

FDI Inflows and CO₂ Emissions in Vietnam: The Moderating Role of Local Governance and the Scale Paradox

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Abstract. Aligned with Vietnam's net-zero 2050 commitment, this study examines how FDI inflows affect provincial CO₂ emissions, considering governance quality and economic scale. Using panel data for 63 provinces (2018-2024), CO₂ emissions are proxied from electricity use per IPCC standards. The model applies FGLS with robustness checks (GMM, Driscoll-Kraay). Results show FDI reduces emissions, reflecting clean technology transfer. However, governance moderates this effect: in provinces with stronger governance, FDI-driven growth increases total emissions (scale effect). Economic scale alone is not a significant moderator. Logistics and industrial activity are key emission sources, while a higher Human Development Index is associated with better environmental quality.

1. INTRODUCTION

As global climate change becomes more serious, many countries have committed to achieving net-zero emissions in the second half of the 21st century, considering green transition as a central direction in their development strategies. At the same time, foreign direct investment continues to play an important role in promoting economic growth, industrialization, and integration into global value chains, especially in developing economies. Therefore, the coexistence of growth objectives and emission reduction requirements has increased attention to the environmental impact of FDI.

International studies on the relationship between FDI and CO₂ emissions show mixed results. Some research suggests that FDI may increase emissions because it expands production scale and energy consumption. However, other studies emphasize the positive role of FDI through technology transfer and improvements in energy efficiency. This difference indicates that the

Received: Mar. 11, 2026.

2020 *Mathematics Subject Classification.* 91B76; 62P20.

Key words and phrases. FDI; CO₂ emissions; local governance; economic scale; sustainable development.

impact of FDI strongly depends on institutional quality and the level of development in each country or locality.

Vietnam is a typical case in this context. After committing to Net Zero at COP26, green transition has become a strategic priority, while FDI remains a key driver of growth, particularly in the manufacturing and processing sectors. Nevertheless, there are significant differences in public governance capacity, economic scale, and industrial structure among the 63 provinces and cities. Because of that, the environmental impact of FDI may not be the same across local areas. This situation highlights the need to analyze the relationship between FDI and carbon emissions at the provincial level.

Based on panel data from 63 provinces and cities during the period 2018-2024, this study examines the impact of FDI on CO₂ emissions. Emissions are estimated from electricity consumption using the IPCC guidelines. The results show that FDI tends to reduce CO₂ emissions in terms of direct effects. However, this impact depends on local conditions, as public governance quality plays an important role in shaping the relationship between FDI and emissions. In addition, logistics and industrial production are identified as the main sources of emissions, while higher human development levels contribute to environmental improvement.

These findings suggest that attracting FDI does not automatically guarantee emission reduction goals. Therefore, policy should shift its focus from the quantity to the quality of FDI. Investment selection needs to be linked with technological standards and energy efficiency requirements. At the same time, improving local governance capacity is necessary to ensure that FDI truly supports green growth objectives and Vietnam's Net Zero pathway.

2. LITERATURE REVIEW

The relationship between FDI and CO₂ emissions has been widely studied in environmental economics, with two main approaches being the "pollution haven" and "pollution halo" hypotheses. Under the first approach, Cole [7] used panel data from developing countries and found evidence that FDI tends to concentrate in pollution-intensive industries in locations with weak environmental regulations. Keller and Levinson [18], studying U.S. states, showed that lax environmental standards can attract more investment in polluting industries. States have shown that LAX environmental standards can attract more investment into polluting industries. Dean et al. [11], analyzing provincial-level data in China, also indicated that FDI in certain industries is positively associated with local pollution levels. These findings support the view that FDI may increase emissions when the institutional environment is not sufficiently strong.

Conversely, several empirical studies support the "pollution halo" hypothesis, arguing that FDI can contribute to improving environmental quality through technology transfer and advanced management standards. Zarsky [24] argued that multinational corporations often bring cleaner technologies and more efficient production processes compared to domestic firms. Antweiler et al. [1], by decomposing the effects of trade into scale, composition, and technical effects, showed

that the technical effect can reduce pollution when the economy gains access to advanced technology. Hossain [16], using panel data from developing countries, also found evidence that FDI can contribute to long-term CO₂ emission reductions when accompanied by technological improvements and income growth. The differences in empirical results suggest that the impact of FDI on CO₂ is not uniform but depends on institutional conditions and the level of economic development.

Governance quality is considered an important factor that modifies the relationship between FDI and the environment. Damania, Fredriksson, and List [10] showed that corruption and weak policy enforcement can increase industrial pollution. Cole [8] also indicated that countries with weak institutions tend to attract more FDI into highly polluting industries. Conversely, Kellenberg [17] demonstrated that high institutional quality reduces the incentive for multinational firms to engage in “pollution haven” behavior. Ben Youssef et al. [3], analyzing panel data from developing countries, concluded that good governance can weaken the positive relationship between FDI and CO₂ emissions. Supporting this argument, Giang and Ha [13] constructed a provincial institutional index based on the Provincial Competitiveness Index (PCI) and found that better institutional quality significantly enhances provincial FDI attraction in Vietnam. Their findings highlight the importance of local governance as a key factor influencing both investment decisions and their potential environmental impacts. However, most of these studies were conducted at the national level, and evidence at the local or provincial level, particularly in the context of Vietnam, remains limited.

