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Nexus between Income Inequality-Institutional Quality and Environmental Degradation: Evidence from Developing South Asian and ASEAN Countries

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Abstract

This study examines the impact of institutional quality and income inequality on environmental degradation for the selected South Asian and ASEAN countries for the time span 1985-2022. To meet this objective, ecological footprint is used as a dependent variable to measure environmental degradation and independent variables include corruption, GDP per capita, GDP per capita square, trade openness, GINI coefficient and energy use. After checking the cross-sectional dependency, the second-generation unit root test is applied and results reveal a mixed order of integration, which enables us to use the panel ARDL approach. The Panel ARDL technique is used to find out the long run and short run relationship among the variables. It is expected that there will be estimated positive impacts of corruption, GINI coefficient, trade openness, energy use, and GDP per capita on ecological footprint. The study will also confirm the existence of the EKC hypothesis in South Asian and ASEAN countries. It is expected that institutional quality and income inequality will help to reduce environmental degradation. The better the quality of institutions, better the policies made by institutes to control income inequality and reduce environmental degradation.

Keywords: Economic development, income inequality, institutional quality, environmental degradation

1. Introduction

Environmental destruction stands out the foremost challenges threatening human existence. Among its many manifestations, greenhouse gas emissions are particularly significant, with unprecedented levels of CO2 accumulation and rising sea levels serving as stark indicators of the crisis's severity. Currently, humanity faces severe repercussions of environmental decline, witnessing its most urgent and impactful effects (Kang & Hwang, 2016). Global warming has triggered a series of consequences, including the increase of extreme weather events, prolonged droughts, and the depletion of essential natural resources. These unpredictable conditions have created a landscape of uncertainty, significantly affecting both human well-being and economic development (Baiardi, 2014). The prevailing theory suggests that technological innovations drive economic growth without causing substantial environmental harm. Conversely, growth based on resource-intensive practices is believed to lead to considerable environmental changes (Sarkodie, 2018). The observed effects bear closely resemblance with the Environmental Kuznets Curve (EKC) hypothesis, highlighting its significance in understanding the complex relationship between economic growth and environmental protection (Mahmood et al., 2020).

Grossman and Krueger (1991) were the pioneers who introduced the concept of the KEC. They hypothesized the relationship between environmental contamination and income disparity that may follow the inverse U-shaped pattern, like the association between income gap and income per capita observed by Kuznets (1945). The EKC elucidates that at the initial phase of economic development, economic activities may put pressure on the environment. However, as economies continue to grow, transitional changes in industrial structures and technological innovations can help to alleviate environmental destruction and improve environmental quality. However, as society approaches a certain threshold, a shift occurs towards a more harmonious coexistence with the environment, resulting in a decline in environmental degradation. The relationship between environmental quality and GDP growth can be delineated through three diverse phases (Grossman and Kruger, 1994). In the initial phase of economic growth, known as the scale effect, increased economic activities that led to environmental destruction. These activities require more natural

resources, consume large amounts of energy, and generate more waste and pollution, thus causing environmental impairment. As economic development progresses, the composition effect starts to occur. With increasing income levels, economies gradually converge towards less polluting industries and cleaner production processes. As a result, people also become more concerned about environmental protection and continuously demand environmentally friendly goods and services. Such changes encourage industries to adopt cleaner methods of production which are a way forward to improvements in environmental quality.

In the third phase, the technological effect becomes increasingly important. As economies become more developed, a colossal resource can be directed towards research and development, innovation and adoption of emerging technology (Halkos & Tzeremes, 2013). These developments replace outdated, resource intensive and polluting production technologies with cleaner and environmentally friendly alternatives. Consequently, technological improvements promote a reversal of environmental degradation, further improving environmental conditions. Panayotou (1993) suggests that many industries contribute to economic erosion through their extensive activities. However, as the economy expands, its composition shifts from technology-intensive sectors to energy-intensive ones. Nevertheless, the relationship between economic growth and environmental quality is difficult and influenced by several interconnected factors, including trade openness, income gap, poverty, and institutional quality.

Critically, past studies on the EKC hypothesis have often fallen short by solely relying on GDP per capita, thereby overlooking crucial determinants of environmental issues and potentially introducing bias (Iwata et al., 2010). Emerging research underscores the importance of considering variables previously neglected, including energy consumption, trade openness, foreign direct investment, institutional quality, and income inequality (Ahmed et al., 2017; Boyce, 1994; Danish & Ulucak, 2020; Lebe, 2016; Muhammad, 2019; Shahbaz et al., 2013). While numerous studies highlight a robust correlation between income disparity and environmental destruction, some theoretical frameworks suggest potential scenarios where inequality could enhance environmental quality. One such argument revolves around individual preferences for environmental preservation within varying income brackets. According to neo-materialist hypothesis of Coburn (2000), market-based societies have more income fragmentation that leads to less social cohesion and trust. When this dynamic relates to income elasticity of demand for environmental quality that may be

positive, can have intriguing effects. By redistributing income from the poor to the rich, there's a simultaneous increase in environmental demand among the wealthy while decreasing it among the impoverished. The net impact depends on the nature of the relationship between income and environmental, whether demand function is concave or convex (Boyce, 2003). In scenarios where the relationship is linear, the trade-off doesn't significantly affect the environment, as each additional unit of income has an identical effect on environmental demand, regardless of whether it accrues to the rich or poor. However, if relationship between income and environmental demand is convex, the transfer of income from disadvantaged people to rich increases environmental demand. This interplay underscores the nuanced dynamics at play, shaping the environmental outcomes of income inequality. Boyce (1994) argues that income inequality perpetuates social hierarchy, granting the affluent greater latitude to engage in environmentally harmful practices while evading the full cost of pollution. Unequal distribution of social power enables the wealthy to exert influence over regulatory bodies, potentially loosening environmental regulations to their advantage, thereby exacerbating environmental degradation.

