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Growth, Fast Fashion, and Environmental Degradation in Vietnam: An Empirical Test of the EKC Hypothesis

[1*]Yoochan Hwang
[1]High School Student: Bangkok Patana School
https://orcid.org/0009-0008-2095-270X

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Abstract

Purpose: The aim of this paper is to examine and evaluate whether the Environmental Kuznets Curve (EKC) hypothesis holds in Vietnam and how the expansion of fast fashion exports has influenced the income–environment relationship in Vietnam from 2000 to 2023.

Methodology: This paper utilizes annual national data compiled from the World Bank, UN Comtrade, and the Worldwide Governance Indicators, with four indicators of environmental degradation analyzed: CO_2 emissions per capita, total greenhouse gas emissions per capita, PM2.5 concentrations, and industrial CO_2 emissions.

Findings: The results of regression analysis show rejection of the EKC hypothesis in the context of Vietnam during the study period of 2000-2023 and highlight that economic growth alone has not led to environmental improvement. Instead, institutional capacity, regulatory enforcement, and targeted industrial and trade policies play a far stronger role in shaping outcomes. More importantly, alongside strengthening governance, it is critical to address high-emission sectors such as fast fashion, aligning with global climate goals.

Unique Contribution to Theory, Practice and Policy: This study contributes to the literature by showing how economic growth, industry structure, and institutional context interact to improve environmental conditions in the developing country context. While industry structure can influence the EKC dynamics, as recent findings suggest, the institutional context, such as the quality of environmental regulation, can has a significant impact of environmental improvement.

Keywords: *Fast Fashion, Environmental Kuznets Curve (EKC), Vietnam, Environmental Degradation, Trade and Sustainability*

JEL Codes: *Q56, F18, O13, L67, O53*

1. INTRODUCTION

As one of the world's leading exporters of textile and garment products, Vietnam has experienced rapid industrial growth, driven largely by the fast fashion industry. This sector accounts for approximately 14 percent of the country's total exports, positioning it as a key factor of Vietnam's economic development (WWF, 2018). However, this growth has come at a significant environmental cost. Particularly, in major rivers such as the Đồng Nai and the Red River, water pollution has intensified, with reports indicating that only around 10 percent of industrial wastewater is properly treated (Hung et al., 2014).

Fast fashion refers to the rapid, high-volume production of low-cost clothing that quickly follows changing trends and encourages short-term use. While this model has expanded global access to affordable apparel, it has also driven overconsumption, excessive waste, and environmental degradation. Worldwide, the fashion industry is responsible for approximately 20 percent of global wastewater and 10 percent of carbon emissions, more than all international flights and maritime shipping combined (UNFCCC, 2018). As calls for sustainability grow louder, many countries are introducing tighter regulations on the fashion sector's environmental footprint. Yet in Vietnam, where fast fashion is a major economic pillar, addressing these externalities presents a particularly difficult trade-off between growth and sustainability.

This study tests a core issue at the intersection of economics and the environment: What effect has Vietnam's fast fashion sector had on the relationship between GDP per capita and environmental degradation, and did it delay the predicted turning point by the Environmental Kuznets Curve (EKC)? In addition, this paper seeks to evaluate whether the EKC hypothesis holds true in the context of Vietnam's rapid textile-driven growth or whether the turning point has been delayed. We also aim to compare Vietnam's trend against the typical EKC pattern to better understand the role of industry-specific dynamics, institutional capacity, and trade pressures in shaping environmental outcomes.

Ultimately, this paper aims to: (1) discuss the applicability of the EKC framework within the specific national context of Vietnam, and (2) explore how institutions, policy decisions, and patterns of international trade have conditioned the country's environmental trajectory.

2. LITERATURE REVIEW

2.1. EKC Hypothesis and its Critiques

The Environmental Kuznets Curve (EKC) hypothesis explains the relationship between economic

growth and environmental degradation. Named after Simon Kuznets, who suggested an inverted-U shape relationship between economic growth and inequality, the EKC hypothesis posits that pollutant emissions, such as CO2, first increase and then decrease with income growth in an economy. This hypothesis reflects the industrial transition from agriculture through manufacturing to services and technological advancements (Dinda, 2004).

