They used the Overlapping generational (OLG) model, where the author found an inverse 'V-shaped' relationship, peaking when the dynamic equilibrium switches from a corner solution of zero environmental investment to an interior optimum with positive investment. Jaeger (1998) and Stokey (1998), using the static model and a choice of production technologies with varying degrees of pollution, found an inverse 'V-shaped' pollution-income path with a sharp peak at the point where a continuum of cleaner technologies becomes available. Jones and Manuelli (2001) used an OLG model with the endogenous formation of political institutions and found Monotonic increasing pollution, inverted 'U-shaped' or sideways-mirrored 'S-shaped'.

Lucas (1988) points out that once one starts to think about economic growth, it is hard to think about anything else. In the traditional growth model, the relationship between economic growth and the environment is not given much importance. Becker (1982) explained and explored the link between economic growth and the environment, focusing on the theoretical aspect of environmental quality in economic growth.

The empirical aspects of the EKC literature aim to identify similar patterns for other pollutants like carbon emissions, lead, hazardous waste, and indoor air pollution. Researchers investigate the sensitivity of these findings to various factors like functional form assumptions, specifications, time periods, countries, and additional control variables. The literature now encompasses papers utilizing dynamic panel data models, fixed and random effects, splines, semi-parametric, and non-parametric specifications, as well as controls for multiple country characteristics like democratization, trade liberalization, and corruption. While some papers confirm inverted 'U-shaped' for other pollutants, countries, and time periods, others argue that the results are spurious and heavily influenced by assumptions and specifications regarding functional forms.

Grossman and Krueger (1991) observed that environmental quality often deteriorates during the early stages of economic growth in low-income countries but improves as income levels rise. Their regression analyses, correlating pollution indicators with GDP per capita, revealed an inverted 'U-shaped' curve - EKC - with peak pollution levels occurring in middle-income countries. This pattern, likened to Kuznets' income-inequality relationship, suggests that economic development initially increases pollution but later fosters environmental improvements. As incomes grow, societies prioritize a clean environment, leading to reduced pollution through higher willingness to pay for preservation and effective regulatory measures.

Aung et al. (2017) analyzed Myanmar's GDP and greenhouse gas emissions from 1970–2014, finding a persistent positive association between GDP and CO_2 emissions, indicating the absence of an EKC. Similarly, Jian et al. (2022)

examined the EKC in Western African countries using panel data. Their findings showed that CO_2 emissions rose with economic growth in the short term but lacked a strong long-term relationship, further supporting the absence of the EKC in these regions.

Criticism of studies analyzing the pollution-economic growth nexus has focused on issues like omitted variables, spurious regression, and time effects (Stern, 1998). To address these concerns, researchers have increasingly employed multivariate time series analysis to explore the relationships among emissions, energy consumption, and economic growth. Soytas et al. (2007) used Granger causality to investigate income, energy consumption, and carbon emissions, finding that energy consumption Granger-caused carbon emissions, but income did not. Halicioglu (2009) identified a cointegrating relationship between CO_2 emissions, energy use, income, and trade in Turkey, with long-run causality running from carbon emissions, energy consumption, and trade to income. Similarly, Alshehry and Belloumi (2015) found bidirectional causality between CO_2 emissions and economic growth in Saudi Arabia and unidirectional causality from energy consumption to emissions. Their variance decomposition analysis revealed minimal contributions of economic growth to emissions.

Mohiuddin et al. (2016) analyzed the relationship between economic growth, energy, and CO_2 emissions from 1971–2013, finding no Granger causality between GDP and CO_2 emissions but showing a 13.7 percent rise in emissions from a 1 percent increase in energy production. Impulse response analysis highlighted contributions of energy production and GDP to emissions. In Nepal, the literature on energy consumption and economic growth is limited. Dhungel (2008) reported unidirectional causality from GDP to energy consumption, without considering emissions. Bastola and Sapkota (2015) included emissions, identifying a long-run relationship between CO_2 emissions and electricity consumption, with feedback between emissions and energy consumption and causality from GDP to both. Nepal and Paija (2018) expanded the analysis to include gross fixed capital formation and population, finding that CO_2 emissions drove economic growth but there was no feedback from electricity consumption to growth.