Martinez Alier (1995) offers a nuanced perspective regarding link between income inequality and environmental quality by classifying environmental goods into two types: luxury goods, which shows low-income elasticity, and necessity, which has high-income elasticity. Regarding income disparities widening, Martinez Alier suggests several critical dynamics unfold. Firstly, the need for the environment as a luxury good among the affluent intensifies. Secondly, there's a parallel increase in supply, as the impoverished, facing income and other social constraints, reduce their demand for environmental necessities. Lastly, income inequality poses a significant risk to the development of environmental quality, as wealthier people have greater influence over resource allocation and regulatory frameworks, potentially impeding progress towards sustainability.

Beyond wealth and income disparity, the interaction between environmental degradation, economic growth, and institutional development is a focal point of contemporary research. Researchers have dedicatedly focused on how influence of institutional quality affects the balance between environmental sustainability and economic prosperity. Several institutional factors, including political stability, bureaucratic efficiency, secure land rights, good governance, the rule of law, and control of corruption, can play pivotal roles in shaping environmental outcomes.

Robust institutional frameworks play instrumental role in addressing the adverse effects of climate change and limiting carbon dioxide emissions. Countries with strong institutional framework can adhere the compliance of stringent environmental policies rigorously, whereas countries with weaker institutions often face difficulties in the enforcement of such type of regulations. Political will is indispensable for achieving and maintaining environmental standards, and sound institutions are imperative for translating policy intentions into actionable measures. Furthermore, the quality of institutions significantly influences a country's attractiveness to foreign investors (Gastanga et al., 1998). Trustworthy institutions foster an environment conducive to investment, attracting foreign direct investment (FDI) that can catalyze economic growth while simultaneously impacting environmental quality. FDI inflows often bring with them cleaner technologies, contributing to reduced environmental degradation. However, the connection between institutions and environmental quality is not always straightforward. Effective institutions can encourage environmental sustainability through impactful industrial regulations, efficient resource allocation and strict pollution control (Egbetokun and Ogundipe, 2016), whereas weak institutional frameworks may hinder environmental regulation and inadvertently facilitate environmental degradation. Thus, promotion of healthy institutional structures is paramount for promoting sustainable economic development and safeguarding environmental integrity.

The existing body of research consistently demonstrates a significant inverse relationship between the institutional attribute and environmental dilapidation. Robust institutions are pivotal in fostering environmental stewardship, as evidenced by numerous studies. Accessible information and political freedoms empower the public, facilitating the emergence of environmental interest groups. These groups are instrumental in enhancing environmental awareness and advocating for the implementation of stringent environmental regulations (Bernauer & Koubi, 2009; Dhrifi, 2018). Moreover, Danish and Ulucak (2020) emphasis that effective institutions are crucial for effective public financial management, enforcement rule of law, and abating corruption. By strengthening institutional quality and accountability, we can assist societies to address environmental challenges and maintain sustainable development for present and future generations.

Institutional effectiveness plays a vital role in shaping income distribution, as poor institutions often aggravating existing income inequality through inappropriate policies, lack of economic

opportunities and concentration of wealth or resources among affluent groups (Albertus & Menaldo, 2014). Research by Daniel et al. (2018) highlights the potential of institutional frameworks to address income inequality through efficient policymaking and market operations. However, several studies have found a positive link between high income inequality and weak institutional quality and emphasized that both underpin each other (Perera and Lee, 2013).

Moreover, there is a study that has demonstrated a significant association between the quality of institutional quality, environmental protection, and income inequality. It stated that effective institutions have the capacity to enhance environmental quality and diminish income difference in developing nations by formulating effective policies that address corruption and ensure rules of law. practically, full-bodied institutions not only contribute to environmental sustainability but also play a crucial role in promoting income equality, particularly in developing nations, through the implementation of efficient policies, reducing corruption, and ensuring social order (Yang et al., 2021).

Addressing environmental degradation and income inequality stands is central aim to the Sustainable Development Goals (SDGs). However, achieving these goals proves more challenging for developing nations compared to advanced economies, which must balance economic growth and environmental degradation while ensuring the fair distribution of income. Against this backdrop, this study focuses on South Asian and ASEAN countries to examine the interplay between economic growth, reducing income inequality, and institutional worth.

In ASEAN, environmental destruction is predominantly driven by shifting political economies and rapid industrialization. The growing demand for a modern lifestyle and consumption pattern propels industrial activity, increasing dependence on both renewable and non-renewable. Rapid urbanization has further increased the demand for energy, transport, housing and other amenities. Consequently, the average energy demand for ASEAN countries is estimated to rise by around 60% (Elliott, 2003). The combined effect of urbanization, industrialization, and lifestyle shifts underscores the pressing need for adoption of sustainable development strategies in South Asian and ASEAN nations to keep balance between the economic growth and environmental quality. These nations must navigate the complexities of economic growth, income distribution, and

environmental preservation to achieve the SDGs and ensure a sustainable future for their populations.

The surge in population across South Asian countries has fueled a notable uptick in urbanization, industrialization, and subsequently, increased traffic, all of which contributing significantly to air pollution in the region. This shift from agrarian to industrial economies has become a major driving force behind the GDP growth in South Asian nations (Sabir et al., 2019). Consequently, there has been a marked increase in the concentration of greenhouse gases, with South Asia accounting for roughly 6-7% of global emissions, a figure expected to climb (Kakakhel, 2012). These nations are grappling with a myriad of environmental challenges, including but not limited to glacier melting, land sliding, deforestation, intensified storms, seismic activity, flooding, loss of biodiversity, heat waves, water scarcity, and rising sea levels, many of which are intensified by climate change. Addressing the plight of these regions necessitates the implementation of stringent environmental policies and the establishment of robust institutional frameworks.