However, there have been critiques on this hypothesis from scholars for its theoretical and empirical limitations. For example, Stern (2004) challenges the validity of this relationship by arguing that many studies are econometrically weak, often failing to address key issues such as omitted variable bias, serial correlation, and non-stationarity. He notes that the assumption of a universal inverted-U shape is not supported across different pollutants or countries, and instead finds that emissions are often monotonically increasing with income. Moreover, Panayotou (1997) challenges the assumption that income growth alone drives environmental improvement by emphasizing that the Environmental Kuznets Curve (EKC) is heavily influenced by governance quality and institutional capacity. He argues that "policy failures and institutional weaknesses explain why some countries fail to follow the EKC pattern" (Panayotou, 1997, p. 4), highlighting that economic growth without strong environmental governance often leads to continued degradation. Crucially, Panayotou notes that countries may fail to reach the turning point of the EKC not because of low income but because of a lack of effective environmental institutions, transparency, and public participation.

2.2. EKC in Developing Country Context

A stock of knowledge suggests that, while the EKC hypothesis may be applied to a developed country context as expected, a developing country context can offer a much more complex relationship between income growth and environmental degradation due to the unique economic structure and social conditions of developing countries.

For example, Al-Mulali et al. (2015) analyze Vietnam's CO_2 emissions using the ARDL bounds testing approach, confirming the EKC hypothesis but raising critical concerns about foreign capital inflows. They find that the economic growth of a country initially increases CO_2 emissions but eventually reduces them, yet caution that FDI, energy consumption, and trade openness are other factors that significantly increase environmental degradation. This supports both the inverted-U pattern and the pollution haven hypothesis, where polluting industries migrate to countries with weaker environmental oversight.

Mai et al. (2025) extend this analysis, revealing how trade liberalization in the post-1986 Đổi Mới

era caused a sharp rise in emissions in Vietnam, especially between 1995 and 2007 during WTO accession. However, the level of pollution eventually plateaued with environmental regulation and efficiency gains, reinforcing that while Vietnam exhibits EKC behavior, institutional decisions, particularly around trade and foreign investment, play a pivotal role in shaping that curve as it is a significant contributor of greenhouse emissions such as CO_2, due to its energy and resource-intensive requirements.

2.3. Sectoral and Trade Dynamics

Previous research highlights the importance of sectoral dynamics in the relationship between income growth and environmental degradation. Particularly, countries where energy-intensive or pollution-intensive industries take a large part of the total GDP and income tend to have distorted EKC patterns, meaning such industries can delay environmental development even as income grows. Roca and Alcántara (2001) highlight how an entrenched energy-intensive industrial structure distorted Spain's EKC trajectory. Between 1972 and 1997, Spain's CO_2 emissions rose by an average of 2.8% per year, despite economic growth, driven by a 25% increase in energy intensity and only a limited 15% reduction in the carbonization index. Even relative improvements, such as a modest drop in CO_2 per GDP in the 1980s, did not translate into actual emission reductions, as overall emissions continued to rise. The authors conclude that without structural changes in production and energy mix, environmental improvements do not occur automatically with income growth, undermining the EKC's income-centric assumptions.

On the other hand, other scholars have begun to examine the impact of trade structure on the relationship between income growth and environmental degradation. For example, the pollution haven hypothesis posits that pollution-intensive industries are increasingly relocated from developed to developing countries as international trade becomes more liberalized, outsourcing environmental damage to regions with weaker regulations to reduce domestic pollution. Cole (2004) empirically supports this mechanism, stating that trade liberalization has the potential to relocate pollution-intensive activities to countries with weak environmental standards. His analysis across OECD countries reveals that for pollutants like CO and VOC, the share of dirty imports from developing nations is significantly and negatively associated with emissions, suggesting that developed countries are indeed displacing pollution abroad. Moreover, Cole finds that EKC turning points often appear artificially low when pollution haven effects are unaccounted for, implying that what appears to be environmental improvement may in fact reflect international pollution displacement.