Brock (2001) makes a seminal contribution to dynamic modeling, demonstrating its utility in analyzing stability and instability in economic systems. His work combines theoretical rigor with practical insights, addressing complex policy challenges through methodologically robust approaches. An introduction by Brock contextualizes his research, unifying his contributions and highlighting the relevance of dynamic modeling in contemporary economic policy. Keeler et al. (1972) present a generalized perspective on environmental risks, emphasizing conceptual parallels across pollutants to promote a unified understanding of environmental degradation. Forster (1973) critiques economic growth theories for neglecting environmental spillovers, such as pollution, reflecting a broader oversight in prioritizing growth over ecological impacts. Becker (1982) examines the balance between capital accumulation and environmental quality, applying the Rawlsian maximin criterion. Using the framework of Brock, the study provides conditions for achieving a fair utility path across generations, supported by competitive pricing and environmental charges. This analysis bridges equity, growth, and sustainability, offering actionable policy insights. Luptfáčik and Schubert (1982) discuss the trade-off between economic growth and environmental quality, rooted in Boulding's 'spaceship earth' concept. They highlight the nuanced debate on whether advancing one goal necessitates sacrifices in the other. Birdsall and Wheeler (1993) challenge the 'pollution haven' hypothesis, arguing that trade liberalization in Latin America has not spurred pollution-intensive industries. Instead, openness promotes cleaner practices through stricter imported standards. Lee and Roland-Holst (1997) use applied general equilibrium analysis to assess the environmental effects of trade liberalization in Indonesia. They find that pairing tariff removal with cost-effective tax policies can improve both welfare and environmental quality. Finally, Maler (2013) critiques the growth-centric paradigm, introducing 'degrowth' as an alternative. This framework emphasizes sustainability, equity, and ecological balance, advocating for economies that operate within environmental limits while promoting equitable wealth distribution and strengthening local systems.

Theoretical Foundation / Framework

The theoretical model considered is the Robinson Crusoe-style model that is elaborated by Levinson (2002) based on Andreoni and Levinson (2001). Let it be imagined that Robinson Crusoe is alone on his island, picking coconuts for food. Each coconut generates one coconut shell, which Crusoe can either toss aside as unsightly litter or dispose of properly in a dump. Crusoe gets utility from the consumption of coconuts 'C' and disutility from pollution 'P' (coconut shell litter).

$$U = U(C,P) \quad \text{.................. (1)}$$

Where, $U_C > 0$ and $U_P < 0$.

Suppose that Crusoe can dispose of his litter properly but at the cost of foregone consumption. Pollution is then a function of consumption '*C*' and effort spent hauling coconuts to the dump, denoted by E.

$$P = P(C,E) \quad \text{..................(2)}$$

Where, $P_C > 0$ and $P_E < 0$.

Finally, suppose Crusoe has an endowment, 'M' of time that can be spent on 'C' or 'E'. For simplicity, normalize the relative costs of 'C' and 'E' to be '1'.

So, 'C' denotes one hour's worth of coconuts, and 'E' denotes one hour's worth of clean-up effort. The resource constraint is, therefore, simply as $C + E = M$.

For example, consider a version of (1) and (2):

$$U = C - P \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$P = C - C^{\alpha}E^{\beta} \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Utility, in equation (3), is additive and linear, and the marginal disutility of pollution is one. Pollution, in equation (4), has two parts. The first term, 'C' is gross pollution before any abatement and is proportional to consumption. The second term is '$C^{\alpha}E^{\beta}$' that represents abatement. So, consumption in this model causes pollution one-for-one, but clean-up effort abates pollution with a standard concave production function.

The nice feature of this Crusoe model with only one economic agent is that without externalities, any private optimum is economically efficient by construction. To solve for Crusoe's optimum consumption and pollution level, substitute (4) into (3) and maximize '$C^{\alpha}E^{\beta}$' subject to '$C + E = M$'. Consumption and effort, then, have standard Cobb–Douglas solutions as follows.

$$C^{*} = \frac{\alpha}{\alpha + \beta} M \text{ and } E* = \frac{\beta}{\alpha + \beta} M \ldots\ldots\ldots\ldots\ldots (5)$$

Substituting (5) into (4), the optimal quantity of pollution becomes as follows.

$$P^{*}(M) = \frac{\alpha}{\alpha+\beta} M - \left(\frac{\alpha}{\alpha+\beta}\right)^{\alpha} \left(\frac{\beta}{\alpha+\beta}\right)^{\beta} M^{\alpha+\beta} \ldots\ldots\ldots (6)$$

Equation (6) represents optimal pollution as a function of Crusoe's endowment. If it is inverse 'U-shaped,' it would be called an EKC. When $\alpha + \beta = 1$, effort spent abating pollution has constant returns to scale, and $\Delta P^{*}/\Delta M$ is constant. However, if $\alpha + \beta > 1$, abatement has increasing returns to scale, and P*(M) is concave. This is what has been described as an EKC.