In addition, the relationship between income and emissions is often analyzed through the Environmental Kuznets Curve (EKC) hypothesis. Grossman and Krueger [14] found an inverted U-shaped relationship between per capita income and certain pollution indicators in cross-country data. Dinda [12] also documented evidence supporting the EKC in certain contexts. However, Stern [22] argued that the evidence for the EKC remains inconsistent and depends on the estimation methodology. Some recent studies, such as Zhu et al. [26], indicate that the impact of FDI on the environment may vary by income level, with higher-income regions tending to attract more high-tech and less polluting FDI. Recent evidence from Vietnam also supports the relevance of the EKC framework. Le et al. [19] showed that the relationship between economic growth and air quality is nonlinear and depends on the stage of economic development, suggesting that economic expansion should be accompanied by technological progress and effective environmental policies to achieve sustainable growth. This suggests that GDP per capita not only directly affects CO₂ emissions but may also play a moderating role in the relationship between FDI and emissions.

Besides FDI and institutional factors, industrial scale and structure are also identified as important drivers of emissions. Antweiler et al. [1] showed that expanding production scale (the scale effect) tends to increase pollution if not accompanied by technological improvements. He [15], studying provincial-level data in China, found a statistically significant positive relationship between industrial output and emissions. Zhang and Zhou [25] also confirmed that industrial

expansion is one of the main factors increasing CO₂ emissions in rapidly industrializing regions. While many studies use industrial value added to reflect the level of development and production efficiency, some studies emphasize the role of gross industrial output as a direct indicator of operational scale and energy consumption. However, simultaneously including both industrial value added and gross industrial output in the same model to distinguish between efficiency and scale effects remains underexplored, especially in provincial-level studies.

Regarding the human development factor, Costantini and Monni [9] pointed out that countries with higher HDI tend to have better emission control in the long term. Neumayer [20] also found a link between social development and improved environmental quality. However, most studies use HDI at the national level, while empirical evidence at the provincial or local level is limited.

From the above overview, three main research gaps can be identified. Firstly, the results on the impact of FDI on CO₂ are inconsistent, and few studies simultaneously test the moderating roles of both governance quality and GDP per capita within the same analytical framework. Secondly, studies on industrial scale often use only one proxy variable and do not clearly distinguish between value added and gross output to separate efficiency and scale effects. Third, in the context of Vietnam, provincial-level studies that integrate FDI, local governance, income, industrial scale, and HDI into a single model are relatively limited. Therefore, constructing a provincial-level panel data model to simultaneously analyze economic and institutional factors will contribute additional empirical evidence to the relationship between FDI and CO₂ emissions in the context of developing economies.

3. DATA AND METHODOLOGY

3.1. Data description. The data used in this research was collected from the Statistical Yearbooks of 63 provinces and centrally-governed cities in Vietnam. It was also combined with financial data provided by FiinPro-X and archived documents from the National Library of Vietnam during the period from 2018 to 2024. Therefore, the dataset has information from different reliable sources.

The dataset is organized in the form of balanced panel data with a two-dimensional structure. In terms of cross-section, the sample covers all 63 provinces and cities across the country. Because of that, the model can reflect the differences in socio-economic development level and public governance capacity between different regions. On the other hand, in the time-series dimension, the data was collected continuously for 7 years, from 2018 to 2024.

This period is important since Vietnam strongly implemented new-generation free trade agreements such as the Comprehensive and Progressive Agreement for Trans-Pacific Partnership and the EU - Vietnam Free Trade Agreement. In addition, the country gradually standardized its environmental reporting system. As a result, the dataset is updated and quite consistent, and it also has high reliability. Therefore, it is suitable for in-depth quantitative analysis. Table 1 presents the list and definitions of the variables used in this study.

TABLE 1. Variable definitions

Variable	Definition	Source	Literature reviews	Expected direction of impact
CO2	Dependent Variable. The natural logarithm of total CO2 emissions, estimated based on commercial electricity consumption and the national grid emission factor.	Statistical yearbook by 63 provinces in Vietnam	IPCC	
FDI	Independent Variable. Total realized Foreign Direct Investment capital disbursed within the province during the year (Unit: Million USD).	Data by FiinProX	Cole [7]; Zarsky [24]; Dean et al. [11]	+/-
PAPI	Moderating Variable. The Provincial Governance and Public Administration Performance Index, reflecting citizens' experiences with local government performance (Scale: 0-100).	UNDP in Vietnam	Damania et al. [10]; Cole [8]; Ben Youssef et al. [3]	-
GDP	Moderating Variable. The annual growth rate of the Gross Regional Domestic Product (GRDP), representing the economic development speed of the province (Unit: %).	Data by FiinProX	Grossman & Krueger [14]; Dinda [12]; Zhu et al. [26]	+
IIP	Control Variable. The Index of Industrial Production, measuring the growth of industrial output compared to the previous year (Unit: %).	Data by FiinProX	He [15]; Zhang & Zhou [25]	+
Freight	Control Variable. The natural logarithm of the volume of freight transport, representing logistics and trade activities (Unit: Million ton.km).	Statistical yearbook by 63 provinces in Vietnam	Antweiler et al. [1]; Copeland & Taylor	+
HDI	Control Variable. The Human Development Index, a composite measure of health, education, and income (Scale: 0-1).	Statistical yearbook by 63 provinces in Vietnam	Costantini & Monni [9]; Neumayer [20]	-
FDI × PAPI	Interaction Variable. An interaction variable between FDI and PAPI, used to test the moderating role of governance quality on the environmental impact of FDI.		Kellenberg [17]; Ben Youssef et al. [3]	-
FDI × GDP	Interaction Variable. An interaction variable between FDI and GDP, used to examine how the scale of economic development moderates the relationship between FDI and emissions.		Zhu et al. [26]; Antweiler et al. [1]	+/-

Source: Compilation by authors from research data

The detailed structure of the research sample plays an important role in supporting the research questions. First of all, by using balanced panel data by province and by time, the model is able to control fixed effects. Therefore, it can remove unobserved factors which are specific and stable over time in each locality, such as geographical location, natural conditions, or available resources. If these factors are not controlled, they may cause bias in the regression estimation.