This study aims to determine the impact institutional effectiveness, and income inequality on environmental destruction in both ASEAN and South Asian economics. By studying these relationships, this study seeks to provide insights on how stronger institutions and lessening socioeconomic disparities can contribute significantly to environmental sustainability. The key innovation of this study lies in its utilization of the ecological footprint (EF) framework rather than relying on traditional metrics of carbon dioxide emissions as proxy of environmental destruction (Wackernagel and Rees, 1996). The ecological footprint offers a more holistic perspective by encompassing a broader array of factors such as land use, resource consumption, and waste production for the measurement of environmental sustainability. Moreover, the study applies the Panel Autoregressive Distributed Lag (ARDL) technique for estimation of dynamic relationship between economic growth, income inequality and environmental destruction across two different regions ASEAN and South Asia. This technique also addresses the econometric problem of heterogeneity, omitting variable bias, and endogeneity, thus yielding more reliable and insightful results.

This remainder of the study is organized into five sections. The theoretical background of the study is included in section two. Section three describes data and methodology. Section four presents the

results and discusses the findings of the study. Section five concludes the study and outlines the policy implications.

2. Theoretical framework

2.1. IPAT Identity

Ehrlic & Holdren (1972) stipulated the framework for IPAT framework as part of a its earlier debates on the drivers of environmental change (Commoner. 1972; Ehrlich &Holdren, 1971). The framework conceptualized the environmental change as function of three factor inputs, and it is given below:

$$I = P * A * T \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots . (1)$$

Where 'P' stands for population, 'A' for affluence or income per capita or consumption per capita, or economic activity per person, and 'T' for technology utilized to produce goods and services that has an environmental impact equal to one unit of economic activity, and 'I' shows the ecological impact. This equation 1 shows the environmental impacts are product function of P, A and T. By rearranging the equation 1 and value of T can be derived using the given values of A, P and I.

$$T = \frac{I}{PA} \qquad (2)$$

Since economic activity per capita is equal to A (affluence), it can also be obtained by reordering the equation as:

$$A = \frac{GDP}{P} \qquad (3)$$

By inserting estimated value of A in equation 2

$$T = I/P(\frac{GDP}{P})$$

$$T = \frac{1}{GDP} \qquad (4)$$

In the backdrop of IPAT framework, T measures the environmental effect of per unit of economic activity, P is measured with population (P), A is captured with GDP per capita, and CO_2 emission per unit of GDP (A) are used in IPAT model to calculate the environmental effect (I).

To provide the rigorous impact of population and economic activities on environmental sustainability, ImPACT of Wagoner and Ausubel (2002) is considered as an improvement over IPAT, and it is decomposed T into two components, i.e., consumption per unit of GDP per capita and retained CO_2 intensity of consumption (T). One of the main drawbacks of both identities is that until the missing terms are found because of known terms, it does not allow hypothesis testing.

2.2. STIRPAT Model

Dietz & Rosa (1997) introduced stochastic regression by taking Population, Affluences and Technology (STIRPAT) as independent variables and measured their impact on environmental quality, which enables hypothesis testing. The STIRPAT model is described as follows:

$$I_i = a\ P_i^b A_i^c T_i^d\ e_i \qquad (5)$$

Here, P, A, and T are estimated using parametric shares b, c and d respectively, i is the cross section of countries, a is constant, and e is an error term. The features of the model include all of them being in logarithmic form, which makes it simple to estimate models with all the terms in logarithmic form. As:

$$lnI_i = a + \beta_1 lnP_i + \beta_2 lnA_i + \beta_3 lnT_i + e_i \qquad (6)$$

Where unknown parameters (βs) are to be estimated, and these parameters are also entitled ecological elasticity. The parameters β_2 and β_1 show change in environmental quality because of change in P and A. however, technological elasticity has not been measured in the literature, and it is clubbed with the error term. So, the equation 6 is modified as:

$$lnI_i = a + \beta_1 lnP_i + \beta_2 lnA_i + e_i$$

Moreover, the STIRPAT model has the flexibility to include all other theoretically justified variables other than the three fundamental factors given above (York et al., 2003). This study

builds on STIRPAT and includes institutional quality measured with control of corruption and income disparity proxied with Gini coefficient as significant elements that influence environmental quality. The ecological footprint is used as a dependent variable to measure environmental impact (I), and trade, GDP per capita, and energy consumption are used as controlled variables and the equation is specified as:

$$lnI_{it} = a + \beta_1 lnP_{it} + \beta_2 lnA_{it} + \beta_3 lnCORRUPT_{it} + \beta_4 lnGINI_{it} + e_i \quad (7)$$

3. Methodology and Data

The study employs the following econometric model based on the established theoretical framework.

$$EF_{it} = \beta_o + \beta_1 GDPp_{it} + \beta_2 GDPp^2{}_{it} + \beta_3 GINI_{it} + \beta_4 CORRUPT_{it} + \beta_5 TO_{it} + +\beta_6 EU_{it} + u_{it} \quad (8)$$

Where, i is the number of nations chose for the analysis based on availability of data and t is the time interval from 1985 to 2025. EF stands for ecological footprint, which serves as a stand-in for degradation of the environment and it is made up of six parts: carbon land, built-up land, grazing land, fishing ground, and forest product. , GDPp is the gross domestic product (GDP) per capita which is used as a proxy of economic growth, and its square term $GDPp^2$ is included to measure the non-linear effect of economic growth on environmental degradation. The GINI coefficient is used to measure income inequality, CORRUPT is an indicator of institutional effectiveness, TO is trade openness (TO) shows the integration of economic in trade of goods and services, and EU is energy consumption across various economic activities, respectively.

The study employs panel data for a subset of South Asian and ASEAN countries due to data constraint. The years, which range from 1985 to 2022, are likewise chosen based on the data that is currently available. The World Development Indicator (WDI) is the source of GDP, trade openness, and energy consumption statistics. The Global Footprint Network is the source of ecological footprint data. Data of corruption is retrieved from the International Country Risk Guide (ICRG). Data on income disparity is collected using the Standard World Income Inequality Database, or SWIID.