2.4 Fast Fashion's Environmental Impact

Since the sectoral and trade structure of an economy may have large implications for the EKC dynamics in a country, scholars have paid particular attention to specific industries that may influence or distort the EKC dynamics. Specifically, the fast fashion industry has garnered a large amount of attention due to its significance in many developing countries' economies. Niinimäki et al. (2020) provide a comprehensive environmental lifecycle assessment of fast fashion, warning that the fashion industry is responsible for approximately 20% of global wastewater and 10% of global carbon emissions. They also emphasize the rise of synthetic fibers such as polyester as a source of microplastic leakage, which produces half a million tons of microfibers annually. Bick et al. (2018) frame this crisis as a global environmental injustice, where fast fashion's environmental and health impacts fall disproportionately on marginalized communities. In essence, the low-income countries absorb the toxic waste, polluted water, and greenhouse gases while consumers in high-income countries benefit from low prices and fast trends.

Furthermore, the fast fashion industry poses a significant risk of distorting the Environmental Kuznets Curve (EKC), particularly in developing countries that rely heavily on textile exports. The EKC hypothesizes an inverted U-shaped relationship between income and environmental degradation, suggesting that pollution rises during early economic development but eventually declines as income and environmental awareness increase. However, in economies where pollution-intensive industries dominate, this progression can be stalled or even reversed (Roca and Alcántara, 2001).

The global fast fashion sector, with its high water usage, toxic chemical runoff, and carbon emissions, disproportionately impacts countries such as Vietnam, Bangladesh, and India, where textile production is a significant economic driver (Niinimäki et al., 2020). As fast fashion brands shift production to lower-cost regions, they externalize the environmental burden, preventing those countries from reaching the EKC's turning point. This relocation of industrial pollution undermines the EKC's assumption that income alone leads to environmental recovery, especially when economic growth is tightly coupled with resource- and pollution-intensive sectors like apparel manufacturing.

3. METHODOLOGY

3.1. Regional Context: Vietnam

This study analyzes Vietnam, where economic development has been heavily reliant on pollutant-intensive industries, such as fast fashion, to test whether EKC dynamics can be applied in this context. Many documents state that while the fashion industry has significantly contributed to Vietnam's economic development, it has also produced environmental injustice. For example, the WWF (2018) reports, along with local testimonies from Hue, describe toxic dye effluents dumped into rivers such as the Huong and the Đồng Nai.

Following the implementation of Đổi Mới economic reforms in 1986, Vietnam rapidly transitioned from a centrally planned economy to a socialist-oriented market system. This shift catalyzed industrialization and global market integration, particularly in the textile and garment sector. Between 2002 and 2017, Vietnam's textile exports surged from approximately USD 2.75 billion to over USD 31.2 billion, representing 14.5% of total national exports by 2017, and the sector employs an estimated over 3 million workers (WWF, 2018). However, this economic growth has come with mounting environmental costs.

As of the early 2010s, fewer than 45% of Vietnam's industrial zones were equipped with central wastewater treatment systems, and wastewater from urban and industrial areas flows into rivers, failing to meet national clean water standards (World Bank, 2010). The discharge from textile production includes high concentrations of biological oxygen demand (BOD_5), chemical oxygen demand (COD), suspended solids, and toxic heavy metals such as chromium, lead, and copper (Nguyen et al., 2024). These pollutants disrupt aquatic ecosystems, contribute to oxygen depletion in rivers, and pose significant public health risks (Nguyen et al., 2024; Le et al., 2021).

In response to worsening environmental conditions, the Vietnamese government has gradually strengthened its regulatory framework through the Law on Environmental Protection, passed in 1993 and updated in 2005, 2012, and 2020. These reforms were significantly influenced by Vietnam's entry into international trade agreements such as the EU–Vietnam Free Trade Agreement (EVFTA) and the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP), which require higher environmental standards and stricter enforcement mechanisms. Despite these policy efforts, implementation capacity remains uneven due to budgetary constraints and limited technical expertise in some regions. (WWF, 2018).

