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Agricultural Development versus Environmental Sustainability: FDI, Carbon Emissions, and Global Warming in Vietnam's Economy

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Abstract

This study provides a comprehensive examination of the environmental consequences of foreign direct investment (FDI) within Vietnam's agri-food sector, focusing on the tension between agricultural expansion and carbon emission control. In the context of rising global climate concerns, the analysis examines how FDI inflows affect CO_2 emissions, while considering agricultural structural transformation, economic development, and trade openness. The results indicate that FDI significantly increases CO_2 emissions, primarily through scale expansion and structural shifts toward emission-intensive agricultural activities. The findings underscore agricultural industrial restructuring as a crucial transmission channel. The study contributes both theoretically and practically by offering policy recommendations aimed at steering FDI toward cleaner agricultural development pathways and supporting Vietnam's transition toward a low-carbon and climate-resilient agri-food system.

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Introduction

In recent years, increasing concern over the environmental consequences of economic expansion has placed the agri-food sector at the forefront of global policy debates, as it is both highly exposed to climate risks and a major contributor to greenhouse gas (GHG) emissions. In this context, foreign direct investment (FDI), a key engine of growth in emerging economies, has gained increasing relevance in discussions on sustainable development. This issue is particularly critical for Vietnam, where rapid economic transformation and agricultural modernisation have contributed to rising CO_2 emissions. According to a UNFCCC report released in December 2023, the rapid expansion of Vietnam's agri-food value chains – partly fueled by rising FDI inflows – has increasingly shaped the nation's carbon footprint, raising important questions about the environmental implications of its development trajectory.

Since the early 1990s, Vietnam's economic liberalisation and integration into global markets have enabled it to attract substantial FDI inflows, supporting sustained GDP growth of over 6% annually during the past decade (General Statistics Office of Vietnam). The economy has advanced, it has also witnessed notable industrial upgrading and deeper integration of the agricultural sector into global supply chains. However, these gains have also led to rising energy demand and mounting environmental pressures. Data from the International Energy Agency (IEA) show that Vietnam's CO_2 emissions have tripled since 1990, largely driven by fossil fuel consumption in manufacturing, urban expansion, and increasingly energy-intensive agri-food processing. This suggests that FDI-led development, while enhancing productivity, may simultaneously reinforce carbon-intensive production structures, intensifying environmental stress.

The Vietnamese government has recognised these challenges and adopted national strategies to promote low carbon development. However, balancing economic competitiveness with agricultural transformation and environmental sustainability continues to be a highly complex challenge. As noted by Tran and Le (2023), understanding the role of FDI in shaping Vietnam's emission trajectory is essential for designing targeted policy

interventions that encourage green-oriented investment and sustainable agricultural transformation. Policy instruments such as Resolution No. 569 (2022), which emphasises technological upgrading and environmentally responsible growth, indicate a growing commitment to aligning investment promotion strategies with climate objectives. In this context, rigorous empirical evidence is needed to clarify how FDI affects CO_2 emissions within the agri-food system.

Although previous studies have examined the FDI-environment relationship in various emerging economies, substantial gaps persist when it comes to Vietnam. First, most studies assess emissions at the aggregate or industrial level without focusing on the agri-food sector, despite its substantial contributions to energy use, land use change, and resource intensive production. Second, the mechanisms through which FDI influences emissions, such as structural upgrading or scale expansion, have not been sufficiently analysed using sector-specific evidence. Third, limited attention has been paid to competing theoretical explanations, including the Pollution Haven and Pollution Halo hypotheses, which carry important implications for sustainability-oriented investment policy.

This study contributes to literature in three main ways. First, it provides sector-specific empirical evidence on the environmental impact of FDI within Vietnam's agri-food system. Second, it examines the mediating role of agricultural structural transformation and economic expansion in shaping the FDI emissions relationship. Third, it incorporates dual theoretical perspectives, namely the Pollution Haven and Pollution Halo hypotheses alongside insights from the Environmental Kuznets Curve (EKC), offering a more nuanced interpretation of whether FDI reinforces carbon-intensive development patterns or promotes cleaner production practices.