3.1. Estimation Technique

The current study estimates the following model to examine the relationship between environmental deterioration and wealth inequality and institutional quality:

$$\ln(EF_{it}) = \beta_o + \beta_1 \ln(GDPp_{it}) + \beta_2 \ln(GDPp_{it})^2 + \beta_3 \ln(GINI)_{it} + \beta_4 TO_{it} + \beta_5 \ln(EU)_{it} + \beta_6 CORRUPT_{it} + u_{it} \quad (9)$$

$$\ln(EF_{it}) = \beta_o + \beta_1 \ln(GDPp_{it}) + \beta_2 \ln(GDPp_{it})^2 + \beta_3 \ln(GINI)_{it} + \beta_4 TO_{it} + \beta_5 \ln(EU)_{it} + u_{it} \quad (10)$$

$$\ln(EF_{it}) = \beta_o + \beta_1 \ln(GDPp_{it}) + \beta_2 \ln(GDPp_{it})^2 + \beta_3 CORRUPT_{it} + \beta_4 TO_{it} + \beta_5 \ln(EU)_{it} + u_{it} \quad (11)$$

$$\ln(EF_{it}) = \beta_o + \beta_1 \ln(GDP_{it}) + \beta_2 \ln(GDP_{it})^2 + \beta_3 \ln(GINI)_{it} + \beta_4 TO_{it} + \beta_5 \ln(EU)_{it} + \beta_6 CORRUPT_{it} + \beta_7 GINICORR_{it} + u_{it} \quad (12)$$

The unit root test is prior to verifying the stationarity of the variables before the estimation of the models. While the standard model presumes that the chosen variables are either stationary or integrated of order I(0), spurious regression can result in biased estimators when the variables observed volatility.

Panel data method offers several advantages of having a higher degree of freedom and remedies multicollinearity and improves estimation efficiency. On the other hand, in case of non-stationarity in the variables, the existence of cross-sectional dependency is obvious because it provides the opportunity to resolve the problems related to the unit root tests. However, various panel data techniques often fail to account the cross-section dependence among cross section units (Hsiao, 2005). This study uses Langrange Multiplier (LM) test proposed by Breusch and Pagan (1980) to assess the existence of cross-sectional dependency.

In cases where cross-sectional independence exists in the variables, as reported by earlier research studies of Harris and Tzavalis (1999), Levin and Lin (1993), and Choi (2001). Pesaran (2007) used a panel unit root test that addresses the potential problem of cross-sectional dependency among cross section units. Using the starting difference of each individual series and the cross-sectional

averages of the lagged levels, a standard Augmented Dickey Fuller regression is employed for the test. This study employs Augmented Dickey Fuller test to examine the stationarity in the selected variables.

3.2. Panel Co-integration

Economic theory may suggest the existence of the long-term cointegrating relationship among the chosen variables, but its empirical reliability can be established using appropriate panel cointegration technique. A residual based cointegration test may enable us to accept the null hypothesis of long run relationship between the variables (Pedroni, 2004). Alternatively, Westerland (2007) proposed a panel co-integration test based on structural dynamics rather than residual dynamics. This technique does not impose any common factor restrictions and examines the significance of the error correlation term to estimate whether long run relationship exists among the variables. Under Westerland's error correction model, rejection of null hypothesis suggests that the entire panel is co-integrated. To estimate both long-term and short-term coefficients where there is co-integration between the variables, the Panel ARDL approach can be utilized.

The pooled mean group (PMG) technique is used for estimating dynamic nonstationary panel data models (Pesaran and Smith,1995) and the PMG approach is also known as Panel ARDL. The short-run (SR) and long-run (LR) relationships between the variables can be found using the panel ARDL approach. This is one way to express the panel ARDL equation:

$$y_{it} = \sum_{j=1}^{p} \gamma_{ij}\, y_{i,t-j} + \sum_{j=1}^{q} \lambda_{ij}\, x_{it} + \epsilon_i + e_{it} \qquad 13$$

The dependent variable is denoted by y_{it}, vector of explanatory or independent variables to be estimated is represented by x_{it}, the fixed effects are denoted with ϵ_i, and the error term represents (k x 1) vector of independent variables. Equation 13 is converted into an error correction model and specified as

$$\Delta y_{it} = \phi_i\left(y_{i,t-1} - \alpha'_i x_{i,t-1}\right) + \sum_{j=1}^{P-1} \gamma_{ij}\Delta y_{i,t-j} + \sum_{j=1}^{q-1} \lambda'_{ij}\Delta x_{i,t-j} + \epsilon_i + e_{it} \qquad 14$$

Where the error correction term is denoted by $\phi_i(y_{i,t-1} - \alpha'_i x_{i,t-1})$, LR coefficients are denoted by α'_i, and the error correction term (ECT) that show the adjustment of speed to LR equilibrium are represented by ϕ_i. If coefficient of ECT has negative sign and is statistically significant, then it provides the evidence of stable long-term relationship among the variables.

4. Results and Discussions

The Breusch & Pagan LM test and the Pesaran cross-sectional dependence test are used to examine cross-sectional dependency and determine whether it exists. The outcomes for LM test of Breusch & Pagan, and LM test of Pesaran for ASEAN and South Asian countries are presented in the table 1.

Table 1: Cross sectional dependence test for ASEAN countries

	Breusch and Pagan	**Pesaran Scalad**	**Conclusion**
LN(EF)	174.011***	28.310***	CD present
	(0.000)	(0.000)	
LN(GDPp)	213.870***	65.357***	CD present
	(0.000)	(0.000)	
$LN(GDPp)^2$	302.537***	60.041***	CD present
	(0.000)	(0.000)	
LN(GINI)	156.102***	62.250***	CD present
	(0.000)	(0.000)	
CORRUPT	58.541***	23.538***	CD present
	(0.000)	(0.000)	
TO	44.658***	24.824***	CD present
	(0.000)	(0.000)	
LN(EU)	117.215***	47.542***	CD present
	(0.000)	(0.000)	

Note: *, **, *** indicates the level of significance at 10%, 5% and 1% respectively.

