

The Impact of Carbon Dioxide Emissions and Fertilizer Consumption on Human Development in Vietnam

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Abstract

In the context of Vietnam promoting economic growth together with sustainable development, it is important to evaluate the impact of economic growth and agricultural emissions on human development. This study uses time series data from 1990 to 2023 and the ARDL model to examine the relationship between GDP per capita, fertilizer quantity, CO₂ emissions in agriculture, and the Human Development Index (HDI). The results show that there is a long-run cointegration relationship among the variables. In the long run, GDP per capita and fertilizer quantity have a positive and statistically significant impact on HDI, while CO₂ emissions from agriculture have a negative impact. These findings indicate that agriculture both improves human well-being and harms environmental quality. Therefore, Vietnam should maintain economic growth, improve agricultural production efficiency, use fertilizer more efficiently, and reduce emissions in agriculture to enhance HDI.

Keywords: Agricultural CO₂ emissions; ARDL model; Economic growth; Human development index (HDI)

1. Introduction

The Human Development Index (HDI) is a measure of human development based on three main areas: health, education, and income (Vu Ha, 2024). According to the UNDP's 2025 report, Vietnam's HDI value in 2023 reached 0.766 (United Nations Development Programme, 2025). With this result, Vietnam ranked 93rd out of 193 countries and territories surveyed. The period from 1990 to 2023 witnessed impressive growth in Vietnam's HDI. Studies suggest that Vietnam needs to increase budget spending on education and health to further enhance sustainable human development.

Thus, HDI is a composite measure of a country's health, education, and standard of living (Bieth, 2021; Hossain & Chen, 2021). Studies in ASEAN countries show a positive and statistically significant relationship between economic growth (GDP) and HDI. Economic growth helps improve social welfare through investment in health and education, while higher human development also supports sustainable economic growth (Elistia & Syahzuni, 2018). However, economic growth is a necessary but not sufficient condition for real social progress. Long-term success depends on how resources are allocated to meet basic human needs (Elistia & Syahzuni, 2018; Natoli & Zuhair, 2011).

The use of fertilizers, especially nitrogen fertilizers, has a positive and direct relationship with emissions in agriculture (Rehman et al., 2019). Empirical evidence shows that a 1% increase in fertilizer use can lead to about a 0.60% increase in emissions in the long run (Rehman et al., 2019). This relationship comes from energy-intensive production processes that use fossil fuels (such as natural gas or coal) and from urea hydrolysis, which releases emissions directly when applied to the soil (Brentrup et al., 2016). This shows that fertilizer use can reduce environmental quality and affect health and human development. Regarding CO₂ emissions and HDI, efforts to achieve higher HDI levels often lead to higher CO₂ emissions due to increased use of fossil fuels (Li et al., 2022). Economic activity is identified as a main driver of rising CO₂ emissions in many developing countries (Hossain & Chen, 2021).

Research gap and the need for study in Vietnam. Although many studies have examined agriculture and emissions in countries such as Brazil, Tunisia, and Indonesia, similar studies for Vietnam are still limited (Adebayo et al., 2021; Ben Jebli & Ben Youssef, 2015, 2016). Agriculture is one of the largest sources of greenhouse gas emissions in many developing countries due to activities such as livestock production and fertilizer use (Khan, 2020; Khan et al., 2023). In Vietnam, agricultural emissions accounted for about 14.8% of total national emissions in 2021; these

mainly come from rice farming, manure management, and the use of synthetic fertilizers. Emissions from cropland are expected to continue increasing by 2025 due to intensive farming practices (Dinh Thi Kim & Nguyen Duc, 2025). Therefore, studying the impact of CO₂ emissions from agriculture on HDI in Vietnam is very important to balance agricultural modernization and human well-being. Understanding these effects can help policymakers design a path toward low-carbon agriculture without reducing quality of life.

2. Methodology

2.1. Data and variable description

The study uses annual time series data for Vietnam from 1990 to 2023, with 34 observations. The data are collected from the World Development Indicators (WDI) of the World Bank, while fertilizer consumption data are obtained from the Food and Agriculture Organization (FAO), as compiled by Our World in Data. The Human Development Index (HDI) is sourced from the United Nations Development Programme (UNDP). The sample size is suitable for time series analysis because the number of observations is much larger than the number of variables in the model, consistent with the suggestions of Tabachnick et al. (2013) and Pham et al. (2022).