The remainder of this paper is structured as follows. Section 2 synthesises previous evidence on the FDI emissions nexus and identifies key policy gaps. Section 3 outlines the empirical framework, variable selection, and data sources. Section 4 presents the empirical findings and interprets them in relation to transmission mechanisms and policy implications. Section 5 concludes with recommendations for restructuring FDI attraction policies, strengthening environmental governance in agriculture, and promoting climate-smart development pathways for Vietnam and similar emerging economies.

Pollution Haven Hypothesis

The Pollution Haven Hypothesis (PHH) posits that multinational corporations may relocate pollution-intensive industries to developing

countries where environmental regulations are relatively weak. Under such conditions, host countries risk becoming "pollution havens" as the inflow of FDI can exacerbate environmental degradation through increased emissions and resource-intensive production. This hypothesis was first formalised by Grossman and Krueger (1991) in their seminal analysis of the environmental implications of NAFTA, highlighting the potential for regulatory arbitrage in global production networks.

Subsequent studies offer substantial empirical support for this mechanism. Xing and Kolstad (2002), for example, report a positive relationship between FDI and pollution levels in China, suggesting that multinational firms favour locations with lower regulatory stringency. Sapkota (2017) further finds that across 14 Latin American countries, strengthened environmental regulations in developed countries accelerate the relocation of energy-intensive and high-emission industries to developing economies, especially under conditions of trade liberalisation. These patterns imply that economic incentives, coupled with weak domestic environmental governance, may encourage developing countries to attract foreign investment at the expense of environmental quality.

Evidence from China also supports the PHH, particularly in the context of rapid industrialisation. Dong and Zhang (2018) demonstrate that FDI inflows have significantly increased industrial pollution, while Hu and Shao (2022) find that in the early stages of development, FDI tends to raise CO_2 emissions. Only at more advanced stages of industrial restructuring do cleaner technologies begin to mitigate environmental impacts. Similar conclusions are drawn by Cheng Qinliang *et al.* (2022) and Zhu Yuke *et al.* (2022), who observe that FDI's environmental effects are strongly conditioned by regional development levels, regulatory enforcement, and industrial composition.

Taken together, these findings indicate that developing countries, especially those prioritising growth and export-oriented industrialisation, may be particularly susceptible to pollution-intensive foreign investment. In Vietnam, its rapid structural transformation and expanding agri-food processing sector represent a context where PHH dynamics could be particularly pronounced.

Pollution halo hypothesis

In contrast, the Pollution Halo Hypothesis argues that FDI can improve environmental quality by introducing advanced technologies, cleaner production processes, and superior environmental management practices. Multinational corporations typically adhere to global environmental standards and can generate knowledge spillovers to domestic firms, thereby fostering greener production practices.

Empirical research provides several examples of this effect. Demena and Afesorgbor (2020), using meta-analytic evidence, find that FDI can reduce the intensity of local carbon emissions under certain institutional conditions. Nadeem *et al.* (2020), analysing Pakistan from 1971-2014, report a long-run negative correlation between FDI and CO_2 emissions, indicating that technology transfer can offset pollution associated with scale expansion.

Studies from China further support this perspective. Li and Li (2021), Lu and Luo (2021) show that coordinated development between FDI and economic growth can weaken emission intensity by facilitating technology upgrading. Zou and Chen (2022) highlight that when FDI enters high-tech industries, the resulting technology spillovers impose a strong inhibitory effect on CO_2 emissions. Additionally, Xiang Yu and Dai (2022) demonstrated that two-way FDI between neighbouring cities generates synergistic effects with local economic growth, thereby reducing carbon emission intensity through technology diffusion.

While the Pollution Halo framework offers an optimistic interpretation of FDI's environmental role, its applicability depends heavily on absorptive capacity, regulatory enforcement, and technological composition of inward investment factors that remain uneven across developing countries such as Vietnam.

Environmental Kuznets Curve

The Environmental Kuznets Curve (EKC) describes an inverted U-shaped relationship between economic development and environmental degradation. At early stages of growth, pollution rises as economies industrialise; after reaching an income threshold, cleaner technologies and stronger regulations lead to declining emissions. This dynamic was first empirically demonstrated by Grossman and Krueger (1995) using panel data from 42 countries.

FDI plays a complex role within the EKC framework. Wang and Huang (2017) find that FDI tends to raise CO_2 emissions in the early stages, but later exhibits a moderating effect as economies advance technologically. Wang *et al.* (2019) studied the Beijing-Tianjin-Hebei region and revealed that the environmental impact of FDI varies significantly with geographical location and industrial structure. Jia and Yang (2020) also provide evidence of heterogeneous FDI effects on emissions across China, using Generalised Method of Moments (GMM) estimation.