The normative implication of this one-person model is that an inverse U-shaped pollution-income path can be entirely consistent with Pareto-optimality. Because there is only one person, his optimum is necessarily socially optimal. There are no market failures, yet Crusoe's world gets dirtier with low income and cleaner at high levels. So, observing an inverse 'U-haped' is insufficient evidence for a market failure.

To examine whether the 'inverse U-shaped' is sufficient evidence for the market to be efficient, consider a multi-person version of the above model:

$$U_i = C_i - P, \qquad i = 1,\ldots,N,$$

$$P = C - C^{\alpha}E^{\beta}, \quad C = \textstyle\sum_i C_i, \; E = \sum_i E_i, \ldots\ldots\ldots (7)$$

$$M_i = C_i + E_i, \; \alpha, \beta \in (0,1)$$

Suppose, individuals indexed $i = 1, \dots, N$, take others' consumption and effort as given. Solving the first-order condition for consumer i yields the best response function:

$$C_i^* = \frac{\alpha}{\alpha+\beta} M_i + \left[\frac{\alpha}{\alpha+\beta} \sum_{j \neq 1} M_j - \sum_{j \neq 1} C_j\right] \dots\dots\dots\dots (8)$$

If all individuals maximize utility this way, the symmetric Nash equilibrium is

$$C_i^* = \frac{\alpha}{\alpha+\beta} M_i \text{ for all } i \dots\dots\dots\dots\dots (9)$$

In this decentralized case, pollution follows the same path as in the example of Crusoe in equation (6) i.e., the pollution–income path is concave and peaks when $\alpha + \beta > 1$. To examine the 'Pareto-efficiency' of this outcome, compare this Nash equilibrium to the centrally planned optimum. The centralized solution maximizes the sum of utilities as follows.

$$\max \sum_i U_i = \sum_i C_i - NP \dots\dots\dots\dots\dots (10)$$

It is to be noted that this aggregate utility function is identical to (3), where 'C' is replaced by $\sum_i C_i$ and the marginal social disutility of pollution is '$-$N' rather than '-1'. This is just like in the model (3) except that when $N > 1$, the disutility of pollution is greater. In the centralized solution,

$$C^* = \frac{\alpha}{\alpha+\beta} M + \frac{1-N}{N(\alpha+\beta)(C^*)^{\alpha-1}(M-C^*)^{\beta-1}} \dots\dots\dots\dots (11)$$

The second term of the equation (11) is negative if $N > 1$ so, ' C*' must be smaller than the Nash equilibrium 'C' in the equation (9), and the corresponding pollution level is lower.

The larger is 'N,' the higher the marginal social cost of a unit of pollution, and the lower the optimal consumption of 'C*.' Though the optimal levels of 'C*' and 'P*' at any income change in response to changes in 'N,' the implications for the inverse 'U-shaped' pollution–income path remain the same – it is the inverse 'U-shaped' so long as $\alpha + \beta > 1$. The normative conclusion must be that observing an inverse 'U-shaped' pollution–income path is neither necessary nor sufficient evidence that environmental policy is efficient because it can be consistent with efficient policies or market failures.

Data and Methodology

Sources of Data

The study uses panel data from six South Asian countries (Bangladesh, Bhutan, India, Sri Lanka, Nepal, and Pakistan) from 1995 to 2018. The data sources of the respective variables are mentioned in Table 1. In the study, the main variables of concern are 'Ecological Footprint' and the 'Per Capita GDP'.

Table 1: Variables and the Data Sources

Acronyms	Variables
EF	Ecological footprint (global hectare per person) *
PGDP	Per capita GDP (constant 2015 US$) **
PGDP²	Square of per capita GDP (constant 2015 US$)
PGDP³	Cubic of per capita GDP (constant 2015 US$)
CO₂	Carbon dioxide emission (Metric ton Per Capita) **
IS	Industry (including construction), value added (% of GDP) **
TRA	Share of trade in GDP (% of GDP) **
POP	Urban population (% of total population) **
FOR	Forest area (% of land area) **

Source: * Global Footprint Network, ** World Bank Data Indicator.

