

Industrial Production, FDI, Trade Openness and CO₂ Emissions: Evidence from Vietnam

Le Phuong Nam

*Vietnam National University of Agriculture, Hanoi, Vietnam, Email: lephuongnam87@gmail.com, ORCID:
<https://orcid.org/0000-0003-0352-7345>*

Abstract

This study examines how industrial production, foreign direct investment (FDI), trade openness, and human capital affect CO₂ emissions in Vietnam over the period 1986–2023, a time marked by rapid industrialization and deeper economic integration. Using annual time-series data from the World Development Indicators and the Penn World Table, the ARDL–ECM approach is employed to estimate both short-run and long-run relationships. The results show a stable long-run relationship among the variables. The error correction term is negative and significant, indicating that short-run deviations are corrected fairly quickly. In the long run, industrial production, FDI, trade openness, and human capital are all associated with higher CO₂ emissions. This suggests that Vietnam’s current growth and integration process still relies heavily on energy use. Diagnostic tests confirm that the model is statistically sound. Overall, the findings imply that policy efforts should focus more clearly on cleaner industrial restructuring, better screening of FDI projects, stronger environmental requirements in trade, and improvements in education and training that support low-carbon development.

Keywords: Carbon emissions; Economic integration; Foreign direct investment; Human capital; Industrialization; Trade openness

1. Introduction

Climate change is mainly driven by greenhouse gas emissions, especially carbon dioxide (CO₂). It remains a major global concern in the 21st century (Bezić et al., 2022; Ghazouani, 2021). Current emissions are still above the levels required to limit temperature increases to 1.5°C or 2°C (Rao et al.; Stavropoulos et al., 2022). CO₂ not only causes global warming. It also harms human health. It reduces biodiversity. Melting ice raises sea levels (Bezić et al., 2022; Stavropoulos et al., 2022). Developing countries account for about 60% of global emissions. This share points to the need for a shift toward low-carbon development (Rao et al.).

Production in industry uses so much energy. It is a major source of CO₂ emissions (Stavropoulos et al., 2022). Foreign direct investment (FDI) supports economic growth. However, its environmental effects are not clear (Boamah et al., 2023; Nie et al., 2022). The Pollution Haven view suggests that polluting industries move from developed countries to developing ones where environmental rules are weaker (Nie et al., 2022). In contrast, the Pollution Halo view argues that FDI can lower emissions by bringing cleaner technologies and better management practices to the host country (Ghazouani, 2021; Nie et al., 2022).

Trade, FDI, and the environment are closely linked. Researchers often discuss three main effects: scale, structure, and technology (Dwi Haryanto et al., 2022; Md, 2022; Nie et al., 2022). Lower trade barriers can increase economic activity. This may raise energy use and CO₂ emissions (Galvan et al., 2022; Md, 2022). At the same time, trade can help countries access cleaner and more efficient production methods (Boamah et al., 2023; Dwi Haryanto et

al., 2022). The impact of trade on emissions is not the same in all countries. Results differ across income levels and stages of development (Dwi Haryanto et al., 2022; Md, 2022).

Human capital is important for sustainable development and for using resources more efficiently (Bashir et al., 2019; Gnangoin et al., 2022). Education increases understanding of climate change and encourages more environmentally friendly behavior in daily life and production (Gnangoin et al., 2022). People with better skills can use new technologies more easily, especially renewable energy technologies. This may lower the use of fossil fuels. Some studies also find that human capital and CO₂ emissions do not move in a straight line. Emissions may decrease only when human capital becomes sufficiently high (Gnangoin et al., 2022).

Vietnam is developing quickly and expanding its industrial sector. At the same time, it needs to protect the environment (Bashir et al., 2019; Nie et al., 2022). It is important to study how CO₂ emissions are linked to industrial production, FDI, trade openness, and human capital. This can help policymakers better understand the path toward lower carbon emissions (Bezić et al., 2022; Nie et al., 2022). Such research may also help shape policies on FDI, trade, and education that aim to reduce pollution in the future (Bezić et al., 2022; Gnangoin et al., 2022; Nie et al., 2022).