Overall, the EKC, Pollution Haven, and Pollution Halo hypotheses together offer a multi-dimensional theoretical foundation for analysing the FDI CO_2 emissions nexus. However, current studies still reveal significant limitations: much of it focuses on static or short-term effects; long-term dynamics remain

insufficiently explored; and few studies incorporate cyclical shocks such as the COVID-19 pandemic. To address these gaps, this study integrates the pandemic period into its empirical analysis to better capture structural changes and dynamic variations in FDI's environmental effects.

1. Theoretical analysis and research hypotheses

Vietnam's strategic role in regional production networks and policies favoring foreign capital have led to a spatially concentrated influx of FDI, particularly in coastal economic zones (Tran & Le, 2023). The environmental impact of FDI can be interpreted through the scale composition technique framework (Grossman & Krueger, 1995). At early development stages, scale effects dominate as FDI-driven production expansion increases energy consumption and emissions. The composition effect emerges when FDI encourages shifts toward emission-intensive agri-industrial activities such as processing and fertilizer production. While FDI may introduce cleaner technologies (technique effect), limited absorptive capacity, weak regulations, and early-stage industrialization often constrain such benefits in developing economies like Vietnam.

Previous studies highlight multiple determinants of emissions, including economic growth, industrial structure, energy consumption, foreign capital, and trade openness (Wang *et al.*, 2024; Li, 2014; Cheng, 2019; Cole & Elliott, 2005). Li *et al.* (2011) showed that both pollution haven and pollution halo effects may coexist, following an inverted U-shaped Environmental Kuznets Curve (EKC) trajectory. In addition, trade openness may amplify environmental pressures when production expansion is resource-intensive (Luan et al, 2019). These findings imply that FDI influences CO_2 emissions through different mechanisms that depend on structural conditions and development stages.

Based on these theoretical insights, this study proposes the following hypotheses:

H1: FDI inflows are positively associated with CO_2 emissions in Vietnam.

H2: Industrial structure mediates the FDI-emissions relationship, with structural upgrading mitigating environmental impact.

H3: Economic development moderates the FDI-emissions nexus in a nonlinear (inverted U-shaped) manner.

H4: Trade openness strengthens the positive effect of FDI on CO_2 emissions.

2. Data description and model construction

Data sources

The dataset used in this study is compiled from internationally recognised sources to ensure consistency and comparability. CO_2 emissions data are obtained from the World Bank's World Development Indicators (WDI), using indicator EN.ATM.CO2E.KT, which reports total national emissions in kilotons (kt). This unit of measurement aligns with international reporting standards and previous empirical studies.

FDI inflows are drawn primarily from the World Bank (2023) and supplemented, where necessary, with data from Vietnam's General Statistics Office (GSO) to ensure accurate representation of investment trends. Data on agricultural value added, gross domestic product (GDP) per capita, and trade openness (measured as the ratio of total trade to GDP) are likewise obtained from WDI. Industrial structure indicators, representing the share of industrial output in GDP, are collected from both WDI and GSO to maintain alignment with domestic classification systems.

The study covers the period 2010-2022, corresponding to the years for which complete and consistent data are available for all variables. This period captures Vietnam's accelerated agricultural modernisation, deepening global integration, and shifts in FDI liberalisation, making it suitable for examining the FDI-CO_2 emissions nexus.

Variable selection

A. Dependent Variable

Following Hu and Shao (2022), CO_2 emissions serve as the dependent variable, representing Vietnam's environmental pressure.

B. Core Explanatory Variable

Consistent with findings by Wu and Liu (2021), FDI inflows are included as the core explanatory variable to evaluate the environmental implications of inward investment.

C. Control Variables

Three control variables are incorporated to strengthen model robustness:

Industrial structure (IS): measured as the ratio of industrial output to GDP, following Yuan and Cheng (2011).

Economic development (PGDP): GDP per capita as a proxy for income level (Liao, 2020).

Trade openness (TRD): the ratio of total imports and exports to GDP (Liao, 2020).

Together, these variables capture key structural and economic determinants of emissions.