The dependent variable in this study is the Human Development Index (HDI), measured as an index. The independent variables include GDP per capita (GDPPC), measured in constant 2015 USD; total fertilizer consumption (FERT), measured in million tons; and CO₂ emissions from agriculture (CO₂AGRI), measured in million tons of CO₂ equivalent (Mt CO₂e). Although the indicator refers to CO₂ emissions from agriculture, the unit CO₂e is used to standardize emissions in terms of CO₂ based on global warming potential (GWP), ensuring consistency in measurement. Total fertilizer consumption is defined as the sum of synthetic inputs of nitrogen, phosphorus, and potassium, as well as organic nitrogen inputs. All variables are transformed into natural logarithms.

Table 1 presents the descriptive statistics of the variables during the study period, including mean, median, standard deviation, kurtosis, skewness, minimum, and maximum values.

Table 1: Descriptive statistics of variables

Indicator	HDI	GDPPC <i>GDP per capita (constant 2015 US\$)</i>	FERT <i>(million ton)</i>	CO ₂ AGRI <i>Carbon dioxide (CO₂) emissions from Agriculture (Mt CO₂e)</i>
Mean	0.65	1893.08	2183757.81	2.13
Median	0.66	1744.31	2272227.50	2.19
Standard Deviation	0.08	924.10	773776.26	0.65
Kurtosis	-1.05	-0.89	-0.58	-0.51
Skewness	-0.30	0.51	-0.63	-0.31
Minimum	0.50	687.86	560259.80	0.91
Maximum	0.77	3775.46	3200646.50	3.41
Count	34	34	34	34

2.2. Autoregressive distributed lag model

The Autoregressive Distributed Lag (ARDL) model is widely used in time series analysis to examine dynamic relationships among variables. This model has two main parts. The first part includes lagged values of the dependent variable, which reflect the effect of its past values on the current value. The second part includes lagged

values of the independent variables, allowing the impact of these variables on the dependent variable over time to be examined.

The ARDL method was introduced by Pesaran and Shin (1999). It can be used when the data are integrated at order I(0) or I(1), and it is suitable for studies with small sample sizes. In this study, an ARDL (p, q₁, q₂, q₃) model is used to analyze the relationship between human development, economic growth, fertilizer consumption, and CO₂ emissions from agriculture, as shown in Equation (Eq.1)

$$\begin{aligned} \Delta \ln \text{HDI}_t &= \alpha \\ &+ \underbrace{\sum_{i=1}^p \beta_i \Delta \ln \text{HDI}_{t-i} + \sum_{j=0}^{q_1} \gamma_j \Delta \ln \text{GDPPC}_{t-j} + \sum_{k=0}^{q_2} \delta_k \Delta \ln \text{FERT}_{t-k} + \sum_{l=0}^{q_3} \theta_l \Delta \ln \text{CO}_2 \text{AGRI}_{t-1}}_{\text{Short run}} + \lambda \left[\underbrace{\ln \text{HDI}_{t-1} - (\pi_0 + \pi_1 \ln \text{GDPPC}_{t-1} + \pi_2 \ln \text{FERT}_{t-1} + \pi_3 \ln \text{CO}_2 \text{AGRI}_{t-1})}_{\text{Long run}} \right] \\ &+ \varepsilon_t \text{ (Eq. 1)} \end{aligned}$$

Where short-term coefficients are: β_i ; γ_j ; δ_k ; θ_l , long-term coefficients are: π_1 ; π_2 ; π_3 ; and the error term is: ε_t . Where p, q₁, q₂, and q₃ denote the lag orders of lnHDI, lnGDPPC, lnFERT, lnCO₂AGRI, respectively.

Equation (Eq.1) shows the general form of the ARDL model, which includes both short-run relationships and the long-run equilibrium relationship among the variables. The first differences of the variables reflect short-run effects, while the term in square brackets represents the long-run equilibrium relationship between HDI, GDP per capita, fertilizer consumption, and CO₂ emissions from agriculture.