Methodology

The empirical part of this study primarily focuses on the validity of the EKC which demands the estimation of the quadratic function. The study affirms the inverted 'U-shaped' relationship between environmental quality and the growth in an economy. In the study, the 'Fixed Effect Model' is chosen after the Breusch and Pagan Lagrangian Multiplier test and the Hausman specification test by converting all the variables into the natural log form. The study used four different models in which EKC, by taking 'Ecological Footprint' as the dependent variable, per capita GDP, per capita GDP^2, and per capita GDP^3 are the core independent variables, whereas CO_2, industrial share in GDP, the share of trade in GDP, urban population, and forest area are the control independent variables.

Model-1 is used to verify the EKC hypothesis by taking 'Ecological Footprint' as the dependent variable and 'Per Capita GDP' and its square as independent variables. The model for the study has been set as follows:

Model-1: $lnEKC_{it} = \alpha_i + \beta_1 lnPGDP_{it} + \beta_2 lnPGDP_{it}^2 + \epsilon_{it}$……… (1)

This model is appropriate for estimating the relationship between the variable used in the study, where *i* denotes the country, '*t*' denotes the time period (year), and e_{it} is the random error term. a_i is a fixed effect for entity i (which is country) which is the sum of the intercept term and unobserved country fixed effect. In Model-1, the study expects $b_1 > 0$ while $b_2 < 0$ for the inverted U-shaped relation between environmental quality and economic growth.

Model-2 is used to check the pattern of the KEC, whether it follows an 'N-shaped' pattern or not, using an additional quadratic form of PGDP specified as follows.

Model-2: $lnEKC_{it} = \alpha_i + \beta_1 lnPGDP_{it} + \beta_2 lnPGDP_{it}^2 + \beta_3 lnPGDP^3 + \epsilon_{it}$ …….(2)

In this model, the study expects the same for β_1 and β_2. But for β_3, if $\beta_3 > 0$, then the KEC follows the 'N-shaped' or sideways-mirrored 'S-shaped,' but if $\beta_3 < 0$, then it follows the downward movement only.

Model-3 is used to explain whether the classical shape of EKC is observed or not by introducing a few controlling variables in 'Model-1,' which is specified as follows.

Model - 3: $$LnEKC_{it} = \alpha_i + \beta_1 lnPGDP_{it} + \beta_2 lnPGDP_{it}^2 + \beta_3 lnCO_2 + \beta_4 lnIS + \beta_5 lnTRA + \beta_6 lnPOP + \beta_7 lnFOR + \epsilon_{it} \quad \ldots\ldots\ldots\ldots (3)$$

Model 4, similarly, checks whether the model follows an inverted 'U-shaped' path by introducing the given control variables in 'Model-2,' which is specified as follows.

Model-4: $$lnEKC_{it} = \alpha_i + \beta_1 lnPGDP_{it} + \beta_2 lnPGDP_{it}^2 + \beta_3\, lnPGDP^3 + \beta_4 lnCO_2 + \beta_5 lnIS + \beta_6 lnTRA + \beta_7 lnPOP + \beta_8\, lnFOR + \epsilon_{it} \quad \ldots\ldots\ldots (4)$$

In this model, the given five control variables were introduced to the previous model-2. This model will check whether model follow 'N-shaped' path with the control variables. If the result is $b_1 > 0$, $b_2 < 0$, and $b_3 = 0$, then an inverted 'U-shaped' relationship of EKC is observed. If $b_1 < 0$, $b_2 > 0$, and $b_3 = 0$, then an 'U-shaped' relationship of KEC is observed. But, if the result is $b_1 > 0$, $b_2 < 0$, and $b_3 > 0$, then a 'Cubic polynomial' or 'N-shaped' relationship of KEC is observed.

Empirical Analysis and Results

In this study, descriptive analysis is first used to explain the nature of the data, followed by panel regression. The descriptive statistics of the data used are shown in Table 2. The mean, standard deviation, Minimum value, and maximum value are reported in the table below.

Table 2: Descriptive Analysis

Variables	Observation	Mean	St. Dev.	Min	Max
ln EF	144	0.152	0.646	- 0.713	1.641
ln PGDP	144	7.095	0.529	6.202	8.333
ln $PGDP^2$	144	50.618	7.645	38.463	69.433
ln $PGDP^3$	144	363.151	83.303	238.54	578.555
ln CO_2	144	- 0.665	0.782	- 2.435	0.604
ln IS	144	3.218	0.301	2.538	3.809
ln POP	144	16.266	2.425	11.593	19.959
ln TRA	144	3.854	0.438	3.088	4.758
ln FOR	144	3.168	0.152	1.597	4.268

Source: Author's calculation, 2023.