Table 2: Cross sectional dependence test for South Asian countries

	Breusch pagan	Pesaran scaled	Conclusion
LN(EF)	87.131***	58.110***	CD present
	(0.000)	(0.000)	
LN(GDPp)	145.720***	47.651***	CD present
	(0.000)	(0.000)	
$LN(GDPp)^2$	168.110***	37.645***	CD present
	(0.000)	(0.000)	
LN(GINI)	174.489***	35.280***	CD present
	(0.000)	(0.000)	
CORRUPT	32.107***	6.890***	CD present
	(0.000)	(0.000)	
TO	68.118***	26.001***	CD present
	(0.000)	(0.000)	
LN(EU)	180.750***	58.507***	CD present
	(0.000)	(0.000)	

Note: *, **, *** indicates the level of significance at 10%, 5% and 1% respectively.

The results presented in table 1 show that variables are statistically significant at the 1% level, and these confirm the rejection of null hypothesis of cross-sectional dependence. This advocates that a shock occurs in one country can have ripple effects on other countries in the chosen sample. According to Sabir et al. (2020), one of the major factors responsible for the cross-sectional reliance between the countries in terms of capital inflow, international trade, and globalization.

Owing to their geographical characteristics, ASEAN and South Asian countries are at the far front of the climatic changes and natural calamities in the form of cloudbursts, floods, draughts, earthquakes, hailstorms, and heat waves. The frequent occurrence of these hazards has intra-regional and inter-regional impacts in the form urban air pollution, water contamination and trans-border pollutions. These frequent interconnected environmental challenges reinforce the importance of addressing CD in panel data analysis. Moreover, the presence of CD among cross sections of countries supports the use of the second-generation unit root test.

4.1. Second Generation Panel Unit Root Test

This study has applied the Pesaran CADF test after testing for cross-sectional dependence in the previous section since the first-generation unit-root test became inconsistent due to the presence of CD among the variables (Bretung & Pesaran, 2005). Table 3 displays the Pesaran CADF test results.

Table 3: Results for Pesaran CADF test for ASEAN countries:

	Level		1st difference			
	Constant	Trend	Constant	Trend	Findings	
LN(EF)	-1.652	-2.148	-3.418***	-5.321***	I(1)	
	(0.880)	(0.415)	(0.000)	(0.000)		
LN(GDPp)	-3.615	-2.491	-2.116***	-3.326***	I(1)	
	(0.250)	(0.729)	(0.000)	(0.022)		
$LN(GDPp)^2$	-3.261	-2.790	-2.116***	-4.963***	I(1)	
	(0.118)	(0.490)	(0.001)	(0.007)		
LN(GINI)	-3.600	-1.546	-2.885**	-3.378***	I(1)	
	(0.815)	(0.928)	(0.030)	(0.010)		
CORRUPT	-4.216***	-3.550***	-4.812***	-3.175***	I(0)	
	(0.000)	(0.000)	(0.000)	(0.000)		
TO	-2.211	-2.671	-2.157***	-5.103***	I(1)	
	(0.689)	(0.719)	(0.000)	(0.000)		
LN(EU)	-3.203	-2.150	-3.625***	-4.881***	I(1)	
	(0.907)	(0.333)	(0.000)	(0.000)		
GINICORR	-4.251	-3.154***	-3.289***	-3.157***	I(0)	
	(0.000)	(0.000)	(0.000)	(0.000)		

Note: *, **, *** indicates the level of significance at 10%, 5% and 1% respectively.

The results presented in table 3 show a mixed order of integration among the variables for the selected ASEAN economies. GDP per capita, its square term, energy use, trade openness, ecological footprint, and GINI coefficient are all regarded as integrated at order one I(1) and it

means that variables have become stationary at first difference. Conversely, corruption is integrated of I(0). None of the variables are integrated into order 2.

Table 4: Pesaran CADF test for South Asian Countries

	Level		1st difference		
	Constant	Trend	Constant	Trend	Findings
LN(EF)	-1.280	-1.358	-3.321***	-3.541***	I(1)
	(0.133)	(0.819)	(0.000)	(0.016)	
LN(GDPp)	-2.525	-2.880	-3.620***	-3.361***	I(1)
	(0.220)	(0.318)	(0.001)	(0.003)	
$LN(GDPp)^2$	-3.050	-3.632	-3.510***	-3.882***	I(1)
	(0.148)	(0.250)	(0.001)	(0.010)	
LN(GINI)	-1.118	-1.812	-3.615***	-4.714***	I(1)
	(0.270)	(0.480)	(0.000)	(0.000)	
CORRUPT	-2.817**	-3.860***	-3.751***	-3.618***	I(0)
	(0.040)	(0.000)	(0.000)	(0.000)	
TO	-1.812	-1.679	-3.445***	-3.417**	I(1)
	(0.421)	(0.812)	(0.000)	(0.020)	
LN(EU)	-1.229	-1.770	-3.564***	-3.211***	I(1)
	(0.266)	(0.750)	(0.000)	(0.000)	
GINICORR	-2.207**	-3.173***	-3.618***	-3.217***	I(0)
	(0.040)	(0.001)	(0.000)	(0.000)	

Note: *, **, *** indicates the level of significance at 10%, 5% and 1% respectively.

Regarding the sequence of integration for selected of South Asian nations, table 4 shows contradictory findings. Because they are stationary at first difference, the variables ecological footprint, GDP, its square, trade openness, GINI coefficient, and energy consumption are I(1). On the other hand, the GINI coefficient is stable at constant and integrated at I(0). Not a single variable is integrated at I(2).

4.2. Westerlund Panel Co-integration Test

The co-integration is tested using a variety of methods, including Pedroni (1999), Kao (1999), and Westerlund (2007). The long-term association and co-integration between the variables are examined in this study using the Westerlund (2007) test. The Westerlund test findings for ASEAN and South Asian nations are displayed in Table 5.