2. Methodology

2.1. Data

The dataset includes annual data from 1986 to 2023 (38 observations). Information is taken from the World Development Indicators and Penn World Table 11.0. The sample size is adequate relative to the number of variables used in the model Tabachnick et al. (2013) and Pham et al. (2022).

CO₂ emissions per capita are used to reflect environmental pressure. Industrial production is measured by the share of industrial value added in GDP. FDI is captured by net inflows as a percentage of GDP. Trade openness is defined as total exports and imports relative to GDP. Human capital is taken from the human capital index in Penn World Table 11.0. Table 2.1 presents the descriptive statistics of the variables used in the study, including CO₂ emissions, industrial production (IND), foreign direct investment (FDI), trade openness (TRADE), and human capital (HC) over the research period.

Table 2.1: Descriptive statistics of variables

Indicator	CO2	IND	FDI	TRADE	HC
Mean	127.71	33.62	4.85	114.88	2.17
Median	96.20	35.34	4.32	123.78	2.16
Standard Deviation	109.96	5.01	2.65	43.74	0.35
Kurtosis	-0.22	-0.35	0.89	-0.23	-1.55
Skewness	0.96	-0.86	0.44	-0.56	0.06
Minimum	20.33	22.67	0.00	18.95	1.70
Maximum	372.95	40.21	11.94	186.68	2.74
Count	38	38	4.85	38	38

2.2. Autoregressive Distributed Lag model

The ARDL model is used to examine short- and long-run relationships in the time series. It includes lagged terms of the variables. Following (Pesaran & Shin, 1999), this study uses ARDL to estimate the effects of industrial production (IND), foreign direct investment (FDI), trade openness (TRADE), and human capital (HC) on CO₂ emissions. The model is written as follows:

$$ARDL: \Delta \ln CO_2_t = \beta_0 + \underbrace{\sum_{j=1}^p \beta_j \ln CO_2_{t-j} + \sum_{i=0}^q \delta_{1,i} \Delta IND_{t-i} + \sum_{i=0}^q \delta_{2,i} \Delta FDI_{t-i} + \sum_{i=0}^q \delta_{3,i} \Delta TRADE_{t-i} + \sum_{i=0}^q \delta_{4,i} \Delta HC_{t-i}}_{\text{Short run}} + \underbrace{\varphi_1 \Delta IND_{t-1} + \varphi_2 \Delta FDI_{t-1} + \varphi_3 \Delta TRADE_{t-1} + \varphi_4 \Delta HC_{t-1}}_{\text{Long run}} + \varepsilon_t$$

In this model, the coefficients of the first-order differences represent the short-term effects β_0 ; β_j ; $\delta_{1,i}$; $\delta_{2,i}$; $\delta_{3,i}$; $\delta_{4,i}$. The coefficients of the lagged variables reflect the long-term relationship among the variables φ_j . The random error term ε_t is assumed to have a mean of zero and constant variance.

The advantage of the ARDL model is that it allows variables to have different optimal lag lengths and can be applied when the data series are integrated at level I(0) or I(1), as long as no variable is integrated of order two, I(2). Therefore, this method is particularly suitable for small sample sizes, such as in the present study.

The analysis followed several steps. The Ng–Perron unit root test was first applied to check the stationarity of the variables (Ng & Perron, 2001). The lag length of the ARDL model was chosen using the Schwarz Criterion. Given the relatively small sample size, this criterion was considered appropriate. EViews software was used to select the optimal lag length (Nsor-Ambala & Amewu, 2023). Next, the Bounds test was used to examine the existence of a long-run relationship. When cointegration was found, an Error Correction Model (ECM) was estimated to capture short-run adjustments. The error correction term is expected to be negative and significant. Diagnostic tests were then performed, including tests for autocorrelation, heteroskedasticity, and model stability using CUSUM and CUSUMSQ.

