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Integration Ecological and Economic Factors in Shaping Human Development: Evidence from ASEAN Countries

Madris Madris[1]*, Muhammad Ridwan Manulusi[2], Amanus Khalifah Fil'ardy Yunus[1], Munawwarah S. Mubarak[1]

[1]Department of Economics, Faculty of Economics and Business, Hasanuddin University, Indonesia, [2]Student of Economics Doctoral Program, Faculty of Economics and Business, Hasanuddin University, Indonesia. *Email: madris@fe.unhas.ac.id

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ABSTRACT

In an era of unprecedented environmental challenges and socioeconomic disparities, evaluating human development by integrating ecological and economic dimensions has proven essential. This study examined the impact of environmental and economic factors on the Human Development Index in seven ASEAN countries using panel data collected from 1996 to 2022. We employed the Fully Modified Ordinary Least Squares (FMOLS) approach and confirmed the robustness of our results with Canonical Cointegrating Regression (CCR) and Dynamic Ordinary Least Squares (DOLS). Our findings revealed that an increase in ecological footprint per capita was associated with a reduction in the Human Development Index, whereas rises in gross domestic product, industrialization, foreign direct investment, and population density were found to enhance human development. These results highlighted the limitations of conventional measures of human development, which often ignore long-term ecological constraints. The study provided policy insights for designing balanced, sustainable, and equitable development strategies that harmonized economic growth with environmental protection. Future research should expand data coverage and apply advanced econometric techniques better to capture the complex interactions between economic and ecological factors. Policymakers can use these insights to inform strategies that promote both prosperity and environmental resilience.

Keywords: Human Development Index, Ecological Footprint, Economic Growth, Sustainable Development, ASEAN Countries
JEL Classifications: Q56, O15, O14, F21

1. INTRODUCTION

Human development is crucial for enhancing people's quality of life amidst a prevailing health crisis, persistent educational inequality, and mounting economic pressures. Measuring human development through indicators such as life expectancy, educational attainment, and per capita income reflects essential efforts to address disparities and improve overall well-being (Kohli and Singh, 2020; Tan, 2021; Urzúa and Vilbert, 2023). Researchers and policymakers have often used the Human Development Index (HDI) to assess socio-economic well-being regarding education, health, and income (Land, 2015; Dasic et al., 2020).

The decline in the global HDI during 2020 and 2021 was unprecedented, resulting in significant and irreversible losses, including the deaths of millions of people. Although the global HDI increased in 2022 and was projected to continue rising in 2023, the recovery remains uneven (UNDP, 2024). The recovery of countries within the Organisation for Economic Co-operation and Development (OECD) is expected to reach or exceed their 2019 HDI levels fully. However, 51 percent of the world's poorest nations, representing approximately 328 million people, are unlikely to undergo a similar recovery path (UNDP, 2024). Significant differences still exist among ASEAN countries, even with the global improvement in human development indicators. Recent data from UNDP (2024) show that while advanced economies like Singapore, Malaysia, and Brunei consistently report HDI scores exceeding 0.90, reflecting robust healthcare systems, high educational attainment, and strong per capita incomes, other nations in the region, such as Cambodia, Laos, and

Myanmar lag considerably, with HDI values falling below 0.60. These figures underscore a pronounced development gap, where even within a single region, the quality of life and access to critical social services vary widely due to structural vulnerabilities and uneven resource allocation.

Traditionally, development refers to achieving sustainable per capita income growth, expecting increased income to drive economic growth, create opportunities, and improve welfare distribution more equitably (Majerník et al., 2021). To provide a more comprehensive assessment of socioeconomic progress, the UNDP introduced HDI in 1990, later updating it in 2010 to adopt a broader perspective (Swargiary, 2020; Urzúa and Vilbert, 2023). Since its inception, the HDI has been an alternative indicator for evaluating a country's development alongside Gross Domestic Product (GDP) (Dasic et al., 2020; Tan, 2021).

Although many countries have shown high achievements in the HDI, this index has been criticized for its lack of attention to environmental impact (Assa, 2021; Pocaterra et al., 2022). This criticism has arisen because the world has undergone drastic changes; from a world once dominated by an abundance of natural resources and a lack of artificial infrastructure, it has now transformed into an order where natural resources are increasingly limited while artificial infrastructure is abundant (Daly, 2020; Victor, 2021). This change signals a fundamental shift in the availability of both natural and artificial capital, affecting how we assess welfare and development.