Secondly, the sample size includes 63 provinces over 7 years, which means the total number of observations is $N = 441$. This number is quite large and provides a strong data foundation for

analyzing interaction effects. In particular, the study tests interaction variables such as FDI $\times$ PAPI and FDI $\times$ GDP. Because of that, the research can better explain the moderating role of institutional quality and socio-economic growth on the impact of foreign direct investment inflows.

As a result, the study is able to clarify the impact mechanism in a deeper and more convincing way. Table 2 presents the summary statistics of the research sample.

TABLE 2. Descriptive statistics

	count	mean	std	min	25%	50%	75%	max	skewness	kurtosis
lnCO2	441	7.514274	1.08319	5.145734	6.701652	7.432774	8.254044	10.22078	0.421699	-0.11193
FDI	441	534.5127	1118.454	-135.29	5.9	91.26	487.77	8454.69	3.810699	17.96836
PAPI	441	54.76035	4.06981	1.25	52.675	54.6625	56.9625	66.625	-4.9489	67.07249
GDP	441	6.650658	3.804366	-10.03	5	7.1	8.58	20.85	-0.48426	3.254845
IIP	441	108.8075	9.988153	73.05	104.32	108.52	113.09	188.48	1.131515	10.34469
lnFreight	441	6.970675	1.452801	2.674149	6.1468	6.920899	7.81709	11.18755	-0.00312	0.638965
HDI	441	0.703492	0.051044	0.57	0.67	0.7	0.73	0.83	0.178997	-0.08337
FDI $\times$ PAPI	441	29445.78	61278.62	-7368.23	310.1925	5204.102	27228.24	475534.4	3.797889	18.0582
FDI $\times$ GDP	441	3894.319	9440.599	-20036.4	12.993	522.432	3275.43	68093.39	3.909565	19.01776

Source: Authors' calculations from research data

The analysis of variable characteristics shows that the dataset clearly reflects the economic and institutional differences between provinces. First of all, foreign direct investment inflows show a serious imbalance. The standard deviation is 973.882, which is about two times higher than the mean value of 482.792. In addition, the Skewness is 3.976 and the Kurtosis is 21.48, which is very high. This means the distribution is strongly right-skewed and there are many outliers in some key provinces or cities. Moreover, the minimum value is negative (-135.29), so it reflects capital withdrawal or project adjustment during the unstable economic period.

In contrast, the dependent variable lnCO₂ ranges from 5.146 to 10.221, with a low Skewness of 0.379. Therefore, after taking logarithm, the emission data becomes more normally distributed, and this helps to improve the stability of regression estimates. Regarding public governance capacity, the PAPI index has relatively low variation (Std. Dev = 3.206) and slightly negative Skewness (-0.218). It shows that the governance quality across provinces is quite similar, and most provinces have scores from average to fairly good (Median = 55.03).

Finally, economic variables such as GDP and IIP record extreme negative values because of the impact of the COVID-19 pandemic. At the same time, there are also sudden high growth rates, above 44% for GDP and up to 114% for IIP. This indicates that the recovery and industrialization process was not equal between provinces. As a result, it directly affects emission dynamics and increases heterogeneity in the analysis model.

The dataset is highly consistent with the research hypotheses based on classical theories in environmental and institutional economics. Specifically, the combination of lnCO₂ and foreign direct investment with large variation creates good conditions to test the Pollution Haven Hypothesis.

Through this, the study can examine the causal relationship between foreign capital intensity and environmental pollution. In addition, using the PAPI index as a moderating variable at the provincial level allows the research to approach Institutional and Environmental Theory more deeply. It also helps to fill the research gap mentioned about the role of governance quality in developing economies.

Besides that, provincial GDP growth data with different growth stages provides empirical evidence to test the Environmental Kuznets Curve. This helps to evaluate whether higher economic prosperity can reduce or increase the negative impact of FDI on the environment. In general, the diversity, balance, and wide coverage of the dataset ensure that the estimation results from FGLS or GMM models in the next step will have high representativeness and better generalization ability for other transition economies similar to Vietnam.

3.2. Methodology. The research model is developed based on the characteristics of developing economies like Vietnam, where the provincial greenhouse gas monitoring system is still limited. The study follows the standard procedure of the IPCC. In particular, commercial electricity consumption is used as a proxy variable to estimate CO₂ emissions through the emission factor of the national power grid. Commercial electricity is selected because it is a downstream indicator that accurately reflects the actual scale of energy consumption. Moreover, it is considered more reliable than other primary fuel data, which are sometimes incomplete or inconsistent.

From a technical perspective, studies by Cole [7] and Huang et al. indicate that traditional OLS or RE models are often biased in environmental analysis, since they fail to control for heteroskedasticity and serial correlation in long panel data. Therefore, this research establishes a panel data model with an extended regression function. It integrates strategic interaction terms in order to evaluate the impact of FDI under the moderating role of public governance quality (PAPI) and the level of economic development (GDP) as follows.

$$\ln\text{CO}_{2it} = \beta_0 + \beta_1\text{FDI}_{it} + \beta_2(\text{FDI}_{it} \times \text{PAPI}_{it}) + \beta_3(\text{FDI}_{it} \times \text{GDP}_{it}) \\ + \beta_4\text{IIP}_{it} + \beta_5\ln\text{Freight}_{it} + \beta_6\text{HDI}_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

where ε is the error.