The total number of observations is 144 (i.e., 24 years of data × 6 countries). The ecological footprint log value is between—0.713 and 1.641. The mean value is 0.152. Descriptive statistics of other variables are shown in Table 2.

The correlation matrix is presented in Appendix-1, and the plot of the ecological footprint of all the countries is shown in Appendix - 3. Table 3 shows the results of the fixed effect model. In Appendix-2, the results of the pool-ability test[2] and the result of the Hausman test is shown. These two tests confirm that the fixed-effect modal should be used to analyze the data. Each column indicates the empirical model, and rows indicate the independent variable. The dependent variable in this study is the log of ecological footprint.

The analysis of Model-1 considers only two variables, i.e., per capita GDP and its square. This model significantly verifies the classical EKC hypothesis in the South Asian region. The coefficient of per capita GDP is positive, and the coefficient of per capita GDP square is negative, which shows an inverted 'U-shaped' nature of the KEC. This shows that, with time, economic growth and environmental degradation increase, and later, the economic growth tends to increase, and the environmental degradation decreases. The R-squared value for the model is 76.8 percent, which is satisfying.

Similarly, Model-2 shows that the path is not just the inverted 'U-shaped' but also the 'N-shaped.' The per capita GDP is positive, and the squared term of the per capita GDP is negative. Again, the cube of per capita GDP is positive, which shows that the curve follows the 'N-shaped'. The R-squared value for the model is 80.4 percent, which allows us to explain the data significantly.

In Model-3, control variables are used to check whether the model follows the inverted 'U-shaped' path in the presence of the control variable. The control variables used in the analysis are carbon emission, industrial structure, share of trade in GDP, urban population, and forest area. The analysis shows that in the presence of the control variable, the model follows the inverted 'U-shaped' significantly, but the control variables are not significant. The results show that carbon emission degrades the environment quality. Similarly, the forest area upgrades the environment quality significantly, and the R-squared value is also 87.8 percent.

In Model-4, control variables are used to check whether the model follows the 'N-shaped' path significantly or not. The results show that the model follows the 'N-shaped' as per capita GDP is positive, then its square is negative, and again, the cube is positive. In this model, the carbon emission and forest area results are significant at 0.1 percent, and results for industrial structure and urban population are significant at 5 percent. In this model, carbon emission degrades the environment quality, and the forest area upgrades the environment quality

2. A pool-ability test is an F-test of the null hypothesis that all fixed effects are jointly 0; it is obtained by comparing fixed-effects estimates to those from pooled regression.

significantly. The results of pooled OLS, fixed effect, and random effect are shown in the appendix for each model.

Table 3: Fixed Effect Results

Variables	Model – 1	Model – 2	Model - 3	Model - 4
ln PGDP	2.242*** (0.284)	25.802*** (4.700)	2.656*** (0.449)	19.031*** (4.509)
ln $PGDP^2$	- 0.131*** (0.020)	- 3.391*** (0.650)	- 0.168*** (0.030)	- 2.436*** (0.623)
In $PGDP^3$	-	0.150*** (0.030)	-	0.104*** (0.029)
ln C_o2	-	-	0.246*** (0.025)	0.221*** (0.025)
ln IS	-	-	0.076 (0.054)	0.138* (0.054)
ln TRA	-	-	- 0.024 (0.034)	- 0.006 (0.033)
ln POP	-	-	0.303* (0.126)	0.252* (0.121)
ln FOR	-	-	- 0.410*** (0.070)	- 0.372*** (0.068)
No. of observation	144	144	144	144
R^2	0.768	0.804	0.878	0.889
R^2 Adj.	0.756	0.793	0.866	0.878

Source: Author's calculation, 2023.

Note: *p < 0.1, p **< 0.05, *** p < 0.0. Standard Error are reported in parenthesis.

Discussions

This study examines the EKC and highlights the 'N-shaped' relationship between economic growth and environmental degradation in South Asia, contrasting the inverted 'U-shaped' model proposed by Brock (2001). While the EKC suggests environmental degradation peaks before improving with growth, the 'N-shaped' pattern reflects a second phase of degradation before transitioning to sustainability, emphasizing the interplay of factors like public awareness, technological progress, and policy shifts (Keeler et al., 1972; Forster, 1973). Becker (1982) links rising income to increased environmental awareness, leading to economic restructuring and cleaner practices. Grossman and Krueger (1991) identify three channels—scale, composition, and technological effects—through which growth impacts the environment. Initially, growth depletes resources and increases waste, but structural shifts from industrial to service and technology-driven economies reduce pollution (Lee & Roland-Holst, 1997).