Overall, these variables are selected to capture key economic, structural, and external factors influencing Vietnam's carbon emissions, thereby forming an integrated analytical framework for subsequent empirical estimation. The model is subsequently developed in the next subsection to analyse both the direct and marginal effects of FDI on CO_2 emissions.

Table 1 - Description of variables

Variant	Variable Symbol	Variable Name	Variable Meaning
Explanatory Variable	CO_2	CO_2 Emissions	Total CO_2 emissions in Vietnam (thousands of tons)
Core Explanatory Variables	FDI	Foreign Direct Investment	Amount of FDI inflows to Vietnam (USD billion)
Control Variable	IS	Industrial Structure	Gross industrial sector product/ GDP (%)
	PGDP	Level of Economic Development	GDP/total population at the end of the year (USD/person)
	TRD	Level of Foreign Trade	Total exports and imports of Vietnam/GDP

Model construction

In many early-stage developing countries, environmental regulations are relatively relaxed or intentionally kept loose to prioritise economic growth. Under such conditions, inward FDI can increase CO_2 emissions through scale effects, particularly when foreign capital flows into emission-intensive sectors. This may lead the host country to function as a "pollution haven". Building on this theoretical foundation, the empirical model for this study is specified as follows:

$$CO_2 = \beta_0 + \beta_1 * FDI_t + \beta_2 * IS_t + \beta_3 * PGDP_t + \beta_4 * TRD_t + \varepsilon_t$$

where:

- CO_{2t} = total CO_2 emissions (kilotons)
- FDI_t = foreign direct investment inflows (billion USD)

- IS_t = industrial structure (% of GDP)
- $PGDP_t$ = GDP per capita (USD/person)
- TRD_t = trade openness (% of GDP)
- ε_t = error term

All coefficients (α_1–α_4) are expected to be positive, reflecting the potential for scale effects, structural dependence, expanding economic activity, and increased trade to raise emissions.

3. Empirical findings

Descriptive statistical analysis

This paper performs descriptive statistics on the acquired data, and the statistical results are presented in Table 2.

Table 2 - Descriptive statistics

Variable	Observations	Minimum	Maximum	Mean	Std. dev.	Variances
CO_2	13	1.5	3.6	2.379	0.7805	0.609
FDI	13	71.47	236.87	145.9677	57.9602	3359.395
IS	13	0.2130	0.6370	0.3756	0.1178	0.014
PGDP	13	1684	4164	2874.46	745.879	556334.936
TRD	13	0.8760	1.8260	1.3533	0.3228	0.104

Table 2 provides descriptive statistics for Vietnam from 2010 to 2022, including indicators related to CO_2 emissions, FDI, industrial structure, economic development, and trade openness. Vietnam's annual CO_2 emissions range from a minimum of 150 million tons to a maximum of 355 million tons, indicating that emissions have more than doubled over nine years.

With respect to FDI, the maximum inflow is USD 23.687 billion, and the minimum is USD 7.147 billion, suggesting that FDI inflows have more than doubled over the study period and confirming Vietnam's continued success in attracting foreign investment.

For the industrial structure, the share of industry in GDP ranges from 0.2130 to 0.6370, reflecting substantial structural variation during the study period. GDP per capita increases from USD 1,684 to USD 4,164, illustrating

Vietnam's rapid economic expansion. Trade openness varies between 0.8760 and 1.8260, with higher values indicating strong reliance on international trade.

This descriptive evidence suggests that Vietnam's economic transformation during 2010-2022 has been associated with rising emissions, deepening integration into global markets, and a growing role for FDI.

Correlation analysis

An ideal model is characterised by the absence of correlation among independent variables, with each variable providing unique information about the dependent variable that is not present in the other independent variables. In this case, the regression coefficient of each independent variable on the dependent variable is unique under the condition that the other independent variables remain constant.

Table 3 - Results of correlation analysis between variables

Variant	**CO_2**	**FDI**	**IS**	**PGDP**	**TRD**
CO_2	1				
FDI	.826** (0.001)	1			
IS	.512** (0.001)	.809** (0.001)	1		
PGDP	.939** (0.000)	.804** (0.001)	.502 (0.080)	1	
TRD	.892** (0.000)	.819** (0.001)	.605* (0.028)	.961** (0.000)	1

* At the 0.05 level (two-tailed), the correlation was significant.
** At the 0.01 level (two-tailed), the correlation was significant.