Table 5: Results of Westerlund panel co-integration test for ASEAN countries

	Model 1	Model 2	Model 3	Model 4
Westerlund test	-2.510**	-2.280**	-2.742**	-2.318**
	(0.011)	(0.010)	(0.010)	(0.010)

Note: *, **, *** indicates the level of significance at 10%, 5% and 1% respectively.

Table 6: Results of Westerlund panel co-integration test for South Asian countries

	Model 1	Model 2	Model 3	Model 4
Westerlund test	-1.227**	-1.270**	-1.363**	-1.475**
	(0.010)	(0.003)	(0.003)	(0.001)

Note: *, **, *** indicates the level of significance at 10%, 5% and 1% respectively.

Tables 5 and 6 display the results of the Westerlund panel co-integration test for the ASEAN and South Asia countries, respectively. The results show that the variables are co-integrated at the 5% level of significance, supporting the long-term link among the variables. We can use the panel ARDL technique to estimate the effect of all independent variables on dependent variables, like an ecological footprint, as the Westerlund test findings suggest that the variables are co-integrated.

4.3. Pooled Mean Group Test (PMG)

Having established the existence of a long-run co-integration among variables using WL test, this study uses the panel ARDL test using PMG estimator. The empirical results are shown in table 7.

Table 7: Results for Panel ARDL test for ASEAN countries

Variables	Model 1	Model 2	Model 3	Model 4
LONG RUN COEFFICIENTS				
LN(GDPp)	2.114***	3.305***	0.512*	3.580***
	(0.001)	(0.000)	(0.076)	(0.000)
LN(GDPp)2	-0.127***	-0.237***	-0.089	-0.290***
	(0.002)	(0.000)	(0.510)	(0.000)
LN(GINI)	3.280***	3.120***		1.598***
	(0.000)	(0.000)		(0.030)
CORRUPT	0.289***		0.108***	-4.719***
	(0.000)		(0.000)	(0.003)
TO	0.011***	0.008**	0.012***	0.011***
	(0.001)	(0.076)	(0.000)	(0.000)
LN(EU)	0.768***	0.366***	0.315**	0.420***
	(0.000)	(0.000)	(0.020)	(0.000)
GINICORR				2.805***
				(0.003)
SHORT RUN COEFFICIENTS				
EC	-0.407***	-0.472***	-0.317***	-0.467***
	(0.000)	(0.000)	(0.010)	(0.000)
LN(GDPp)	6.914***	5.273***	9.325***	6.314***
	(0.000)	(0.000)	(0.000)	(0.000)
$LN(GDPp)^2$	-0.625***	-0.579***	-0.628***	-0.774***
	(0.000)	(0.000)	(0.000)	(0.000)
LN(GINI)	0.726	0.050		0.130
	(0.961)	(0.317)		(0.645)

CORRUPT	0.013		0.030	1.687
	(0.514)		(0.661)	(0.194)
TO	-0.007***	-0.004	-0.006	-0.005**
	(0.000)	(0.110)	(0.305)	(0.057)
LN(EU)	-0.122	0.012	0.025	-0.068
	(0.296)	(0.657)	(0.692)	(0.643)
GINICORR				-4.621
				(0.150)
C	-10.224***	-11.717***	-0.667**	-10.691***
	(0.001)	(0.000)	(0.040)	(0.001)

Note: *, **, *** indicates the level of significance at 10%, 5% and 1% respectively.

According to Model 1 in Table 7, GDPp has statistically significant, and positive effect on ecological footprint in short and long-term. A 1% rises in GDPp led to increase in ecological footprints of 2.114% and -0.127%. GDPp square has a significant negative relationship with ecological footprints over both the long and short term, at the 1% significance level. The ecological footprint reduces by 0.127% over the long term and by 0.625 % in the short term for every 1% growth in GDP per capita square. The data in this table 7 offers additional evidence to the EKC hypothesis, which assumes an inverse U-shaped relationship between GDPp and environmental destruction or degradation over time. As a result, once the optimum level is reached, the relationship between GDPp, and ecological footprints turns out positive. Previous studies also supported these findings (Sabir & Ghorus, 2019; Al-Mulali et al., 2014; Shehbaz et al., 2015). Long-term income inequality has a favorable influence on the ecological footprint; in the short term, however, it becomes insignificant. The findings show that an increase in income inequality of 1% caused a rise in the ecological footprint of 0.617%. Intensified income inequality causes environmental deterioration because governments in high-income inequality countries tend to prioritize income inequality issues over environmental policies (Akbas & Lebe, 2021).

At the 1% significance level, corruption has a long-term, considerable beneficial impact on ecological footprint, but in the short-term, it has insignificant effect. The study indicates that for

every unit rise in corruption, the ecological footprint increases by 0.289 units. Direct corruption diminishes the enactment of environmental regulations, which worsens the state of the environment. Because they are subject to bribery, administrators in charge of enforcing environmental laws are willing to approve environmentally dangerous actions (Damania, 2002). The end result are aligned with the studies carried out by Cole (2007), Welsuch (2004), and Damania et al. (2003). In both the short and long terms, trade openness is relevant at the 1% level of significance. Long-term data indicates a positive relationship between trade openness and ecological footprint, with 1% higher trade openness translating into a 0.011% increase in ecological footprint. The findings are supported by the study of Jozwik et al., (2022). The chosen countries are growing economies, and increased trade with these nations promotes growth and increased industrial and environmental contamination (Gozgor, 2017). Energy consumption affects the ecological footprint in a favorable and statistically meaningful way over the long run but has negative short-term effects. The empirical data show that an increase in energy use of 1% correlates to an increase in the ecological footprint of 0.768%. Fossil fuels, such as gas, coal, and oil, account for the bulk of energy consumed in South Asian countries and have a considerable effect on greenhouse gas emissions, particularly carbon dioxide. Wasteful energy consumption methods have a adverse effect on the environment. The findings are aligned with the studies carried in past (Heidari et al., 2015; Wang et al., 2016; Siddique et al., 2016).