The highlight of the model is the inclusion of two interaction terms at the same time. First, FDI $\times$ PAPI is used to test whether public governance capacity determines if FDI is “clean” or “polluting.” Second, FDI $\times$ GDP is added to examine how the environmental impact of FDI changes when the local economic scale fluctuates, which reflects the theory of scale effect and technique effect. In addition, control variables such as the Industrial Production Index (IIP), freight transport revenue ($\ln\text{Freight}$), and the Human Development Index (HDI) are included to remove potential disturbing effects.

The estimation procedure follows strict econometric standards. At the beginning, F-test and Breusch-Pagan Lagrange Multiplier tests are conducted to choose between Pooled OLS, Fixed Effects (FE), and Random Effects (RE) models. After that, the Hausman test is applied to determine

the most appropriate specification. Because preliminary diagnostics often show that panel data in Vietnam suffer from heteroskedasticity and serial correlation, the study prioritizes the Feasible Generalized Least Squares (FGLS) method as the main analytical model. FGLS has strong advantages in correcting these two problems at the same time, so it can produce more reliable and robust regression coefficients.

To strengthen the robustness of the results, additional tests are carried out using Driscoll-Kraay estimation to deal with cross-sectional dependence and time-related errors. At the same time, the System GMM model is employed to solve the endogeneity problem of macroeconomic variables such as GDP and FDI. This method also captures the dynamic nature of panel data by using lagged variables as instruments. Finally, the study calculates and plots the marginal effects of FDI on CO2 emissions at different levels of governance and economic development in order to visualize this complex moderating mechanism more clearly.

4. EMPIRICAL RESULTS AND DISCUSSION

4.1. Experimental regression results. The study first estimates the Pooled OLS model as an initial benchmark for comparison. However, the diagnostic tests indicate serious violations of the classical assumptions of the OLS method. In particular, the results show the existence of heteroskedasticity ($p = 0.0001$) and serial correlation ($p = 0.000$). Because of these problems, the OLS estimators are no longer efficient, and the standard errors become biased.

Therefore, the research applies the Feasible FGLS model to correct these defects and improve the reliability of the estimates. By using this method, the regression coefficients can be more consistent and statistically valid. In other words, FGLS helps reduce the estimation problems that appear in the traditional OLS approach, so the results become more trustworthy for further analysis.

TABLE 3. Comparison of Pooled OLS and Fixed Effects (FE) Estimates

Variables	OLS (Baseline)		FE/FGLS (Main)	
	Coefficient	Standard Error	Coefficient	Standard Error
const	1.9634***	0.756	7.5396***	0.114
FDI	-0.0022***	0.001	-0.0002**	7.27e ⁻⁰⁵
FDI x PAPI	5.659e ⁻⁰⁵ ***	1.61e ⁻⁰⁵	4.091e ⁻⁰⁶ **	1.64e ⁻⁰⁶
FDI x GDP	-1.278e ⁻⁰⁵	8.29e ⁻⁰⁶	5.817e ⁻⁰⁷	8.62e ⁻⁰⁷
IIP	-0.0003	0.004	0.0008**	0.000
lnFreight	0.2680***	0.034	0.0406***	0.013
HDI	5.0985***	0.979	-0.3092**	0.149
Province Effects	No		Yes	
Observations	441		441	
R-squared	0.501		0.997	
Adj. R-squared	0.494		0.997	

***, **, *: Statistically significant at the levels of 1, 5 and 10%

Source: Authors' calculations from research data

The results in Table 3 show a significant change in the statistical significance of the main variables when the model is transformed. In the FGLS model, FDI has a negative coefficient (-0.0002) and is statistically significant at the 5% level ($p = 0.022$). Meanwhile, in the OLS model, this coefficient is overstated to -0.0022. This difference confirms that after controlling for provincial and time-specific effects, foreign capital still directly contributes to reducing CO₂ emissions. Therefore, the finding supports the Pollution Halo hypothesis, which suggests that FDI can transfer cleaner technology to the host country.

It is important to note that the interaction term between local governance and FDI (FDI x PAPI) has a positive coefficient (4.091×10^{-6}) and high statistical significance ($p = 0.013$). On the other hand, the interaction term between FDI and economic growth (FDI x GDP) is not statistically significant ($p = 0.500$). This means that governance capacity, rather than economic growth, plays a key moderating role in determining the environmental impact of FDI in Vietnam. In addition, the FGLS model reports an R^2 of 0.997, which indicates a very strong explanatory power for the variation in provincial carbon emissions.