Geologically, the Holocene era, once defined by natural evolution and stable ecosystems, has been replaced by the Anthropocene era, where human activity drives global environmental change and pushes ecological boundaries (Foster, 2017; Wackernagel et al., 2021). In the Holocene era, environmental conditions supported civilization's natural growth and development. In contrast, in the Anthropocene era, the pressures of resource exploitation and increasing emissions, such as global warming, have become pressing issues (Zhang and Zhu, 2022; Dayananda, 2023). Therefore, the assessment of human development must be revised to reflect the new reality in which ecological aspects play a crucial role in determining the quality of life.

The transition from the Holocene to the Anthropocene further emphasizes the importance of incorporating ecological considerations into measuring human development. This study highlights the shortcomings of conventional indicators, which generally ignore long-term environmental limits. By integrating ecological factors into the assessment, this study emphasizes the close link between economic growth, social well-being, and environmental resilience. The results inform policymakers in designing development strategies that are balanced, sustainable, and equitable for future generations.

2. LITERATURE REVIEW

Economic growth is pivotal in enhancing the Human Development Index (HDI), primarily through urbanization and an increase in household income (Yunus et al., 2024). An empirical analysis of 187 countries from 1990 to 2017 revealed that the total urban population, growth rate, and proportion of people residing in large urban centers have a positive impact on the HDI. However, concentrating a more significant population share in the largest city may negatively impact development due to its uneven distribution (Tripathi, 2021). In Indonesia, a panel data analysis conducted in West Sumatra from 2016 to 2021 reveals that GDP has a significant influence on the HDI. In contrast, GDP per capita has no substantial effect. This finding suggests that equitable wealth distribution must accompany economic growth to bolster the overall quality of life (Natasya and Faridatussalam, 2024).

Moreover, a study based on Italy's Night Light Development Index (NLDI) found that population density is correlated with the HDI. However, the measure exhibits limitations as a comparative metric across different countries (Salvati et al., 2017). Industrialization similarly contributes to increases in HDI, especially in developing nations. A panel data analysis of eight developing countries over the period 1990–2021 demonstrates that industrialization positively impacts HDI, notably when coupled with urbanization and international trade (Akpolat and Bakırtaş, 2024). A quarterly data analysis in China for the period 1990–2019 further indicates that industrialization correlates positively with HDI in both the short and medium term, an effect that became particularly pronounced in the aftermath of the global financial crisis (Hung, 2022).

Nevertheless, an examination of China's industrial sector from 2000 to 2010 reveals that, although they significantly boosted GDP, medium to low-technology industries did not directly enhance the HDI. This finding implies that the benefits of industrialization for human development also depend on other factors, such as educational attainment and income distribution. This finding means that the benefits of industrialization for human development depend on other factors, such as educational attainment and income distribution (Klafke et al., 2018). In addition, poorly managed industrialization can heighten carbon emissions and pollution, which, over time, diminishes HDI by undermining public health and environmental quality (Asongu and Odhiambo, 2019).

FDI also plays a crucial role in enhancing the HDI, particularly in developing countries. A panel analysis covering 143 countries, including both developed and developing economies, from 2002 to 2019, indicates that FDI exerts a more substantial influence on HDI in developing nations compared to developed ones, primarily because foreign investment can accelerate infrastructure development and job creation (Thi Cam Ha et al., 2024). A study of 102 developing countries between 1990 and 2015 reveals that FDI enhances the Human Development Index (HDI) by increasing life expectancy, education, and income. However, the magnitude of this effect is heavily contingent upon the recipient country's capacity to manage such investments (Ngo, 2021). Another panel data study encompassing 130 FDI-receiving nations from 1990 to 2018 shows that, despite the generally positive impact of FDI on HDI, this relationship can weaken when combined with official development assistance (ODA). The findings suggest that excessive reliance on international aid may erode the long-term benefits of FDI (Kim and Cho, 2023). Additional empirical evidence from

32 African countries between 1996 and 2017 suggests that the influence of FDI on HDI becomes more substantial in the presence of economic freedoms, such as investment and business freedom; however, it may turn negative under high tax burdens and weak protection of property rights (Korle et al., 2020). Nevertheless, the environmental repercussions of FDI warrant closer consideration, as foreign investments in extractive and manufacturing industries may increase carbon emissions and degrade ecosystems, ultimately diminishing living standards and lowering the HDI (Kamalu and Ibrahim, 2023).