All other independent variables in model 2 stay the same while the institutional quality variable is eliminated. The empirical results show that the ecological footprint increases in the short term and in the long term for every 1% growth in GDPp but GDPp square has significant negative short- and long-term association with EF. It demonstrates that GDPp and ecological footprint have an inverse U-shaped connection, hence supporting the facts of the EKC hypothesis. The long-term results for energy consumption, income inequality, and trade openness are similar with the findings of estimated model 1. A 1% rise in income inequality augmented the ecological footprint by 3.120%. Trade openness is positive, but its impact is slightly less as compared to model 1, 1% rise in trade openness cause 0.008% increase in ecological footprint. In case of energy use, 1% rise in energy use causes 0.366% increase in ecological footprint. The impact of trade openness, income inequality and energy use on EF are insignificant in short run.

In Model 3, economic inequality is replaced with institutional quality. Under both the short and long perspectives, the results indicated a statistically significant positive relationship between GDPp and ecological footprint. For every 1% increase in GDPp, the ecological footprint grows by 0.512%. The statistical significance of GDPp square is destructive, with an inverted U-shaped connection with EF. Overall, there is a large positive association between institutional quality and ecological footprint over the long term; its effect is insignificant in the short term. Energy use and trade openness have long-term benefits and are insignificant in the short term. A cross-section term called GINICORR is incorporated into model 4. The findings demonstrate the importance and long- and short-term benefits of GDPp. The ecological footprint might increase by 6.314 in the short term and 3.580% in the long run for every 1% increase in GDP per person. GDP per capita revealed an inverted U-shaped association and are statistically significant in both the short and long run, in line with the previous model. Income disparity has a long-term positive statistical significance. The ecological footprint increases by 1.598 % for every 1% increase in inequality of income. In the short term, its impact is insignificant. Although the corruption is insignificant in the short term, it is positive and significant over the long term at the 1% significance level. Both trade openness and energy use are important in the long run. Energy use is insignificant in the short run, but trade openness has a negative relationship with EF. The cross-section term has a long-term positive correlation with ecological footprint but is statistically insignificant in the short term. In every model, the error correction term, which describes the short-term relationship between variables, is statistically significant and negative.

Table 8: Results for Panel ARDL test for South Asian countries

Variables	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Long run Coeffficients				
LN(GDPp)	2.214***	3.200***	5.287***	4.312***
	(0.000)	(0.000)	(0.000)	(0.000)
LN(GDPp)2	-14.291***	-12.314***	-16.665***	-16.287***
	(0.001)	(0.000)	(0.000)	(0.000)
LN(GINI)	3.116***	2.223***		0.812**

	(0.000)	(0.001)		(0.020)
CORRUPT	0.054**		0.026**	0.073*
	(0.015)		(0.023)	(0.017)
TO	0.011**	0.012**	0.010*	0.088*
	(0.050)	(0.050)	(0.060)	(0.045)
LN(EU)	0.412***	0.205**	0.363**	0.020**
	(0.010)	(0.020)	(0.010)	(0.010)
GINICORR				0.032*
				(0.061)
SHORT RUN COEFFICIENTS				
EC	-0.314*	-0.382***	-0.349***	-0.382***
	(0.066)	(0.000)	(0.000)	(0.000)
LN(GDPp)	-0.918*	0.680*	2.561**	-6.720*
	(0.073)	(0.080)	(0.046)	(0.095)
LN(GDPp)2	6.477	-5.365	-6.517*	-6.313*
	(0.120)	(0.115)	(0.100)	(0.100)
LN(GINI)	-1.283**	-2.068		-0.516
	(0.044)	(0.252)		(0.365)
CORRUPT	-0.030		-0.040	5.662**
	(0.315)		(0.128)	(0.016)
TO	0.018**	0.010**	0.004**	0.067
	(0.045)	(0.033)	(0.040)	(0.165)
LN(EU)	-0.124**	-0.128**	-0.159**	-0.008**
	(0.041)	(0.025)	(0.030)	(0.030)
GINICORR				-1.664***
				(0.010)

C	10.128**	8.054***	8.318***	8.724***
	(0.065)	(0.010)	(0.010)	(0.000)

Note: *, **, ***indicates the level of significance at 10%, 5% and 1% respectively.

The outcomes of panel ARDL for South Asian countries are shown in Table 8. The empirical findings in model 1 demonstrate that, at the 1% level of significance, GDPp is significant and positively correlated with ecological footprint. A 1% increase in GDPp results in 2.214 % long-term increase in ecological footprint. Additionally, GDPp square has a long-term, inverted U-shaped relationship with ecological footprint and is statistically significant. The long-term inverted U-shaped relationship between GDPp and ecological footprint is hypothesized by the EKC hypothesis, which is also supported by these findings. It reveals that initially GDP per capita affects environment deterioration positively, however, increase in GDP per capita after achieving an optimal point is helpful in diminishing environmental degradation. These findings are confirmed by previous studies (Sabir & Gorus 2019).

The ecological footprint is positively impacted by inequality in income over the long term at a 1% significance level, although its short-term effects are insignificant. The results reveal that a 1 unit rise in GINI leads to a 3.116-unit increase in ecological footprint. The greater income disparities lead to environmental destruction because, when income inequalities are high, the government focuses more on addressing income inequality rather than environmental strategies. (Akbas & Lebe, 2021).

Long-term effects of corruption are beneficial and significant at the 5% significance level, whereas short-term effects are negative. The results indicate that a 1-unit rise in corruption causes a 0.054-unit rise in ecological footprint. The results are consistent with the study of Yandle et al., (2019) which shows that environmental quality improvements provided that institutions are efficient enough to impose environmental standards and regulations.