TABLE 4. Results of FE/FGLS model estimation

Variables	Expectation	Coefficient	Std. Error	t-stat	P-value
Intercept	+	7.5396***	0.114	65.897	0.000
FDI	+/-	-0.0002**	$7.27e^{-05}$	-2.302	0.022
FDI x PAPI	-	$4.091e^{-06}$ **	$1.64e^{-06}$	2.490	0.013
FDI x GDP	+	$5.817e^{-07}$	$8.62e^{-07}$	0.675	0.500
IIP	+	0.0008**	0.0004	2.044	0.042
lnFreight	+	0.0406***	0.013	3.094	0.002
HDI	-	-0.3092**	0.149	-2.073	0.039

***, **, *: Statistically significant at the levels of 1, 5 and 10%

Source: Authors' calculations from research data

The estimation results from the FE/FGLS model (Table 4) show a very high goodness of fit, with an adjusted R^2 of 0.997. This means the model explains most of the variation in CO₂ emissions after controlling for specific characteristics of each province. The main independent variable, FDI, has a negative regression coefficient (-0.0002) and is statistically significant at the 5% level. This confirms that foreign direct investment contributes to reducing emissions, which is consistent with the Pollution Halo hypothesis. However, the interaction term FDI x PAPI is positive ($4.091e^{-06}$) and significant at 5%, indicating that public governance quality plays an important moderating role and changes the level of FDI's environmental impact.

Besides that, factors related to economic activities and infrastructure also show clear effects. The Industrial Production Index (IIP) and freight transport capacity (lnFreight) both have positive coefficients, 0.0008 and 0.0406, and are statistically significant at 5% and 1% levels, respectively.

This suggests that increases in production and logistics still are major drivers of greenhouse gas emissions. Interestingly, the Human Development Index (HDI), after controlling for provincial fixed effects, turns into a negative impact (-0.3092) and is statistically significant. This result shows that improving living standards and social awareness can help reduce environmental pressure in the long run, although the effect may not appear immediately.

4.2. Discussion and theoretical interpretation.

4.2.1. *Support for the Pollution Halo hypothesis.* The negative coefficient of FDI ($\beta = -0.0002$, $p = 0.022$) confirms that, after controlling for provincial characteristics, an increase in foreign direct investment directly contributes to the reduction of CO₂ emissions. This means that when FDI rises, carbon emissions tend to decrease at the local level. Therefore, the result strongly supports the Pollution Halo hypothesis.

From a theoretical view, this argument is consistent with Zarsky [24] and Hossain [16], who argue that multinational corporations often bring cleaner technology, more advanced management processes, and stricter environmental standards than domestic firms. In the context of Vietnam during 2018 - 2024, this finding reflects the effectiveness of implementing new-generation free trade agreements such as CPTPP and EVFTA. These agreements require FDI inflows to meet higher technical standards in order to join global value chains.

As a result, the study rejects the existence of the Pollution Haven hypothesis, which was a concern raised by Cole [7] and Dean et al. [11] for other cases. For the overall situation of Vietnamese provinces, the evidence does not show that the country becomes a pollution haven, although in some sectors the impact may still be different.

4.2.2. *The regulatory role of local governance and the paradox of scale.* The finding about the interaction term FDI $\times$ PAPI, which has a positive coefficient (4.091×10^{-6} , $p = 0.013$), creates a special discussion point compared to the current theoretical framework. In the literature review, Kellenberg [17] argues that higher institutional quality will reduce firms' motivation to search for "pollution havens." However, the result in Vietnam shows a different nuance. In provinces with better public governance capacity (high PAPI scores), the impact of FDI on emissions turns out to be positive.

This paradox can be explained by the interaction between the technique effect and the scale effect. Provinces with high PAPI index, transparent investment environment, and good infrastructure usually attract very large FDI projects with extremely high production intensity. Although these projects may apply modern technology under the Pollution Halo hypothesis, the production scale is so large that total energy consumption exceeds the compensation from the technique effect. As a result, absolute emissions still increase.

Therefore, good governance can be considered a double-edged sword. On the one hand, it helps filter cleaner capital flows. On the other hand, it creates strong investment attraction, which may increase pressure on the total emission level of the province in the long term.

4.2.3. *The absence of the moderating effect of GDP and the EKC theory.* An important finding that needs discussion in this study is the absence of the moderating role of economic growth in the relationship between FDI and carbon emissions. According to the Environmental Kuznets Curve (EKC) theory of Grossman and Krueger [14], economic development is expected to act as a natural filter, improving environmental behavior when income reaches a certain threshold. However, the results in Table 4 show that the interaction term FDI $\times$ GDP is completely insignificant ($p = 0.500$). This suggests that in the context of Vietnamese provinces during the research period, economic growth alone is not strong enough to change the environmental impact mechanism of foreign capital.

This argument reflects a noticeable reality in many transition economies. Stern [22] points out that evidence for the EKC is often inconsistent and depends heavily on estimation methods as well as national characteristics. The empirical results of this study indicate that GDP growth in Vietnamese provinces is still mainly driven by the scale effect, where economic targets may dominate sustainability concerns. When the interaction term is not statistically significant, it confirms that whether a province grows fast or slowly, the nature of FDI's impact on emissions does not change simply because of income level.

Instead of relying on economic prosperity itself to solve environmental problems, as expected by the EKC theory, the findings emphasize that balancing FDI attraction and environmental protection requires proactive intervention from non-economic factors. In other words, administrative capacity, institutional transparency (represented by PAPI), and local knowledge level are the real filters that determine the quality of capital inflows. Therefore, provinces should not expect that becoming richer will automatically reduce pollution from FDI. They need to improve governance capacity in order to guide foreign investment toward a greener growth path.

4.2.4. *Impact of control factors: Logistics, Industry, and HDI.* Besides the variables related to capital inflows and governance capacity, the FE/FGLS model results show the important role of economic structure and social development level in shaping emission dynamics in Vietnam. The consistency of the control variables not only helps isolate disturbing effects but also provides more empirical evidence about the main emission sources at the provincial level.