Equation (Eq.2) presents the ARDL model in the Error Correction Model (ECM) form. In this form, the differenced variables capture the short-run effects of the independent variables on changes in lnHDI, while ECT_{t-1} is the error correction term representing the long-run equilibrium relationship. The coefficient λ of ECT_{t-1} shows the speed of adjustment, meaning how fast short-run deviations return to the long-run equilibrium.

ECT_{t-1} is calculated from the residuals of the long-run equation, which is based on the long-run relationship between HDI and the independent variables in the model (Eq.3). If the coefficient of ECT_{t-1} is negative and statistically significant, it indicates the existence of a long-run cointegration relationship, and any short-run deviations will gradually adjust back to equilibrium over time.

$$\begin{aligned} \Delta \ln \text{HDI}_t &= \alpha + \sum_{i=1}^p \beta_i \Delta \ln \text{HDI}_{t-i} + \sum_{j=0}^{q_1} \gamma_j \Delta \ln \text{GDPPC}_{t-j} + \sum_{k=0}^{q_2} \delta_k \Delta \ln \text{FERT}_{t-k} + \sum_{l=0}^{q_3} \theta_l \Delta \ln \text{CO}_2 \text{AGRI}_{t-1} + \lambda \text{ECT}_{t-1} \\ &+ \varepsilon_t \text{ (Eq. 2)} \end{aligned}$$

$$\text{ECT}_{t-1} = \ln \text{HDI}_{t-1} - (\pi_0 + \pi_1 \ln \text{GDPPC}_{t-1} + \pi_2 \ln \text{FERT}_{t-1} + \pi_3 \ln \text{CO}_2 \text{AGRI}_{t-1}) \text{ (Eq.3)}$$

The ARDL model is flexible because each variable can have a different lag, so it is suitable for small sample studies. The model can be used when the data are integrated at I(0) or I(1), and it allows estimation of both short-run and long-run effects in one framework.

The estimation process is as follows. First, the variables are tested for stationarity using ADF and PP tests to make sure that no variable is integrated at order I(2). Next, the optimal lag length is selected based on the Akaike Information Criterion (AIC), with support from EViews (Nsor-Ambala & Amewu, 2023). Then, the Bounds test is used to check the existence of a long-run cointegration relationship among the variables.

If cointegration is confirmed, the long-run coefficients are estimated to measure the long-run impact of the independent variables on lnHDI. After that, an Error Correction Model (ECM) is used to examine short-run effects. The ECT coefficient is expected to be negative and statistically significant, showing the speed of adjustment to the long-run equilibrium.

Finally, diagnostic tests such as autocorrelation, heteroskedasticity, CUSUM, and CUSUMSQ are conducted to check the stability of the model and the variance of the errors over time.

3. Results and discussion

3.1. Unit root test and cointegration test

The results of the ADF and PP unit root tests show that lnHDI and lnFERT are stationary at level, meaning they are integrated at order zero, I(0). Meanwhile, lnGDPPC and lnCO2AGRI are not stationary at level but become stationary at first difference, meaning they are integrated at order one, I(1). Therefore, the variables in the model include only I(0) and I(1), which is suitable for applying the ARDL model (Pesaran et al., 2001).

Table 2: Unit root test

Null hypothesis (H0): The variable has a unit root (non-stationary).

Variable	ADF		PP		Order of integration (with constant)
	At level	At first difference	At level	At first difference	
lnHDI	-7.1812***	-1.4603 ns	-11.7384***	-2.2064 ns	I(0)
lnGDPPC	-2.0408ns	-2.6479*	-2.7167*	-4.2145***	I(1)
lnCO2AGRI	-2.3979ns	-10.5845***	-2.5791ns	-10.3374***	I(1)
lnFERT	-3.2853**	-8.5477***	-6.2575***	-8.5309***	I(0), I(1)

Note:

***, **, * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

ns: not statistically significant.

The tests are conducted with a constant.

H0: The series has a unit root (non-stationary). Reject H0 when the test statistic is statistically significant.