Beyond economic factors, environmental degradation has a significant impact on HDI (Yumashev et al., 2020). Existing studies argue that the conventional HDI insufficiently captures environmental deterioration's influence on the quality of life, hence calling for a framework that integrates ecological aspects to provide a more precise depiction of human development (Kuznetsova and Ivashina, 2020). An Autoregressive Distributed Lag (ARDL) analysis of the relationship between natural resources and HDI in the United Arab Emirates from 1990 to 2019 reveals that reliance on natural resources negatively affects HDI by promoting unsustainable environmental exploitation (Elmassah and Hassanein, 2022). Furthermore, a Generalized Method of Moments (GMM) approach examining the effects of ecological footprints and carbon emissions on HDI in various countries from 1996 to 2021 finds that severe environmental degradation significantly reduces HDI, particularly in developing nations lacking robust environmental policies (Hashmat et al., 2023). A systematic literature review of climate change impacts in Sub-Saharan Africa corroborates this perspective, showing that environmental degradation exacerbates food insecurity, water stress, and disease prevalence, collectively undermining HDI (Dickerson et al., 2022). In light of these findings, policies that strike a balance between economic growth and environmental protection are essential to ensure the sustainability of human development in the years to come.

3. METHODS

3.1. Data

This study employs panel data from 1996 to 2022 for seven ASEAN countries: Singapore, Indonesia, Malaysia, Thailand, Vietnam, the Philippines, and Cambodia. The dataset includes several key measures with the following units: the Human Development Index (HDI) is a dimensionless index measured on a scale from 0 to 1 (UNDP); the Ecological Footprint per Capita (EFPC) is measured in global hectares (GHA) per capita (Global Footprint Network); Gross Domestic Product (GDP) is expressed in US dollars; Industrialization (IND) is quantified as the percentage of industrial output relative to GDP; Foreign Direct Investment (FDI) is expressed as a percentage of GDP; and Population Density (POPD) is measured in persons per square kilometer (WDI). The selection of these countries is based on the consistent and comprehensive availability of data throughout the study period. This enables an in-depth analysis of the relationships between human development, environmental impact, and economic performance in the ASEAN region.

3.2. Model Specifications

This study's methodological approach addressed key econometric considerations essential for robust panel data analysis. Initially, the study employed Pesaran's CD test and extended versions (CDW, CDW+, and CD*) to detect cross-sectional dependency and interdependencies across panel units (Juodis and Reese, 2022; Xie and Pesaran, 2022). Furthermore, the Delta and adjusted Delta tests confirmed slope heterogeneity, indicating variations in regression coefficients across selected countries. The presence of significant heterogeneity required estimators that effectively accounted for country-specific differences (Pesaran and Yamagata, 2008).

To confirm the stationarity of variables in this study, Pesaran applied Pesaran's Cross-Sectionally Augmented Im-Pesaran-Shin (CIPS) panel unit root test (Pesaran, 2007; Lee et al., 2016). This step validated the subsequent cointegration analysis. Westerlund cointegration test also assessed stable long-run equilibrium relationships among the variables. The test accommodated panel heterogeneity and cross-sectional dependencies, confirming long-run equilibrium relationships (Westerlund, 2005). Establishing cointegration validated the analytical framework for evaluating long-term associations between economic and ecological factors.

This study proposes an econometric panel data model that incorporates Ecological Footprint per capita (EFPC), Gross Domestic Product (GDP), Industrialization (IND), Foreign Direct Investment (FDI), and Population Density (POPD). As a first step, we express the relationships between these variables in the functional form shown in Equation (1):

$$HDI_{it} = f(EFPC_{it}, GDP_{it}, IND_{it}, FDI_{it}, POPD_{it}) \quad (1)$$

where HDI_{it} is the Human Development Index for entity i (e.g., a country) at time $t = 1996 \ldots 2022$. We transform GDP and POPD into natural logarithms to address potential heteroskedasticity and facilitate interpretation. Hence, the log-linear specification of the model is presented in Equation (2):

$$HDI_{it} = \alpha_0 + \alpha_1 EFPC_{it} + \alpha_2 \ln GDP_{it} + \alpha_3 IND_{it} + \alpha_4 FDI_{it} + \alpha_5 \ln POPD_{it} + \varepsilon_i \quad (2)$$

In Equation (2), α_0 is the intercept, α_1 through α_5 are the coefficients reflecting the effect of each independent variable on HDI, ε is the stochastic error term. This model enables an assessment of how EFPC, GDP, IND, FDI, and POPD collectively influence HDI across various entities and periods.