Table 3 shows the correlation analysis of each variable, in which the core explanatory variable, FDI, is significantly positively correlated with CO_2. The results suggest that Vietnam's economic development is expanding with the continuous inflow of FDI, which requires the consumption of large amounts of energy and other resources. High-intensity energy consumption will increase the total amount of CO_2 emissions; therefore, FDI is significantly and positively related to CO_2 emissions in Vietnam.

From the perspective of industrial structure, Vietnam is in the stage of rapid industrialization, and the expansion of the industrial sector has increased the demand for energy, especially high-carbon energy sources such as coal and oil. The industrial structure is dominated by manufacturing and export processing industries, which typically have higher energy consumption, especially if fossil fuels are used, leading to higher CO_2 emissions. The agricultural sector, which still accounts for a large share of Vietnam's economy, has relatively low direct CO_2 emissions compared to the industrial sector, but agricultural expansion may lead to deforestation and land-use change, indirectly increasing CO_2 emissions. At the same time, technological underdevelopment in industry and inefficient energy consumption lead to increased CO_2 emissions per unit of output.

From the perspective of the level of economic development, as Vietnam's level of economic development increases and industrialization accelerates, the expansion of the industrial sector has led to an increase in the demand for energy, especially the use of fossil fuels. At the same time, to develop infrastructure work, such as roads, buildings, and power facilities, these increase CO_2 emissions. In addition, the shift in consumption patterns is also a manifestation of the increased level of economic development. As people's income increases, the demand for energy-intensive goods such as automobiles and electronics rises, further pushing up CO_2 emissions.

From the perspective of the level of foreign trade, Vietnam mainly plays the role of manufacturing and assembly in the global value chain. Vietnam's export-oriented economic model has led to the expansion of production scale, especially in the export processing industry, and these activities are usually energy-intensive, which directly increases energy consumption and CO_2 emissions; on the import side, Vietnam imports a substantial amount of raw materials and energy products, particularly fossil fuels, to sustain its industrial production, which in turn contributes to higher CO_2 emissions.

To summarize, FDI shows a clear impact on CO_2 emissions in Vietnam. On the one hand, the FDI inflow exerts a significant impact on Vietnam's CO_2 emissions while promoting its economic growth and industrial upgrading; on the other hand, with the rise in per capita income and the change in consumption patterns, foreign-funded enterprises have expanded their production scale to meet the domestic and international market demands, which may lead to an increase in energy consumption and CO_2 emissions. Meanwhile, the increase in the level of foreign trade, especially the expansion of export-oriented industries, intensifies production activities, which in turn increases CO_2 emissions. Therefore, in the process of attracting FDI, Vietnam needs to pay due attention to the comprehensive impact of industrial restructuring, per capita income growth, and foreign trade

expansion on CO_2 emissions to realize a win-win situation for both economic development and environmental protection.

Regression analysis

Table 4 reports the regression estimates for Vietnam's CO_2 emissions from 2010 to 2022. All coefficients are statistically significant at the 1% or 5% levels, and their signs are consistent with theoretical expectations:

Table 4 - Coefficients and significance results for each variable

Variables	Coefficients	t-statistics	p-values
Constant	0.976	1.611	0.001
FDI	0.897	4.893	0.000
IS	0.680	2.283	0.043
PGDP	0.942	8.874	0.000
TRD	0.953	6.738	0.000

FDI: The results of the core explanatory variable FDI are significantly positive, and the impact of FDI on Vietnam's CO_2 emissions is mainly in terms of capital deepening and technological advancement. FDI brings investment in capital-intensive industries, which tend to be more energy-intensive, leading to an increase in CO_2 emissions (Nadeem *et al.*, 2020; Demena & Afesorgbor, 2020). However, the introduction of more advanced production technologies and clean energy technologies in the future will help to improve energy utilization efficiency, thus curbing the growth of CO_2 emissions to a certain extent. Overall, the impact of FDI on CO_2 emissions in Vietnam depends on the relative intensity of capital increasing and technological progress (Grossman & Krueger, 1995).