Both in the short and long terms, trade openness is statistically significant at the 5% significance level. Long-term data implies a optimistic relationship between ecological footprint and trade openness, with 1% more trade openness converting into a 0.011% increase in ecological footprint. The results are well-suited with the study of Ling et al., (2020) and Jozwik et al., (2022). Firmansyah & Oktavila (2016) found that trade openness mounts the CO_2 emission growth that

threatens environment. The members of ASEAN, the more trade more that enhances growth which raises industrial impurity and environmental contamination (Gozgor, 2017; Acar & Asici, 2016).

The ecological footprint is positively and statistically significantly impacted by long-term energy use, although short-term effects are insignificant. An increase of 1% in energy use increases in ecological footprint by 0.412%. Fossils fuels including coal, oil, and gas are usually used to produce energy in South Asian nations, which results in significant emissions of greenhouse gases.

Model 2 shows an inverted curved relationship between GDPp and ecological footprint, confirming the existence of the EKC hypothesis. The findings demonstrate a strong and positive long- and short-term link between GDPp and ecological footprint, with a rise in GDPp, ecological footprint also increases. The long-term effects of energy consumption, income inequality, and trade openness are similar with the findings of model 1 and are positively and significantly correlated with ecological footprints. There is a 2.223% increase in the ecological footprint for every 1% increase in disparity in income. The ecological footprint increases by 0.010% for every 1% growth in trade, demonstrating the positive and important effects of economic openness. An increase in energy use of 1% leads to an increase in the ecological footprint of 0.205%. Additionally, these three factors have a significant short-term impact.

In model 3, the study substitutes institutional quality for economic inequality. The findings showed that, both over the long and short term, GDPp and ecological footprint are positively and strongly correlated. The statistically significant inverted U-shaped association between GDPp square and ecological footprint indicates a negative relationship. This strengthens the validity of EKC hypothesis. Institutional quality has positive link with ecological footprint in long term, and it is statistically significant at the 5% significance level but insignificant in the short term. Trade openness and energy usage have favourable long-term and short-term effects on EF.

The estimation of model 4 includes an interaction term of GINI coefficient and corruption called GINICORR. To evaluate the model's strength, this phrase has been included. The findings demonstrated the long-term positive and considerable impact of GDPp. Like the previous model, the square of GDPp also produced statistically significant results with an inverted U-shaped relationship. With a 1% increase in income inequality resulting in a 0.812% increase in the ecological footprint, income inequality is both large and positive over the long term. Both in the

short and long term, the institutional quality is likewise significant and positive at the 10% significance level. In the long run, energy consumption and trade openness are significant and advantageous to the environment. However, there is a short-term negative and significant link between energy use. The interaction term is not important in the short term, but it is significant and positively connected with ecological footprint in the long run. The short-term relationship between the variables is indicated by the error correction term, which is substantial and negative.

5. Conclusion and Policy Recommendations

Environmental contamination has emerged as a great challenge that is facing all countries globally. A lot of efforts have been put up by countries to cope with this issue. Environmental destruction badly affecting the South Asian and ASEAN countries due to massive industrialization, urbanization and extensive use of fossils fuel. The region is vulnerable to climatic changes such as melting of glaciers, land sliding, floods, earthquakes, water scarcity, mounting sea level, and increasing temperature.

This study looked at how certain South Asian and ASEAN economies' institutional eminence and income inequality affected environmental devastation. To achieve its goals, the study employed panel data covering the years 1985–2025. The study's initial step is to confirm whether a cross-section dependence existed among the variables using the cross-sectional dependence test. The study further demonstrated that all the variables were integrated of I(0) or I(1), had different orders of integration, and none of the variables were integrated of I(2). This was confirmed by using a second-generation unit root test due to the presence of cross-sectional dependency among variables. Following the unit root test, the Westerlund co-integration test is used to confirm the long-term relationship between the variables. To estimate the models, the study used the Panel ARDL technique.

The empirical findings showed that the EKC hypothesis has appeared in all estimated models for ASEAN and South Asian nations. There is an inverted U-shaped relation between the variables which showed that initially increasing growth causes environmental degradation and after attaining an optimal point it starts declining environmental degradation because of the use of environment-friendly technologies. The results also revealed that corruption has a significant and positive impact on environmental deterioration. When the institutions are not weal, there is a decline in the

execution of environmentally friendly policies which further reduces the quality of the environment. The bureaucrats who are responsible for the implementation of the environmental regulations are exposed to receiving bribes and allow damaging environment. GINI coefficient has also significant and positive impact on environmental deterioration, the greater income inequalities cause more environmental degradation because the countries where income inequalities are high, the government try to fix the issues of income inequality rather than environmental policies.

Trade openness is positive and significantly impacts environmental degradation, as increase in trade causes growth and industrialization, which in turn causes environmental degradation. Degradation of the environment was also strongly favourably impacted by energy consumption. Burning coal and other fossil fuels provide the bulk of the energy consumed in South Asian and ASEAN countries but doing so results in large emissions of carbon dioxide and other greenhouse gases. Accordingly, the findings indicated that every factor is causing the environment to deteriorate.

6. Policy Recommendations

Following are some recommendations, based on the findings of the study:

- Corruption is observed to have a positive and significant impact on environmental degradation. High corruption causes delays in government policies made or the environment, which result in damage of environmental quality. The regulatory policies of environment need to be imposed more strictly through better control of corruption therefore, the environmental deterioration in future can be reduced in the region.
- Income inequality also showed a positive and significant impact on ecological footprint. Higher inequalities can cause higher environmental degradation. Sound institutions are needed to cope with this issue. If the institutions are sound and implementing the rules and laws and controlling corruption, they can make effective policies to reduce income inequalities.
- The results also consistently show that, in the selected economies of South Asia and ASEAN, increased energy use is associated with environmental degradation. To improve the region's energy efficiency, a shift from environmentally harmful energy sources to renewable energy sources is needed. To limit carbon emissions in the region, investments should also be made in energy-saving projects.

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