3. Results and Discussion

3.1. Unit root test and cointegration test

The Ng–Perron unit root test results show that $\ln CO_2$, IND, FDI, and TRADE are not stationary at the level form but become stationary after first differencing, implying that these variables are integrated of order one, I(1). Conversely, the variable HC is stationary at the level form, that is, integrated of order zero, I(0). Thus, no variable is integrated of order two, I(2), and therefore the conditions for applying the ARDL model are satisfied (Table 3.1).

Table 3.1: Ng–Perron Unit Root Test (MZA Statistic)

H0: The series has a unit root.

Variable	Level (MZA)	1st Difference (MZA)	Order of Integration
$\ln CO_2$	0.783	-15.1065***	I(1)
IND	-1.1684	-16.7686***	I(1)
FDI	-4.3473	-17.7540***	I(1)
TRADE	0.1276	-17.6784***	I(1)
HC	-345.1840***	-2.1649	I(0)

Notes: For the Ng–Perron test, the critical values for MZA are: 1% = -13.8000; 5% = -8.1000; 10% = -5.7000

Decision rule: If MZA < critical value, reject H0 or the series is stationary.

***, **, and * denote rejection of the null hypothesis at the 1%, 5%, and 10% levels, respectively.

In Table 3.2, the F-statistic is 9.1914. It is higher than the upper bound critical value at the 1% level. This suggests a long-term link among CO₂ emissions, industrial production, FDI, trade openness, and human capital over the sample period.

Table 3.2: Bounds Test Results

Null Hypothesis: No cointegration exists (at the level form)

F-statistics	Critical values of the Bound test		
	Significance level	I(0)	I(1)
9.1914	10%	2.696	3.898
	5%	3.276	4.63
	1%	4.59	6.368

3.2. Short-term and Long-term relationships

Table 3.3 reports the ARDL–ECM results. The error correction term (COINTEQ) is negative (–0.9879) and significant at the 1% level. This supports the presence of a long-run relationship among the variables. Around 98.8% of short-term deviations are corrected within one period. In the short run, CO₂ emissions depend on their own past values. FDI shows a negative effect at the first and second lags. Trade openness has a negative effect at the first lag. Human capital also has a negative impact at several lags. Current industrial production and current FDI are not significant in the short term.

In the long term, all variables—IND, FDI, TRADE, and HC—have positive and statistically significant coefficients, implying that increases in industrialization, FDI inflows, trade openness, and human capital lead to higher CO₂ emissions in the long term.

Table 3.3. Estimation results of the ARDL–ECM model and diagnostic tests

Variables	Coefficient	Standard Error	t-statistic	p-value
Short-term relationship				
COINTEQ*	0.9879** *	0.1303	7.5793	0.0000
D(LNCO2(-1))	0.3090**	0.1124	2.7495	0.0124
D(LNCO2(-2))	0.4592** *	0.1519	3.2659	0.0039
D(IND)	-0.0035	0.0055	0.6431	0.5274
D(FDI)	0.0028	0.0062	0.4481	0.6589
D(FDI(-1))	0.0200** *	0.0055	3.6425	0.0016

Variables	Coefficient	Standard Error	t-statistic	p-value
Short-term relationship				
D(FDI(-2))	0.0208** *	0.0054	3.8557	0.0010
D(TRADE)	0.0012	0.0014	0.8955	0.3812
D(TRADE(-1))	0.0042** *	0.0012	3.5577	0.0020
D(HC)	3.5863** *	1.0411	3.4479	0.0026
D(HC(-1))	-4.5239**	1.6742	2.7022	0.0137
D(HC(-2))	-0.9045	1.3259	0.6821	0.5030
D(HC(-3))	-1.4462	0.9219	1.5687	0.1324
C	1.0239** *	0.1441	-7.105	0.0000
Long-term relationship				
IND	0.0333** *	0.0108	3.075	0.0045
FDI	0.0260** *	0.0094	2.7747	0.0094
TRADE	0.0075** *	0.0014	5.1851	0.0000
HC	1.6911** *	0.1439	11.7519	0.0000
Model testing				
Testing	F-Statistic	P-value (Prob.)		
Breusch-Godfrey autocorrelation test (LM test)	0.48829	0.6237		
Breusch-Pagan-Godfrey heteroskedasticity test	0.55773	0.8786		

Note: ***, **, * correspond to statistical significance levels of 1%, 5%, and 10%, respectively.