IS: The impact of FDI on Vietnam's industrial structure acts on CO_2 emissions. If FDI is mainly concentrated in energy-intensive industries, the entry of foreign direct investment may exacerbate CO_2 emissions; when FDI is mainly concentrated in high-tech clean energy industries, the entry of foreign direct investment will inhibit CO_2 emissions (Cheng, 2019). This study finds that Vietnam is currently in a period of rapid economic development and is mostly dominated by traditional manufacturing industries and other industries in terms of industrial layout, so its CO_2 emissions have increased significantly (Li, 2014).

PGDP: As Vietnam's level of economic development increases, the impact of FDI on CO_2 emissions shows a growing trend. Increased income and upgraded consumption brought about by economic development have prompted FDI firms to expand production to meet market demand, which may lead to an increase in energy consumption and CO_2 emissions. However, economic development also provides Vietnam with more resources and capacity to adopt eco-friendly technologies and implement emission reduction measures, which may offset some of the growth in emissions (Grossman & Krueger, 1991; Sarkodie & Strezov, 2019).

TRD: Increasing levels of foreign trade exacerbate the impact of FDI on Vietnam's CO_2 emissions. Export-oriented FDI is often associated with energy-intensive and emission-intensive activities, and as the level of foreign trade increases, the production activities of foreign-owned firms increase, leading to a rise in CO_2 emissions (Luan & Bowen, 2019). The expansion of foreign trade is likely to bring more international pressure and market demand, which will prompt the Vietnamese government and enterprises to take more active measures in reducing emissions.

Therefore, although changes in the level of foreign direct investment have supported Vietnam's economic development and enhanced living standards, they have also generated growing environmental concerns. However, Vietnam's ecological environment has also seen a significant increase in CO_2 emissions due to the imbalance in the industrial structure. During the current stage of Vietnam's development, there is still much room for adjusting the industrial structure, especially in the introduction of future industries, attention needs to be paid to improving the development of clean industries.

To provide a deeper interpretation of the empirical results, it is necessary to clarify the transmission mechanisms through which FDI influences CO_2 emissions. The significant and positive coefficient of FDI suggests that the scale effect currently dominates in Vietnam's agri-food sector (Grossman & Krueger, 1995). In particular, foreign capital inflows tend to expand production capacity in energy-intensive segments such as agricultural processing, fertilizer production, and mechanized farming, leading to an increase in aggregate energy consumption and associated emissions. By contrast, the technique effect, which implies the transfer of cleaner technologies and more efficient production methods through FDI, appears limited under current conditions due to relatively low domestic absorptive capacity, weak environmental enforcement, and the predominance of cost-driven investment strategies pursued by foreign enterprises (Li *et al*., 2011).

This pattern of influence is more aligned with the Pollution Haven Hypothesis (PHH), which posits that foreign firms may relocate pollution-intensive activities to developing countries with relatively lenient environmental regulations (Zarsky, 1999). Conversely, the Pollution Halo

Hypothesis, which argues that FDI can contribute to environmental improvements through technological spillovers and higher management standards, is not strongly supported by the present evidence (Li *et al.*, 2011). Hence, while FDI contributes to economic expansion and agricultural modernization, its environmental implications reflect an early-stage development context in which productivity-driven growth outweighs technological upgrading with low-carbon orientations.

Robustness Test

A. Shortening the sample period

Considering the outbreak of the COVID-19 pandemic from 2020 to the end of 2022, followed by the relaxation of control measures in 2023, foreign direct investment has become active again in Vietnam. In this paper, the sample period is adjusted to 2010-2019 to exclude the impact of pandemic-related factors, and regression calculations are carried out. The results in Table 5 show that FDI in Vietnam before the pandemic increased significantly with a high value of coefficient and the p-value of the F-test is less than 0.05, which indicates that the estimated coefficients in the model are significant at the 1% level, and the significance is also better than the previous one. It indicates that the empirical results are robust. FDI significantly increases CO_2 emissions in Vietnam.

Table 5 - Coefficients and significance results for each variable

Variables	Coefficients	t-statistics	p-values
Constant	0.988	3.906	0.005
FDI	0.938	6.576	0.000
IS	0.977	3.310	0.011
RGDP	0.954	7.112	0.000
TRD	0.939	4.949	0.001

B. Carbon emissions per capita

To further test the impact of FDI on CO_2 emissions in Vietnam, the regression test is conducted again with carbon emissions per capita as the explanatory variable, and the core explanatory variables and control variables remain unchanged, and the results are shown in Table 6.