First of all, industrial production activities and the logistics system appear as the strongest drivers of emissions. The positive coefficients of the Industrial Production Index (IIP) ($\beta = 0.0008$, $p = 0.042$) and freight transport capacity ($\ln\text{Freight}$) ($\beta = 0.0406$, $p = 0.002$) confirm that increases in production intensity and goods circulation are still the main causes of rising greenhouse gases. This result is consistent with He [15] and Zhang [25] and Zhou [26], who argue that during rapid industrialization, the scale effect of physical activities often outweighs improvements in efficiency. In many Vietnamese provinces, expanding production goes together with high energy demand and large transport systems, which creates strong pressure on local carbon reduction targets.

Finally, an encouraging point in the empirical findings is the positive role of the Human Development Index (HDI) in improving environmental quality. After controlling for provincial-specific

factors, HDI shows a statistically significant negative coefficient ($\beta = -0.3092$, $p = 0.039$). This indicates that improving living standards and social awareness can reduce emission pressure in the long run. The finding also supports the view of Costantini & Monni [9] and Neumayer [20] that human development is central to sustainable development. In areas with higher human development, people tend to care more about non-economic values and demand stricter environmental standards, so both local governments and firms are pushed to follow tougher emission regulations.

4.3. Marginal effect analysis. To provide a more detailed and visual view about the moderating role of local governance, the study conducts a marginal effects analysis of FDI on CO₂ emissions at different PAPI score levels. The empirical results from the FGLS model show a clear shift in the nature of this relationship.

In provinces with low PAPI scores (below the average threshold of around 45-50 points), the marginal effect of FDI is negative, which reflects a real tendency of emission reduction. This finding supports the Pollution Halo hypothesis because foreign capital brings cleaner technology and helps improve the outdated emission conditions in these local areas.

However, when public governance capacity goes beyond the average threshold, the marginal effect turns positive and tends to increase the total absolute emissions. The statistically significant interaction coefficient ($\beta = 4.09 \times 10^{-6}$, $p = 0.013$) confirms that the quality of local governance actually changes the nature of the relationship between FDI and the environment in Vietnam. In other words, governance does not only influence the amount of FDI, but also affects how this capital impacts environmental outcomes.

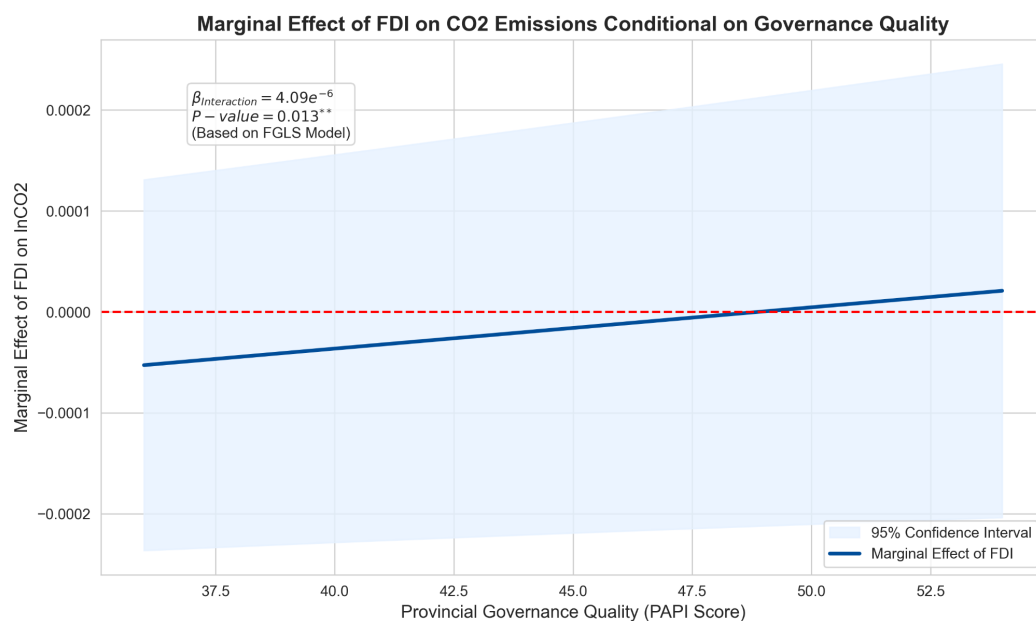


FIGURE 1. Marginal effect of FDI on CO₂ emissions conditional on Governance Quality

To clarify the nature of this shift, the Interaction Plot in Figure 2 presents the relationship between FDI and CO₂ emissions at three governance levels: Low, Medium, and High. By comparing the differences in slopes, the analysis shows a strong divergence among these groups.

For provinces with low governance quality (the red dashed line), the slope is the flattest. This means when FDI increases, emissions grow more slowly, mainly because the technique effect from cleaner technology plays a dominant role. In other words, foreign investment helps improve outdated production systems, so the increase in emissions is limited.

In contrast, provinces with high governance quality (the dark blue line) record the steepest slope. This provides evidence for the scale paradox. Although good governance helps attract cleaner projects, a transparent and stable investment environment also attracts very large industrial complexes. As a result, the total energy consumption of these mega-projects exceeds the compensation effect from advanced technology. Therefore, absolute emissions increase more strongly in these provinces, even when governance quality is high.