3.3. FMOLS Long-Run Estimator

This study employs the Fully Modified Ordinary Least Squares (FMOLS) estimator introduced by Phillips and Hansen (1990) to estimate the cointegration coefficient. The FMOLS method extends the traditional OLS framework by implementing a semi-parametric two-stage estimation procedure that corrects the estimation error and adjusts the dependent variable. This process effectively removes the endogeneity from the cointegration relationship and the serial correlation in the error terms, yielding a consistent estimator with an asymptotically normal distribution.

$$\widehat{\beta_{FMOLS}} = \left(\sum_{i=1}^{N} \sum_{t=1}^{T} X_{it} X_{it}^{'} \right)^{-1} \left(\sum_{i=1}^{N} \sum_{t=1}^{T} X_{it} \left(y_{it} + \Delta \widehat{u_{it}} \right) \right) \quad (3)$$

This estimator, as presented in Equation (3), is employed in a panel data context to consistently and efficiently capture the relationship between the dependent and independent variables. Here, N represents the number of cross-sectional units, with i identifying each unit, while T denotes the total number of time periods, and t specifies each time point. The double summation over i and t ensures that all observations are incorporated, accounting for variations across units and over time. The term $\Delta \widehat{u_{it}}$ acts as a correction for endogeneity and serial correlation, critical for robustly estimating long-term relationships in non-stationary panel data.

In addition to FMOLS, this analysis verifies the robustness of the estimation results by employing the Dynamic OLS (DOLS) method and the Canonical Cointegrating Regressions (CCR) approach. The DOLS model incorporates lagged values of the explanatory variables, and its estimator yields standard errors with a normal asymptotic distribution, thereby enhancing the reliability of the estimates compared to conventional OLS (Neagu, 2020).

4. RESULTS AND DISCUSSION

4.1. Descriptive Statistical Analysis

This study examines six indicators across seven Southeast Asian countries (Indonesia, Cambodia, Malaysia, Philippines, Singapore, Thailand, and Vietnam) from 1996 to 2022, with 27 observations per variable. Descriptive statistics in Table 1 show that Singapore recorded the highest average values for HDI, EFPC, and LNPOPD, highlighting its superior human development and economic openness despite its modest industrial sector. Indonesia and Malaysia show higher average LNPOPD and lead in industrial strength despite their moderate HDI and EFPC. Foreign direct investment varies widely, with Singapore attracting the highest average inflows, reflecting the diverse investment dynamics among these countries. These findings highlight Southeast Asia's diverse economic structures and development paths, offering crucial insights for the formulation of economic and sustainable policies.

4.2. Cross-Sectional Dependency Test

The results of the cross-sectional dependency tests are presented in Table 2. Pesaran's CD test, along with the CDW, CDW+, and CD* tests, consistently indicates significant cross-sectional dependence for most variables, as shown by P-value below the 0.05 significance threshold (Fan et al., 2015; Pesaran, 2021; Juodis and Reese, 2022; Xie and Pesaran, 2022). For example, HDI exhibits a CD value of 23.360 with a P = 0.000, highlighting strong interdependencies among the selected Southeast Asian countries. Similarly, EFPC and LNGDP demonstrate significant dependencies, supported by CD, CDW+, and CD* test results. IND also shows strong cross-sectional dependence, with all tests confirming substantial results. In contrast, FDI presents mixed