Selden and Song (1994) argue higher incomes foster demand for environmental quality through investments in green technologies and consumption patterns.

Trade also influences the EKC with conflicting impacts. John and Pecchenino (1994) attribute trade to increased pollution via scale effects, while Birdsall and Wheeler (1993) highlight its potential for environmental improvements through stricter regulations and cleaner technologies. Thus, trade may exacerbate or mitigate environmental degradation depending on income levels and regulatory frameworks. The study underscores that pollution is inherent to development, reinforcing the **'Grow Now, Clean Later'** dynamic. However, to achieve sustainability, the concept of degrowth offers an alternative. Maler (2013) advocates redefining prosperity, prioritizing ecological balance, equity, and local economies over GDP growth. The concept of degrowth emphasizes reduced resource-intensive production, fair wealth distribution, and alternative well-being indicators, challenging the unsustainable pursuit of unbridled economic expansion. The concept of degrowth does not imply regression but promotes a holistic approach to progress that aligns human well-being with ecological limits, addressing global challenges like climate change and social inequality. This paradigm shift fosters a sustainable and equitable future, transcending traditional growth metrics to embrace broader measures of prosperity.

Conclusion

The EKC hypothesis assumes that the initial increases in environmental pressure are temporary but that the subsequent decreases are permanent. Only a few authors have questioned whether these observed decreases could also be a temporary phenomenon due to technological limitations. The result would be an 'N-shaped' curve. An upswing of EKC can be explained by the difficulty of keeping up efficiency improvements (innovation) with continuing production growth. An aggregated indicator of material and energy throughout suggests that in the second half of the 1980s, most developed economies have gone through a phase of re-linking them with economic growth. The fact that re-linking cannot be found for pollutants like solferdie oxide (SO_2), particulate matter, and CO_2 may reflect the continuing importance of end-of-pipe solutions over more fundamental changes in the economy. Pollutants for which the end-of-pipe solution is costly may follow a similar 'N-shaped' pattern.

However, this study contributes to the ongoing discourse surrounding the EKC by challenging the conventional inverted 'U-shaped' relationship. This study emphasizes the need for a more nuanced understanding of the relationship between economic growth and environmental quality by providing empirical evidence supporting an' N-shaped' path. Acknowledging the turning point where environmental concerns become a priority is crucial for formulating effective policies and strategies that promote sustainable development. The 'N-shaped' path suggests a transition from degradation to improvement as economies advance.

This study acknowledges that its findings are limited in generalizability due to its specific period and geographical scope. Future research should expand the scope of the study and incorporate additional variables to enhance understanding. Case studies and comparative analysis across countries and regions can provide deeper insights into the 'N-shaped' path of the EKC. Nevertheless, this study contributes to the growing knowledge surrounding sustainable development by highlighting the significance of prioritizing environmental preservation and adopting cleaner technologies as economies grow.

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Appendix -1: Correlation Matrix

Variables	lnEF	$lnCO_2$	lnPGDP	$lnPGDP^2$	$lnPGDP^3$	lnIS	lnPOP	lnTRA	lnFOR
lnEF	1	0.379***	0.521***	0.518***	0.513***	0.694***	-0.771***	0.811***	-0.576***
$lnCO_2$	0.379***	1	0.678***	0.662***	0.645***	0.531***	0.202*	0.111	0.041
lnPGDP	0.521***	0.678***	1	0.999***	0.997***	0.537***	-0.290***	0.466***	0.237**
$lnPGDP^2$	0.518***	0.662***	0.999***	1	0.999***	0.533***	-0.300***	0.464***	0.231**
$lnPGDP^3$	0.513***	0.645***	0.997***	0.999***	1	0.528***	-0.308***	0.461***	0.226**
lnIS	0.694***	0.531***	0.537***	0.533***	0.528***	1	-0.343***	0.595***	-0.420***
lnPOP	-0.771***	0.202*	-0.290***	- 0.300***	- 0.308***	-0.343***	1	-0.787***	0.439***
lnTRA	0.811***	0.111	0.466***	0.464***	0.461***	0.595***	-0.787***	1	-0.413***
lnFOR	-0.576***	0.041	0.237**	0.231**	0.226**	-0.420***	0.439***	-0.413***	1

Appendix -2: Hausman Test

Hausman Test	Coefficient
Chi-Square test Value	136.38
P-Value	0.000

Alternative hypothesis: one model is inconsistent (Fixed effect model is appropriate)

Appendix -3: Plot of Ecological footprint (in log)