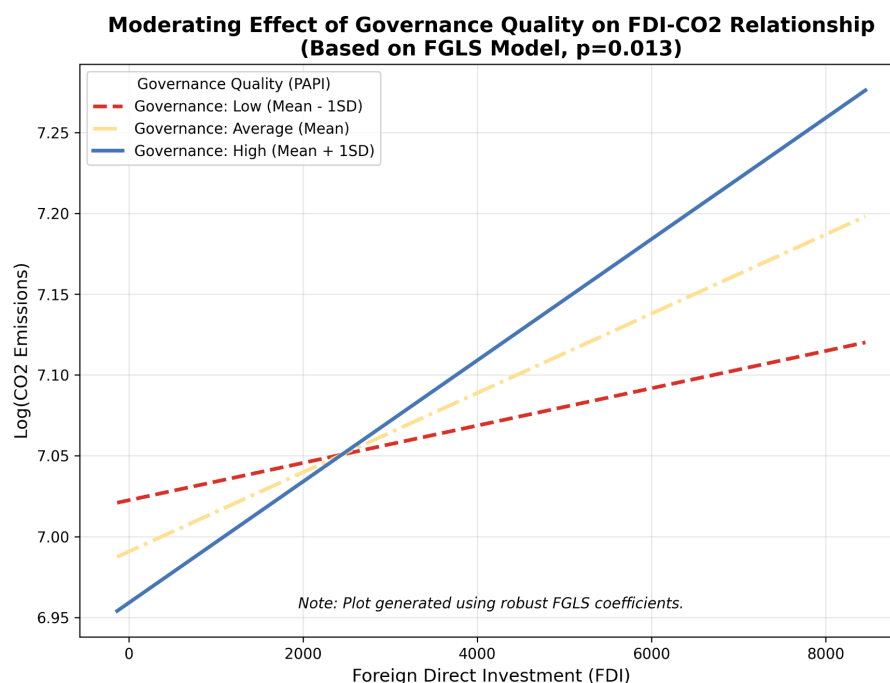


FIGURE 2. Moderating effect of Governance Quality on FDI - CO₂ relationship (Based on FGLS Model, $p = 0.013$)

The intersection point and the meaning of the threshold effect in the graph also provide important implications. At a small scale of FDI capital (below 2000 million USD), provinces with high governance actually have significantly lower emission levels compared to the low-governance group (the blue line lies below the red line). This shows that when the investment scale is still under control, strong governance capacity can maximize its environmental supervision role.

However, when FDI exceeds this threshold, the scale effect starts to dominate. Emissions in the high-governance group increase rapidly and even surpass the other groups. This reversal confirms that governance capacity (PAPI) acts like an amplifier of impact. At a large capital scale, good governance creates favorable conditions for industrial expansion. As a result, the trade-off between environmental quality and massive economic growth becomes almost unavoidable, especially if there are no stricter policies to control emission intensity.

4.4. Robustness checks. To ensure the reliability of the findings, the study conducts robustness checks using the GMM model and Driscoll-Kraay standard errors. The regression results from GMM/IV2SLS show that after controlling for endogeneity and the dynamic nature of panel data, factors such as logistics ($p = 0.033$) and industrial production ($p = 0.073$) still maintain their direction of impact and relatively stable statistical significance. This means the main relationships are not changed much when different estimation techniques are applied.

At the same time, the Driscoll-Kraay model confirms that the key conclusions remain robust even when cross-sectional dependence and spatial autocorrelation among neighboring provinces are taken into account. Therefore, the empirical evidence becomes more convincing, because the results are consistent under different methodological approaches, although the magnitude of some coefficients may slightly change.

TABLE 5. GMM regression results for CO₂ emissions and economic drivers

Variable	Coefficient	Std. Error	t-Statistic	P-value
Constant	7.1979***	0.256	28.090	0.000
Industrial Production Index (IIP)	0.0015*	0.001	1.802	0.073
ln(Freight)	0.0583**	0.027	2.142	0.033
Human Development Index (HDI)	-0.1092	0.322	-0.339	0.735
Foreign Direct Investment (FDI)	-0.0001	0.000	-0.367	0.714
FDI x PAPI	3.375e-06	6.51e-06	0.518	0.605
FDI x GDP	-1.035e-06	3.04e-06	-0.340	0.734
Province Fixed Effects	Included			
Observations	378			
R-squared	0.990			
Adjusted R-squared	0.987			
F-statistic	436.4			
Prob (F-statistic)	0.000			

TABLE 6. Robustness check - Driscoll-Kraay standard errors (Kernel HAC)

Variable	Coefficient	Std. Error	t-Statistic	P-value
Constant	7.1813***	0.3909	18.369	0.0000
Foreign Direct Investment (FDI)	-4.727e-05	9.281e-05	-0.5093	0.6108
FDI x PAPI	1.026e-06	1.819e-06	0.5640	0.5731
FDI x GDP	5.686e-07	1.382e-06	0.4114	0.6810
Industrial Production Index (IIP)	0.0004	0.0010	0.3656	0.7149
ln(Freight)	0.0272	0.0397	0.6850	0.4937
Human Development Index (HDI)	0.1348	0.2590	0.5206	0.6029
Entity Fixed Effects	Included			
Observations	441			
R-squared (Within)	0.0109			
Robust F-statistic	174.84			
Prob (F-statistic)	0.0000			

5. CONCLUSION AND POLICY IMPLICATIONS

5.1. Policy implications. Based on empirical findings, the study offers several key policy implications to support Vietnam in realizing its green growth goals and its commitment to achieving Net Zero by 2050, in line with the direction set by the Vietnamese Government in the National Strategy on Green Growth for the period 2021-2030, with a vision to 2050 [5].