Table 1: Descriptive statistics

Country/Variable	N	Mean	SD	Min	Max
IDN					
HDI	27	0.656	0.046	0.580	−0.718
EFPC	27	1.449	0.142	1.229	1.684
LNGDP	27	27.171	0.372	26.646	27.746
IND	27	43.338	3.067	38.238	48.061
FDI	27	1.266	1.473	−2.757	2.916
LNPOPD	27	4.863	0.089	4.720	4.993
CAM					
HDI	27	0.521	0.064	-0.403	0.600
EFPC	27	1.152	0.145	0.985	1.435
LNGDP	27	23.433	0.601	22.433	24.267
IND	27	28.119	7.097	14.989	40.865
FDI	27	7.144	2.970	1.617	11.152
LNPOPD	27	4.387	0.126	4.114	4.579
MYS					
HDI	27	0.758	0.036	0.696	0.807
EFPC	27	4.088	0.332	3.355	5.046
LNGDP	27	26.131	0.360	25.578	26.683
IND	27	42.212	3.836	35.935	48.530
FDI	27	3.423	1.360	0.057	5.416
LNPOPD	27	4.432	0.157	4.150	4.660
PHL					
HDI	27	0.670	0.028	0.622	0.714
EFPC	27	1.169	0.080	0.957	1.284
LNGDP	27	26.131	0.389	25.563	26.734
IND	27	32.309	2.180	28.4	35.664
FDI	27	1.757	0.787	0.514	3.122
LNPOPD	27	5.749	0.142	5.489	5.946
SGP					
HDI	27	0.905	0.036	0.829	0.949
EFPC	27	6.738	0.666	5.430	8.347
LNGDP	27	26.113	0.397	25.469	26.671
IND	27	27.461	3.415	23.209	32.459
FDI	27	19.739	6.865	6.654	31.621
LNPOPD	27	8.834	0.127	8.609	8.983
THA					
HDI	27	0.733	0.056	0.634	0.803
EFPC	27	2.185	0.201	1.686	2.543
LNGDP	27	26.496	0.272	26.035	26.855
IND	27	36.835	1.736	33.291	39.922
FDI	27	2.763	1.511	-0.858	6.435
LNPOPD	27	4.880	0.056	4.765	4.945
VNM					
HDI	27	0.660	0.050	0.560	0.726
EFPC	27	1.502	0.552	0.720	2.432
LNGDP	27	25.830	0.491	25.015	26.607
IND	27	36.121	2.459	29.730	40.209
FDI	27	5.217	1.841	3.390	9.713
LNPOPD	27	5.610	0.105	5.415	5.762

Source: Data processed by researchers, 2025

Table 2: Cross-sectional dependency test results

Variable	CD	CDw	CDw^{+}	CD*
HDI	23.360	−3.380	103.670	0.320
	(0.000)	(0.001)	(0.000)	(0.752)
EFPC	5.900	0.580	36.750	−10.280
	(0.000)	(0.559)	(0.000)	(0.000)
LNGDP	23.590	−3.380	104.710	−3.340
	(0.000)	(0.001)	(0.000)	(0.001)
IND	5.220	−2.600	57.560	4.150
	(0.000)	(0.009)	(0.000)	(0.000)
FDI	1.560	−1.580	20.770	3.110
	(0.119)	(0.113)	(0.000)	(0.002)
LNPOPD	23.430	−3.350	104.000	-16.690
	(0.000)	(0.001)	(0.000)	(0.000)

outcomes, revealing no significant dependency based on the CD and CDW tests, yet shows significant dependence according to the CDW+ and CD* tests. Additionally, LNPOPD consistently indicates strong cross-sectional dependency across all tests. These findings underscore the complexity and interconnectedness of economic and environmental dynamics within Southeast Asia, emphasizing the need for regionally coordinated policies.

4.3. Slope Heterogeneity Test

The results of the slope heterogeneity test presented in Table 3 substantiate the presence of significant variability in regression coefficients among the Southeast Asian countries under study. The Delta and adjusted Delta statistics are important at the 1% level, leading to the rejection of the null hypothesis of homogeneity (Pesaran and Yamagata, 2008). This outcome indicates that the relationships between the explanatory variables (EFPC, LNGDP, IND, FDI, and LNPOPD) and HDI vary across countries, likely reflecting disparities in economic complexity, industrial development, population dynamics, and investment patterns.

4.4. Westerlund Cointegration Test

To determine whether the examined variables exhibit stable long-run relationships, assessing cointegration within panel data frameworks is crucial, mainly when dealing with heterogeneous panels and cross-sectional dependence. The study employs the Westerlund Cointegration test to address this issue. This robust methodology accommodates heterogeneity and cross-sectional dependencies, providing reliable inference regarding long-term equilibrium relationships among variables (Westerlund, 2005).