3.3. Diagnostic and Stability Tests

The Breusch–Godfrey test results indicate no evidence of autocorrelation (p-value = 0.6237), while the Breusch–Pagan–Godfrey test shows no evidence of heteroskedasticity (p-value =

0.8786) (Table 3.3). In addition, both the CUSUM and CUSUMSQ plots remain within the 5% critical bounds, confirming that the estimated coefficients are stable throughout the study period (Figure 1). Therefore, the ARDL–ECM model satisfies the necessary econometric assumptions and ensures the reliability of the estimation results.

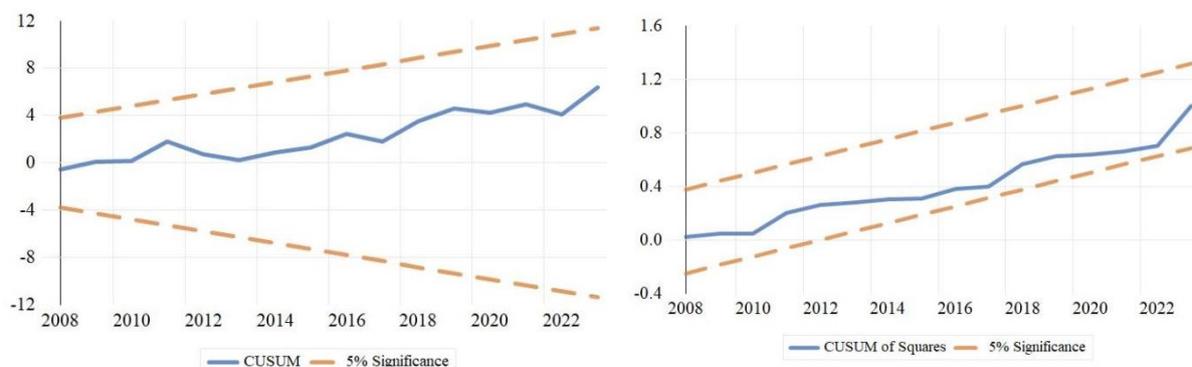


Figure 1: CUSUM and CUSUMSQ graphs of the ARDL model

3.4. Discussion

In the long run, industrial production (IND) increases CO₂ emissions. This suggests that ongoing industrialization adds pressure to the environment. Similar results are reported in other studies, where industry accounts for a large share of energy use and carbon emissions (Zhang et al., 2020). At a middle level of industrial development, heavy and energy-intensive sectors often remain important. In such cases, higher output usually comes with higher emissions. Countries like China have seen this link between industrial growth and rising emissions (Zhang et al., 2020).

Foreign direct investment (FDI) inflows have a positive and statistically significant long-term effect on CO₂ emissions. Higher FDI is associated with higher CO₂ emissions. The result is consistent with the Pollution Haven view. Countries with weak environmental rules may receive more pollution-intensive industries (Boamah et al., 2023; Fang et al., 2022; Wang et al., 2024). Foreign direct investment (FDI) inflows have a positive and statistically significant long-term effect on CO₂ emissions. This means that higher FDI is linked with higher emissions. The result is consistent with the Pollution Haven view. Countries with weak environmental rules may receive more pollution-intensive industries (Boamah et al., 2023; Fang et al., 2022; Wang et al., 2024). In many cases, FDI flows into low value-added sectors that rely on older and less efficient technologies. This can raise emissions in the host country (Boamah et al., 2023; Wang et al., 2024). Some African and middle-income countries show the same trend (Boamah et al., 2023).