Table 6 - Coefficients and significance results for each variable

Variables	Coefficients	t-statistics	p-values
Constant	0.946	2.599	0.025
FDI	0.890	5.021	0.000
IS	0.690	2.317	0.041
PGDP	0.912	7.288	0.000
TRD	0.927	5.729	0.000

The results show that the significant level of the core explanatory variables and CO_2 is in line with the test results, thus further validating the previous conclusions.

Therefore, after the empirical analysis and robustness analysis, hypothesis 1, hypothesis 2, and hypothesis 4 are in line with the performance of the findings of this paper, and hypothesis 3 is still showing a positive impact due to the current industrial structure of Vietnam.

Conclusions and implications

Vietnam, as a rapidly industrialising and structurally transforming emerging economy, is experiencing a marked increase in CO_2 emissions driven by economic growth, rising energy demand, and expansion of agro-industrial activities. Based on empirical evidence from 2010 to 2022, this study offers several key conclusions regarding the environmental implications of FDI in Vietnam.

First, FDI has a statistically significant and positive effect on CO_2 emissions. Capital inflows, particularly those allocated to energy-intensive agribusiness operations, fertiliser production, and large-scale food-processing sectors, have been shown to amplify emission levels. These activities expand production capacity, increase reliance on fossil fuels, and intensify pressure on the environment. The findings therefore reflect the structural trade-off inherent in export-oriented agricultural development, where productivity gains are achieved at the cost of greater carbon intensity.

Second, Vietnam's economic structure, especially the ongoing expansion of agro-industrial activities, plays a critical role in shaping emission outcomes. The current production system remains heavily dependent on carbon-intensive processes in both manufacturing and modernised agri-food value chains. Without a shift toward cleaner and more technologically advanced production structures, achieving substantial decarbonisation will remain

challenging. This underscores the need to align agricultural modernisation with environmental sustainability goals.

Third, the process of economic development has consistently coincided with rising levels of emissions. As income levels grow, infrastructure construction expands, consumer demand for energy-intensive goods increases, and agricultural production scales up; together, these factors contribute to higher CO_2 emissions. While economic growth has improved productivity and competitiveness, it has also intensified environmental pressures, highlighting the urgency of transitioning to low-carbon growth pathways.

Fourth, trade openness is positively associated with CO_2 emissions. Vietnam's export-oriented economic model continues to rely on resource-intensive and energy-demanding production activities. To mitigate emission intensity while maintaining competitiveness, Vietnam must move toward higher-value and lower-carbon export products, such as certified sustainable agricultural goods.

Taken together, these findings provide stronger empirical support for the Pollution Haven Hypothesis than for the Pollution Halo Hypothesis, indicating that scale effects of FDI currently outweigh potential technology-induced environmental improvements in Vietnam. Weak regulatory enforcement limited absorptive capacity, and the dominance of cost-driven FDI all constrain the realisation of cleaner production benefits.

Based on the findings, several policy implications emerge: (i) Promote green-oriented FDI and strengthen screening mechanisms: Vietnam should refine its investment promotion strategies to privilege environmentally responsible projects, especially those involving clean technologies, renewable energy, and sustainable agri-food processing. Strengthened FDI screening and environmental impact assessments are essential to prevent the relocation of pollution-intensive industries; (ii) Accelerate industrial restructuring within the agri-food sector: Policies encouraging technological upgrading, digitalisation, and efficient resource use in agricultural processing can reduce emission intensity. Incentives should support shifts from low-value, energy-intensive production to higher-value and low-carbon agri-food activities; (iii) Enhance environmental regulations and enforcement capacity: Stricter enforcement of emission standards paired with transparent monitoring can reduce the pollution-haven risk. Expanding the use of carbon pricing, green certification, and emission-reporting requirements can further align domestic practices with international environmental commitments; (iv) Strengthen absorptive capacity for green technologies: Promoting human capital development, strengthening university–industry linkages, and expanding technology-transfer programmes will enhance the capacity of domestic firms to absorb and apply the cleaner technologies introduced through FDI; (v) Advance sustainable and low-carbon trade strategies: Vietnam should

gradually shift toward exporting products with lower carbon footprints, supported by certification schemes and traceability systems. This is especially crucial given that global markets, with the EU at the forefront, are raising the stringency of environmental regulations on imported products.

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