The results of the Bounds test (Table 3) show that the F-statistic is 8.4978, which exceeds the upper bound critical values I(1) at the 10%, 5%, and 1% significance levels. Therefore, the null hypothesis of no cointegration is rejected, confirming the existence of a long-run equilibrium relationship among the variables in the model.

Table 3: Bounds test results

Null hypothesis: No cointegration relationship exists (at level)

F-statistic	Bounds test critical values		
	Significance level	I(0)	I(1)
8.4978	10%	3.008	4.150
	5%	3.710	5.018
	1%	5.333	7.063

Note: I(0) and I(1) are the lower and upper bound critical values of the Bounds test, respectively.

If the F-statistic > I(1), reject H0 and conclude that cointegration exists.

3.2. Short-run and long-run relationships

Short-run results: The ARDL–ECM estimation indicates that the ECT coefficient is -0.2125 and statistically significant at the 1% level, confirming the presence of a long-run adjustment mechanism. Approximately 21.25% of the disequilibrium is corrected in each period. In the short run, the lagged dependent variables lnHDI(-1), lnHDI(-2),

and $\ln\text{HDI}(-3)$ all have negative effects, with $\ln\text{HDI}(-1)$ and $\ln\text{HDI}(-3)$ being statistically significant at the 1% level, while $\ln\text{HDI}(-2)$ is weakly significant. GDP per capita shows a positive and statistically significant impact through its current value and second lag, whereas the first lag is not statistically significant. Fertilizer consumption has a positive and statistically significant effect in the current period, but its lagged term shows a negative and statistically significant effect. CO_2 emissions from agriculture exhibit a negative and statistically significant effect in the current period, while their lagged terms have positive and statistically significant impacts. The constant term is also statistically significant.

Long-run results: The long-run estimation indicates that a 1% increase in GDP per capita leads to an increase of approximately 0.1361% in HDI, and this effect is statistically significant. Similarly, a 1% increase in fertilizer consumption raises HDI by about 0.1377%, with strong statistical significance, highlighting the important role of agricultural inputs in improving human development. In contrast, a 1% increase in CO_2 emissions from agriculture reduces HDI by approximately 0.1882%, and this effect is statistically significant, suggesting that environmental degradation adversely affects human development in the long run.

Table 4. ARDL–ECM estimation results and diagnostic tests

Selected model: ARDL(4,3,2,3), T = 30 (1994–2023), AIC criterion, Case 3 (unrestricted constant).

Variable	Coefficient	Standard error	p-value
Short-run relationship			
ECT	-0.2125***	0.0331	0.0000
D($\ln\text{HDI}(-1)$)	-0.7885***	0.1893	0.0006
D($\ln\text{HDI}(-2)$)	-0.4384*	0.2168	0.0592
D($\ln\text{HDI}(-3)$)	-0.7733***	0.186	0.0007
D($\ln\text{GDPPC}$)	0.0673**	0.0268	0.0227
D($\ln\text{GDPPC}(-1)$)	0.0626 ^{ns}	0.0379	0.1169
D($\ln\text{GDPPC}(-2)$)	0.1748***	0.0493	0.0025
D($\ln\text{FERT}$)	0.0115***	0.0027	0.0005
D($\ln\text{FERT}(-1)$)	-0.0087**	0.0033	0.0176
D($\ln\text{CO}_2\text{AGRI}$)	-0.0144***	0.0031	0.0003
D($\ln\text{CO}_2\text{AGRI}(-1)$)	0.0213***	0.0048	0.0003
D($\ln\text{CO}_2\text{AGRI}(-2)$)	0.0083***	0.0026	0.0053
C	-0.6799***	0.1052	0.0000
Long-run relationship			
$\ln\text{GDPPC}$	0.1361***	0.0135	0.0000
$\ln\text{FERT}$	0.1377***	0.0393	0.0016
$\ln\text{CO}_2\text{AGRI}$	-0.1882***	0.051	0.0010

Note:

- (1) ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.
- (2) ns: not statistically significant.
- (3) Error Correction Term (ECT).