First, the process of attracting FDI needs to be greened from the source of capital itself, rather than focusing solely on the scale of investment. As Resolution No. 50-NQ/TW emphasized, Vietnam needs to shift from extensive FDI attraction toward improving the quality, efficiency, and sustainability of foreign investment inflows [2]. Accordingly, local authorities should prioritize projects that use clean technology, save energy, and generate high value added, while being more cautious with projects characterized by high energy intensity or environmental pollution risks. This approach is also consistent with the OECD's [21] recommendation to enhance the quality of FDI in order to promote sustainable development.

Second, beyond the policy framework, implementation capacity at the local level also plays a crucial role in controlling the environmental impacts of FDI. According to guidance issued by the Government of Vietnam [6], the national action plan on green growth emphasizes strengthening monitoring, evaluation, and environmental information transparency in production and business activities. Measures such as periodic inspections of electricity consumption, emission monitoring in industrial zones, and public disclosure of inspection results can create stronger compliance pressure than merely issuing regulations on paper. International experience shows that in localities with strong governance capacity, strict enforcement of environmental standards significantly limits the negative environmental impacts of FDI [23].

Third, emissions from logistics and transportation need to be reduced through both greening vehicles and transforming transport modes. According to Vietnam's Logistics Service Development Strategy, optimizing supply chains and reducing logistics costs are closely linked to the requirement of sustainable development [4]. In addition to solutions such as route optimization, development of centralized logistics centers, and encouragement of fuel-efficient vehicles, the State needs to promote a restructuring of the transport system toward reducing dependence on road transport and increasing the share of railways and inland waterways, which are modes with lower emission intensity. This group of solutions is feasible and can deliver significant emission reductions in the short and medium term.

Fourth, greening human resources is a foundational factor to ensure the sustainability of green growth policies. Raising environmental awareness among workers and FDI enterprises should be integrated into existing vocational training, management training, and occupational safety programs, rather than designing separate programs. When workers understand that energy saving and waste reduction not only protect the environment but also help firms reduce costs and enhance competitiveness, green measures are more likely to be accepted and effectively implemented.

Finally, at the national level, standardizing provincial-level emission data is a necessary condition for building evidence-based policies. In the short term, using proxy indicators such as electricity consumption remains a reasonable choice in the context of limited emission data. However, the OECD [21] emphasizes that in the long term, developing a unified and streamlined emission reporting system across provinces will improve management effectiveness, enhance policy comparability, and support Vietnam's roadmap for developing a carbon market.

In summary, for FDI to truly become a driver of green growth, Vietnam needs a comprehensive strategy based on holistic greening alongside institutional improvements and enhanced local governance quality. This combination helps align FDI attraction objectives with existing government resolutions and sustainable development strategies, thereby creating an essential foundation for reconciling economic growth with environmental protection in subsequent stages of development.

5.2. Conclusion. Overall, the study indicates that FDI inflows in Vietnam during the 2018–2024 period tend to reduce CO₂ emissions, thereby supporting the "Pollution Halo" hypothesis through technology transfer and more efficient production processes. However, this effect is significantly contingent upon the quality of local public governance. In provinces with strong governance capacity, the scale effect of large FDI projects may outweigh the technological effect, leading to an increase in total emissions, while GDP growth does not appear to play a clear moderating role. In addition, the logistics and industrial sectors are identified as the primary sources of emissions, whereas a higher Human Development Index (HDI) contributes to environmental improvement. These findings highlight the crucial role of institutional quality and human development in promoting sustainable and green growth.

In terms of academic contribution, this study provides three main values. First, it simultaneously examines the two opposing hypotheses, Pollution Haven and Pollution Halo, within a single

analytical framework. This approach helps clarify the conditional nature of FDI's environmental impact rather than treating it as a simple either/or outcome. Second, by incorporating the quality of local public governance as a moderating variable, the research expands previous studies that have mainly concentrated on macroeconomic factors at the national level. This addition offers a more comprehensive understanding of how institutional capacity influences the environmental effects of FDI across different provinces. Third, the use of CO₂ emission interpolation based on electricity consumption presents a practical and relatively reliable methodological solution for environmental research in countries where official emission data at the local level are limited or unavailable.

Nevertheless, the study still faces several limitations, which also suggest directions for future research. In particular, the use of electricity consumption as a proxy for CO₂ emissions stems from the lack of official provincial-level emission data during the study period. Although this approach reasonably captures industrial production activities associated with FDI, it does not fully account for emission sources beyond the energy sector, especially those arising from agriculture and waste treatment.

Furthermore, the study does not disaggregate FDI by sector or by the "greenness" of individual projects due to the absence of consistent and publicly available data on technological characteristics and emission intensity at the local level. Given that the structure of FDI can generate substantially different environmental impacts, this remains an important area for further investigation. Finally, the reliance on secondary provincial-level data limits the ability to examine micro-level transmission mechanisms, such as the environmental compliance behavior of FDI firms or the role of specific incentive policies. This limitation highlights promising avenues for future research once more detailed firm-level data become available.

In conclusion, the study affirms that FDI can only truly serve as a driver of green growth when it operates within an appropriate institutional environment, where the quality of public governance and human development play pivotal roles. These findings not only contribute to the theoretical foundations of environmental economics and institutional economics, but also provide important empirical evidence for the design of FDI attraction policies aligned with sustainable development objectives in Vietnam and other transition economies with similar characteristics.

Acknowledgement: The authors gratefully acknowledge the financial support from the Banking Academy of Vietnam.

Conflicts of Interest: The authors declare that there are no conflicts of interest regarding the publication of this paper.

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