Trade openness (TRADE) has a positive and significant long-run effect on CO₂ emissions. Greater economic integration is associated with higher energy production and consumption. Evidence from developing countries shows a similar pattern: when trade expands, production and energy use usually increase, and emissions rise as well (Feng et al., 2024; Galvan et al., 2022). International trade may relocate production to areas with lower costs but higher emission intensity, a process often referred to as “carbon leakage” (Meng et al., 2023). More import and export activity can also raise energy demand in transport and logistics, adding further pressure on environmental quality (Feng et al., 2024).

In the long run, CO₂ emissions tend to rise as human capital increases. In other words, when the workforce becomes more skilled, economic activity often expands and energy use grows as well. Similar patterns can be observed in a number of emerging economies, where better labor skills go together with larger and more resource-intensive production systems (Feng et al., 2024; Murniati, 2023). In the early stage of development, human capital increases productivity and consumption. However, without strong environmental knowledge, this process can lead to higher emissions (Feng et al., 2024). Studies in Indonesia and other developing countries also show that rising human capital is not always accompanied by effective emission reduction in the short term (Murniati, 2023).

4. Conclusion and policy implications

This study applies the ARDL–ECM model to examine the relationship between CO₂ emissions and industrial production, FDI, trade openness, and human capital in Vietnam from 1986 to 2023. The results confirm a long-term cointegration among the variables. The error correction term is negative and statistically significant, showing a fast adjustment toward long-term equilibrium. In the long run, industrial production, FDI, trade openness, and human capital all have positive and significant effects on CO₂ emissions. These results suggest that Vietnam's growth and integration remain linked to an energy-intensive and high-emission development path.

The findings point to practical implications. A gradual shift toward cleaner and more energy-efficient technologies appears necessary in the industrial sector. FDI screening could place greater weight on environmental performance, giving priority to projects that meet clear standards. Trade policy may also benefit from stronger environmental safeguards to prevent the expansion of high-emission activities. With regard to human capital, current skill upgrading seems to be closely tied to economic expansion. Incorporating environmental knowledge and green technology content into education and training programs may help redirect this process. In this way, improvements in human capital could support emission reduction rather than additional growth in emissions. Overall, Vietnam's growth pattern still relies heavily on energy use. Moving toward a lower-carbon path will likely depend on continued technological upgrading and improvements in institutional quality.

References

1. Bashir, A., Thamrin, K. M. H., Farhan, M., Mukhlis, & Atiyatna, D. P. (2019). The causality between human capital, energy consumption, CO₂ emissions, and economic growth: empirical evidence from Indonesia. *International Journal of Energy Economics and Policy*, 9(2), 98-104. <https://doi.org/10.32479/ijeep.7377>
2. Bezić, H., Mance, D., & Balaž, D. (2022). Panel Evidence from EU Countries on CO₂ Emission Indicators during the Fourth Industrial Revolution. *Sustainability*, 14(19), 12554.
3. Boamah, V., Tang, D., Zhang, Q., & Zhang, J. (2023). Do FDI Inflows into African Countries Impact Their CO₂ Emission Levels? *Sustainability*, 15(4), 3131.
4. Dwi Haryanto, R., Rahmawati, Y., Altamirano, O. G. R., Ahsani, S. F., Hudang, A. K., & Haryanto, T. (2022). An Empirical Investigation between FDI, Tourism, and Trade on CO₂ Emission in Asia: Testing Environmental Kuznet Curve and Pollution Haven Hypothesis. *International Journal of Energy Economics and Policy*, 12(4), 385-393. <https://doi.org/10.32479/ijeep.13242>
5. Fang, H., Jiang, C., Hussain, T., Zhang, X., & Huo, Q. (2022). Input Digitization of the Manufacturing Industry and Carbon Emission Intensity Based on Testing the World and