3.3. Diagnostic tests and model stability

Diagnostic tests: Table 5 reports the results of the model diagnostic tests. The Breusch–Godfrey LM test yields a p-value of 0.2671, which is greater than the 5% significance level, indicating no evidence of serial correlation. Similarly, the Breusch–Pagan–Godfrey test shows a p-value of 0.0789, which also exceeds 5%, suggesting the absence of heteroskedasticity, although the result is marginal at the 10% significance level. Overall, the model satisfies the standard diagnostic conditions.

Model stability: Figure 1 presents the CUSUM and CUSUMSQ test results. The CUSUM line remains within the 5% critical bounds, confirming the stability of the model parameters over time. In contrast, the CUSUMSQ line crosses the 5% bounds at certain points, suggesting potential instability in the variance during some periods.

Table 5. Model diagnostic test results

Tests	F-Statistic	p-value (Prob.)
Breusch–Godfrey autocorrelation test (LM test)	1.4765	0.2671
Breusch–Pagan–Godfrey heteroskedasticity test	2.1615	0.0789

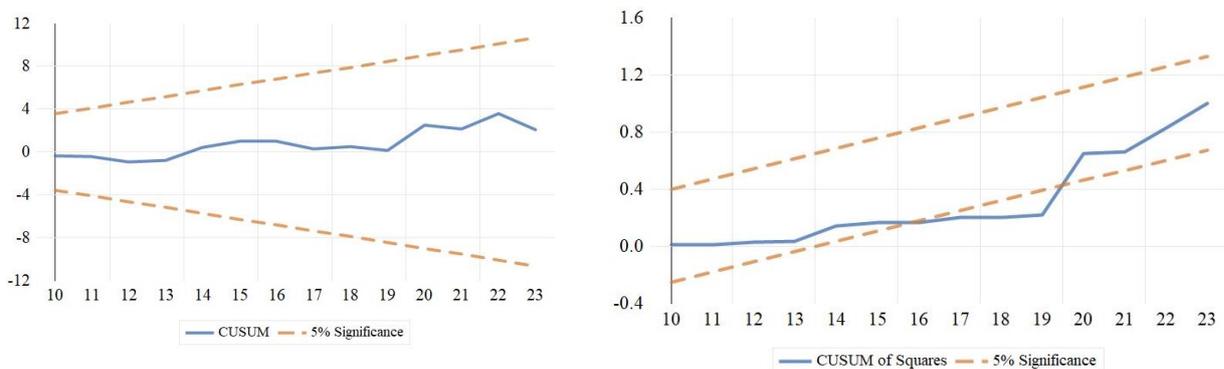


Figure 1: CUSUM and CUSUMSQ stability tests

3.4. Discussion

According to the model results, GDP per capita has a positive and statistically significant effect on HDI, showing that economic growth contributes to improving human development. Income growth is considered a main factor that directly improves individual capacity and the development of a country. Higher income helps expand choices and access to resources for both households and the government (Ranis, 2004). Higher income also plays an important role in increasing people’s purchasing power for better and more nutritious food for health (Azizah Nur et al., 2025).

In this study, fertilizer consumption also has a positive effect on HDI, highlighting the role of agricultural inputs in improving welfare. The use of mineral fertilizers helps improve household welfare directly by increasing farmers’ income, and indirectly by reducing food prices in the market. Better access to fertilizers can increase crop productivity and bring welfare benefits to all types of households, including non-farming households (Legesse et al., 2019). Increased fertilizer use, together with new crop varieties, is a key foundation for sustainable agricultural growth in developing countries (Shaqiri, 2019). However, to achieve full rural poverty reduction, increasing agricultural inputs should be combined with policies that help farmers access markets more easily (Boulanger et al., 2017).

This result shows that CO₂ emissions from agriculture have a negative and statistically significant effect on HDI, suggesting that environmental pollution reduces the quality of human development. Modern agriculture is one of the main sources of greenhouse gas emissions and plays an important role in driving the greenhouse effect and global climate change (Khosravi et al., 2025). The loss of nutrients from fertilizers and agricultural waste causes many negative impacts on the environment, disrupts ecosystem functions, and harms human health (Sokal & Kachel, 2025).

Air pollutants from farming activities and agricultural waste treatment reduce air quality and directly affect nearby communities (Sokal & Kachel, 2025).