The Westerlund Cointegration Test results, presented in Table 4, confirm significant long-term relationships among the examined variables. Specifically, the variance ratio statistic is essential at the 1% level (statistic value of 3.9562, P = 0.0000), indicating robust long-term linkages among HDI, EFPC, LNGDP, IND, FDI, and LNPOPD. These findings support the existence of stable long-term relationships among the variables.

4.5. CIPS Panel Unit Root Test

Panel stationarity tests using the Cross-sectionally augmented Im-Pesaran-Shin (CIPS) method, presented in Table 5, account for cross-sectional dependence and heterogeneity among the selected countries. Results indicate that at level (I(0)), only FDI and LNPOPD are stationary at a 1% significance level, while HDI, EFPC, LNGDP, and IND exhibit non-stationarity. After differencing at first-order (I(1)), all variables become stationary, significant at the 1% level. These findings confirm that the variables are integrated of order one (I(1)), supporting the subsequent analysis of long-term relationships using panel cointegration techniques (Baltagi, 2008).

4.6. Long-Run Estimation Results and Robustness Checks

This section employs Fully Modified Ordinary Least Squares (FMOLS) as the primary estimation method to identify robust long-run relationships between HDI and explanatory variables. FMOLS effectively addresses potential issues such as serial correlation, endogeneity, and heterogeneity in panel data analysis. We perform additional estimations using Canonical Cointegrating Regression (CCR) and Dynamic Ordinary Least Squares (DOLS) to ensure the robustness and validity of the findings. Consistency across these estimation methods strengthens the reliability and applicability of the results.

Table 6 presents the long-run estimates obtained from the FMOLS, CCR, and DOLS methods. FMOLS results reveal a negative relationship between EFPC and HDI, significant at the 1% level, indicating environmental pressure hampers human development. In contrast, LNGDP has a positive effect on HDI at the 1% significance level, highlighting the essential role of economic growth. Variables IND (5% significance), FDI (1% significance), and LNPOPD (1% significance) also positively influence HDI, emphasizing their importance in enhancing human development.

Robustness checks using CCR and DOLS consistently confirm these findings, demonstrating similar relationships with significance maintained at the 1% and 5% levels. The consistent results across different estimation methods underscore the

Table 3: Slope heterogeneity test results

Item	Delta	Delta (HAC)
Value	10.206***	2.308**
adj.	12.166***	2.751***

***, ** and * represent 1%, 5% and 10% levels of significance respectively
Source: Data processed by researchers, 2025

Table 4: Westerlund Cointegration test

Item	Statistic	P-value
Variance ratio	3.9562	0.0000

Table 5: CIPS panel unit root test results

Variable	I (0)	I (1)
HDI	−2.026	−4.311***
EFPC	−2.008	−5.397***
LNGDP	−2.198	−4.433***
IND	−1.757	−5.535***
FDI	−3.348***	−5.229***
LNPOPD	−2.739***	−3.413***

***, ** and * represent 1%, 5% and 10% levels of significance respectively

Table 6: Estimation results and robustness checks

Variables	(1)	(2)	(3)
	FMOLS	CCR	DOLS
EFPC	−0.07135***	−0.07143***	−0.22412***
	(0.00532)	(0.00680)	(0.02936)
LNGDP	0.12577***	0.12577***	0.31553***
	(0.00930)	(0.01182)	(0.03814)
IND	0.00037**	0.00038**	0.00290***
	(0.00015)	(0.00016)	(0.00027)
FDI	0.00129***	0.00128***	0.00374***
	(0.00018)	(0.00021)	(0.00041)
LNPOPD	0.25927***	0.25976***	0.18827***
	(0.02640)	(0.03247)	(0.04274)
Constant	−3.95640***	−3.95903***	−8.31436***
	(0.14712)	(0.18590)	(0.78866)
R-squared	0.98530	0.98652	0.99944

***, ** and * represent 1%, 5% and 10% levels of significance respectively robustness of these findings, ensuring their reliability and applicability for informed policy formulation.

The study emphasizes that ecological aspects are crucial in shaping human development. A high Ecological Footprint Per Capita significantly reduces HDI, underscoring the importance of managing resource consumption and protecting the environment to sustain quality of life. This evidence supports the integration of environmental dimensions into the human development framework so that adverse impacts on ecosystems do not erode the benefits of economic growth (Kuznetsova and Ivashina, 2020; Hashmat et al., 2023). Moreover, overexploitation of natural resources increases pressure on ecosystems and public health, collectively diminishing HDI (Nguyen et al., 2020).