- Developing Countries. *International Journal of Environmental Research and Public Health*, 19(19), 12855. <https://www.mdpi.com/1660-4601/19/19/12855>
6. Feng, M. Q., Morake, O., Sampene, A. K., & Agyeman, F. O. (2024). Trade openness, human capital, natural resource, and carbon emission nexus: a CS-ARDL assessment for Central Asian economies. *Environmental Science and Pollution Research*, 31(21), 31424-31442. <https://doi.org/10.1007/s11356-024-33059-6>
 7. Galvan, L. P. C., Bhatti, U. A., Campo, C. C., & Trujillo, R. A. S. (2022). The Nexus Between CO2 Emission, Economic Growth, Trade Openness: Evidences From Middle-Income Trap Countries [Original Research]. *Frontiers in Environmental Science, Volume 10 - 2022*. <https://doi.org/10.3389/fenvs.2022.938776>
 8. Ghazouani, T. (2021). Impact of FDI inflow, crude oil prices, and economic growth on CO2 emission in Tunisia: Symmetric and asymmetric analysis through ARDL and NARDL approach. *Environmental Economics*. [https://doi.org/10.21511/ee.12\(1\).2021.01](https://doi.org/10.21511/ee.12(1).2021.01)
 9. Gnangoin, T. Y., Kassi, D. F., Edjoukou, A. J.-R., Kongrong, O., & Yuqing, D. (2022). Renewable energy, non-renewable energy, economic growth and CO2 emissions in the newly emerging market economies: The moderating role of human capital [Original Research]. *Frontiers in Environmental Science, Volume 10 - 2022*. <https://doi.org/10.3389/fenvs.2022.1017721>
 10. Md, Q. (2022). Nexus between energy intensity, human capital development, Trade and environmental quality in LIC, LMIC and UMIC: Evidence from GMM. *GSC Advanced Research and Reviews*, 13(2), 051-068. <https://doi.org/10.30574/gscarr.2022.13.2.0293>
 11. Meng, J., Huo, J., Zhang, Z., Liu, Y., Mi, Z., Guan, D., & Feng, K. (2023). The narrowing gap in developed and developing country emission intensities reduces global trade's carbon leakage. *Nature Communications*, 14(1), 3775. <https://doi.org/10.1038/s41467-023-39449-7>
 12. Murniati, M. (2023). Impact of Economic Growth on Human Capital, Work Participation, and Emission Reductions: Case Study in Indonesia. *Asia Pacific Journal of Management and Education*, 6(1). <https://doi.org/10.32535/apjme.v6i1.1647>
 13. Ng, S., & Perron, P. (2001). LAG Length Selection and the Construction of Unit Root Tests with Good Size and Power. *Econometrica*, 69(6), 1519-1554. <https://doi.org/10.1111/1468-0262.00256>
 14. Nie, Y., Liu, Q., Liu, R., Ren, D., Zhong, Y., & Yu, F. (2022). The Threshold Effect of FDI on CO2 Emission in Belt and Road Countries. *International Journal of Environmental Research and Public Health*, 19(6), 3523.
 15. 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>
 16. 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/DOI: 10.1017/CCOL521633230.011>
 17. 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>
 18. Rao, G. M., Hu, X., Yuan, H., & Wang, Y. (2018). Analysis on Screening Methods Of Key Sectors Of Industrial CO2 Emission.

19. Stavropoulos, P., Panagiotopoulou, V. C., Papacharalampopoulos, A., Aivaliotis, P., Georgopoulos, D., & Smyrniotakis, K. (2022). A Framework for CO2 Emission Reduction in Manufacturing Industries: A Steel Industry Case. *Designs*, 6(2), 22.
20. Tabachnick, B. G., Fidell, L. S., & Ullman, J. B. (2013). *Using multivariate statistics* (Vol. 6). pearson Boston, MA.
21. Wang, F., Ye, L., Zeng, X., & Zhang, W. (2024). The impact of FDI on energy conservation and emission reduction performance: A FDI quality perspective. *Heliyon*, 10(4), e25676. <https://doi.org/https://doi.org/10.1016/j.heliyon.2024.e25676>
22. Zhang, S., Yang, F., Liu, C., Chen, X., Tan, X., Zhou, Y., Guo, F., & Jiang, W. (2020). Study on Global Industrialization and Industry Emission to Achieve the 2 °C Goal Based on MESSAGE Model and LMDI Approach. *Energies*, 13(4), 825. <https://www.mdpi.com/1996-1073/13/4/825>