4. Conclusion and policy implications

This study examines the relationship between economic growth, fertilizer use, and CO₂ emissions in agriculture and human development in Vietnam from 1990 to 2023. The results show that there is a long-run equilibrium relationship among the variables. In the long run, GDP per capita has a positive effect on HDI, confirming the important role of economic growth in improving social welfare. Fertilizer use also improves HDI by increasing agricultural productivity and income. However, CO₂ emissions from agriculture have a negative effect on HDI, showing that environmental pollution can reduce the quality of human development. These results highlight the dual role of agriculture: it both improves welfare and causes environmental problems. Therefore, agricultural development should balance growth and environmental protection.

The findings show that economic growth and fertilizer use have positive effects on human development, while CO₂ emissions from agriculture have a negative effect. Therefore, Vietnam should maintain economic growth and improve agricultural efficiency, while controlling fertilizer use and reducing emissions in agriculture. Policies should promote efficient and environmentally friendly agriculture to ensure a balance between growth and sustainable development.

References

1. Adebayo, T. S., Akinsola, G. D., Kirikkaleli, D., Bekun, F. V., Umarbeyli, S., & Osemeahon, O. S. (2021). *Economic Performance of Indonesia amidst CO₂ Emissions and Agriculture: A Time Series analysis*. Research Square. <https://dx.doi.org/10.21203/rs.3.rs-285102/v1>
2. Azizah Nur, R., Sri, S., & Haetami. (2025). The Role of Human Development Index (HDI) and Population Growth in Improving Food Security from the Perspective of Defense Economics in Indonesia. *Formosa Journal of Social Sciences (FJSS)*, 4(1), 147-158. <https://doi.org/10.55927/fjss.v4i1.126>
3. Ben Jebli, M., & Ben Youssef, S. (2015). *Renewable Energy Consumption and Agriculture: Evidence for Cointegration and Granger causality for Tunisian Economy* (MPRA Paper 68018). <https://mpra.ub.uni-muenchen.de/68018/>
4. Ben Jebli, M., & Ben Youssef, S. (2016). *Combustible renewables and waste consumption, agriculture, CO₂ emissions and economic growth in Brazil* (MPRA Paper 69694). <https://mpra.ub.uni-muenchen.de/69694/>
5. Bieth, R. C. E. (2021). The Influence of Gross Domestic Product and Human Development Index on CO₂ Emissions. *Journal of Physics: Conference Series*, 1808(1), 012034. <https://doi.org/10.1088/1742-6596/1808/1/012034>
6. Boulanger, P. H., Dudu, H., Ferrari, E., Mainar Causapé, A. J., & Proietti, I. (2017). *Boosting the Fertilizer Production in Kenya: a CGE analysis* (978-92-79-70976-0).
7. Brentrup, F., Hoxha, A., & Christensen, B. (2016). Carbon footprint analysis of mineral fertilizer production in Europe and other world regions. The 10th International Conference on Life Cycle Assessment of Food (LCA Food 2016), University College Dublin (UCD), Dublin, Ireland.
8. Dinh Thi Kim, P., & Nguyen Duc, T. (2025). Overview of carbon emission from land use in Vietnam. *HUIT Journal of Science*, 25(S2_ICA), 115-132. https://doi.org/10.62985/j.huit_ojs.vol25.noS2_ICA.221
9. Elistia, E., & Syahzuni, B. A. (2018). The correlation of the human development index (HDI) towards economic growth (GDP per capita) in 10 ASEAN member countries. *Journal of Humanities and Social Studies*, 2(2), 40-46. <https://doi.org/10.33751/jhss.v2i2.949>
10. Hossain, M. A., & Chen, S. (2021). Nexus between Human Development Index (HDI) and CO₂ emissions in a developing country: decoupling study evidence from Bangladesh. *Environmental Science and Pollution Research*, 28(41), 58742-58754. <https://doi.org/10.1007/s11356-021-14822-5>
11. Khan, R. (2020). Agricultural production and CO₂ emissions causes in the developing and developed countries: New insights from quantile regression and decomposition analysis. *bioRxiv*, 2020.2011.2016.384370. <https://doi.org/10.1101/2020.11.16.384370>