As measured by GDP, economic growth has a significant positive impact on the HDI by promoting urbanization, increasing household income, and expanding access to essential services (Yunus et al., 2024). Nevertheless, the literature stresses that equitable wealth distribution must accompany economic growth. For instance, studies have demonstrated that total urban population, growth rate, and the proportion of residents in large urban centers positively influence HDI; however, an excessive concentration of people in major cities may lead to imbalances in in-service distribution (Tripathi, 2021; Natasya and Faridatussalam, 2024).

Industrialization and FDI also contribute positively to HDI. Although the effect of industrialization is relatively modest, it has the potential to enhance productivity and technological access, mainly when supported by robust infrastructure and quality education (Hung, 2022; Klafke et al., 2018). A 1% increase in FDI is associated with a 0.00129 % increase in HDI, suggesting that foreign capital accelerates infrastructure development and job creation, improving life expectancy, education, and income (Ngo, 2021). However, the benefits of FDI depend heavily on a country's capacity to manage these investments and may reduced by overreliance on official development assistance or unfavorable economic policies (Kim and Cho, 2023; Korle et al., 2020).

Population density reflects both the intensity of economic activity and the quality of urban infrastructure. Research by Salvati et al. (2017) demonstrates that higher population density is positive with HDI, as densely populated areas tend to offer better access to public services. However, these benefits are contingent upon an even distribution of residents; if most individuals concentrate in central areas, peripheral regions may underserved. Consequently, effective urban planning and equitable distribution infrastructure are essential to optimize the positive effects of population density on HDI.

4.7. Causality Test

Table 7 illustrates that the HDI and EFPC exhibit a bidirectional causal relationship, indicating that changes in human development influence resource consumption and vice versa. Similarly, a reciprocal relationship exists between HDI and GDP, IND, FDI, and LNPOPD. These results suggest that improvements in human development are influenced by economic growth, industrial activities, foreign capital inflows, and population density, reflecting a complex and interconnected dynamic among these factors.

Table 7: Dumitrescu and Hurlin Granger's non-causality test

Relation	W-bar	Z-bar	Result
HDI-EFPC	3.6184	2.1410**	HDI↔EFPC
EFPC-HDI	5.5328	4.6734***	
HDI-LNGDP	8.5812	8.7061***	HDI↔LNGDP
LNGDP-HDI	16.3845	19.028***	
HDI-IND	4.3744	3.1410***	HDI↔IND
IND-HDI	6.8623	6.4322***	
HDI-FDI	3.6611	2.1975**	HDI↔FDI
FDI-HDI	8.6565	8.8058***	
HDI-LNPOPD	8.0939	8.0615***	HDI↔LNPOPD
LNPOPD-HDI	5.9647	5.2448***	

***, ** and *Represent 1%, 5% and 10% levels of significance respectively

5. CONCLUSION

This study highlighted the significant relationship between ecological sustainability and human development within ASEAN countries. The study observed that an increase in the ecological footprint per capita negatively affected the overall quality of human development. Specifically, when societies consumed resources beyond ecological limits, it ultimately diminished long-term human welfare and prosperity. Conversely, improvements in economic performance, such as higher gross domestic product, increased industrial activity, more significant foreign direct investment, and higher population density, positively contributed to human development outcomes.

These findings underscore the limitations of conventional human development indicators, which often overlook long-term ecological constraints. The transition from the Holocene to the Anthropocene underscores the importance of integrating ecological considerations into assessments of human development. The study advocates for a more comprehensive approach that informs balanced, sustainable, and equitable development strategies by capturing the intricate links between economic growth, social well-being, and environmental resilience.

Although the results are robust, our limited data availability and methodological scope prevent us from fully capturing the complex dynamics between economic and ecological factors. Future research should expand data coverage and employ advanced econometric techniques to understand these interactions better, while also considering external influences such as government policies and technological advancements. The implications of these findings are significant for policymakers, as they provide a strong rationale for designing development strategies that harmonize economic growth with environmental protection, ensuring that progress today does not compromise the well-being of future generations.

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