12. Khan, R., Alabsi, A. A. N., & Muda, I. (2023). Comparing the effects of agricultural intensification on CO₂ emissions and energy consumption in developing and developed countries [Original Research]. *Frontiers in Environmental Science, Volume 10 - 2022*. <https://doi.org/10.3389/fenvs.2022.1065634>
13. Khosravi, H., Raihan, A. S., Islam, F., Nimbarte, A., & Ahmed, I. (2025). A Comprehensive Approach to CO₂ Emissions Analysis in High-Human-Development-Index Countries Using Statistical and Time Series Approaches. *Sustainability, 17*(2), 603. <https://doi.org/10.3390/su17020603>
14. Legesse, E. E., Srivastava, A. K., Kuhn, A., & Gaiser, T. (2019). Household Welfare Implications of Better Fertilizer Access and Lower Use Inefficiency: Long-Term Scenarios for Ethiopia. *Sustainability, 11*(14), 3952. <https://doi.org/10.3390/su11143952>
15. Li, D., Shen, T., Wei, X., & Li, J. (2022). Decomposition and Decoupling Analysis between HDI and Carbon Emissions. *Atmosphere, 13*(4), 584. <https://www.mdpi.com/2073-4433/13/4/584>
16. Natoli, R., & Zuhair, S. (2011). Measuring Progress: A Comparison of the GDP, HDI, GS and the RIE. *Social Indicators Research, 103*(1), 33-56. <https://doi.org/10.1007/s11205-010-9695-3>
17. Nsor-Ambala, R., & Amewu, G. (2023). Linear and non-linear ARDL estimation of financial innovation and economic growth in Ghana. *Journal of Business and Socio-economic Development, 3*(1), 36-49. <https://doi.org/10.1108/JBSED-09-2021-0128>
18. Pesaran, M. H., & Shin, Y. (1999). An Autoregressive Distributed-Lag Modelling Approach to Cointegration Analysis. In S. Strøm (Ed.), *Econometrics and Economic Theory in the 20th Century: The Ragnar Frisch Centennial Symposium* (pp. 371-413). Cambridge University Press. <https://doi.org/10.1017/CCOL521633230.011>
19. Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics, 16*(3), 289-326. <https://doi.org/10.1002/jae.616>
20. Pham, M. H., Nguyen, A. T., & Le, P. T. (2022). The relationship between ghg emissions and economic growth in Vietnam. *Science & Technology Development Journal - Economics - Law and Management*. <https://doi.org/10.32508/stdjelm.v6i1.802>
21. Ranis, G. (2004). *Human Development and Economic Growth* (Center Discussion Paper No. 887, Issue. <https://hdl.handle.net/10419/98324>
22. Rehman, A., Ozturk, I., & Zhang, D. (2019). The Causal Connection between CO₂ Emissions and Agricultural Productivity in Pakistan: Empirical Evidence from an Autoregressive Distributed Lag Bounds Testing Approach. *Applied Sciences, 9*(8), 1692. <https://www.mdpi.com/2076-3417/9/8/1692>
23. Shaqiri, F. (2019). The Human Development Index and Agricultural Growth in Selected Countries. Integrated Safety of Environs 2019: Proceedings of the International Scientific Conference, Bratislava, Slovak Republic.
24. Sokal, K., & Kachel, M. (2025). Impact of Agriculture on Greenhouse Gas Emissions—A Review. *Energies, 18*(9), 2272. <https://doi.org/10.3390/en18092272>
25. Tabachnick, B. G., Fidell, L. S., & Ullman, J. B. (2013). *Using multivariate statistics* (Vol. 6). pearson Boston, MA.
26. United Nations Development Programme. (2025, 2025/05/07). Viet Nam maintains high human development: UNDP report [Việt Nam duy trì mức phát triển con người cao: Báo cáo của UNDP]. <https://www.undp.org/vi/vietnam/press-releases/viet-nam-duy-tri-muc-phat-trien-con-nguoi-cao-bao-cao-cua-undp>
27. Vu Ha. (2024, 2024/04/15). HDI and What Needs to Be Done [HDI và những việc cần làm]. <https://hanoimoi.vn/hdi-va-nhung-viec-can-lam-663665.html>