3.2. Data and Sources

The analysis utilizes the annual panel of Vietnam's macroeconomic, environmental, and institutional indicators from 2000 to 2023. The dataset was compiled from international sources, including the World Bank, UN Comtrade, and the Worldwide Governance Indicators (WGI), ensuring the quality and credibility of the data. All variables were organized into a single panel structure.

The dependent variables, representing different forms of environmental degradation in Vietnam, include CO_2 emissions per capita (metric tons), Total greenhouse gas (GHG) emissions per capita, PM2.5 air pollution exposure (μg/m³), and CO_2 emissions from industrial processes (Mt CO_2).

The primary explanatory variable for testing the EKC hypothesis is GDP per capita (constant 2015 US$ to control for inflation), along with its squared term to capture the potential nonlinear, inverted-U relationship. To assess the role of Vietnam's fast fashion industry in shaping environmental outcomes, two additional independent variables included log-transformed fast fashion export value, based on combined HS codes 61, 62, and 63 from UN Comtrade (current USD, FOB), and textile export share, measured as the percentage of total merchandise exports composed of fashion exports.

Control variables were selected to account for structural and institutional factors influencing emissions: Urban population (% of total); Trade openness (sum of exports and imports as % of GDP); Industry value added (% of GDP); FDI inflow (% of GDP); Regulatory quality, obtained from WGI data.

For all models, GDP per capita and FDI were expressed in logarithmic form to reduce skewness. Where appropriate, missing values were linearly interpolated or dropped from the regression sample.

3.3. Empirical Strategy

To evaluate the validity of the Environmental Kuznets Curve (EKC) hypothesis in Vietnam, the study first estimates a baseline quadratic regression model using CO_2 emissions per capita as the dependent variable. The functional form is specified as follows:

$$CO_{2t} = \beta_0 + \beta_1 GDP_t + \beta_2 GDP_t^2 + \varepsilon_t$$

This model was estimated with and without structural controls. Here, CO2t denotes CO_2 emissions per capita in metric tons for the year t, GDPt represents real GDP per capita in constant 2015 US dollars, GDP_t^2 is the squared term of GDP per capita, included to test for nonlinearity, and ε_t is the

error term capturing unobserved factors. This specification follows the widely accepted EKC structure, where the coefficient β_1 captures the linear effect of income on emissions and β_2 reflects whether the relationship is inverted-U shaped. If the EKC hypothesis holds, it is expected that $\beta_1 > 0$: CO_2 emissions increase with income in early stages of development, and $\beta_2 < 0$: emissions decline after a certain income threshold.

The potential influence of the fast fashion industry was assessed by including either log(fashion exports) or fashion export share as an independent variable in the EKC model. This was also extended by testing interaction terms between GDP per capita and fashion variables to evaluate whether fashion exports moderate the GDP–emissions relationship.

To account for unobserved time effects, a year trend variable was included in the final models. Additionally, to address potential autocorrelation and heteroskedasticity in the time series data, Newey-West standard errors were applied using a lag of 2. This robust approach ensures more reliable inference in a single-country, small-N time series context.

All regressions were estimated using ordinary least squares (OLS) in R. The quality of model fit was assessed using adjusted R^2 and residual standard error, while statistical significance was evaluated at conventional thresholds (10 %, 5%, and 1%).

4. RESULTS

4.1. EKC Patterns and the Role of Fast Fashion in Vietnam (2000–2023)

This section presents visual evidence regarding the Environmental Kuznets Curve (EKC) hypothesis using four environmental degradation indicators: CO_2 emissions per capita, PM2.5 concentrations, total greenhouse gas (GHG) emissions per capita, and industrial CO_2 emissions. It also examines the influence of Vietnam's fast fashion export intensity using visual overlays and subgroup analysis.

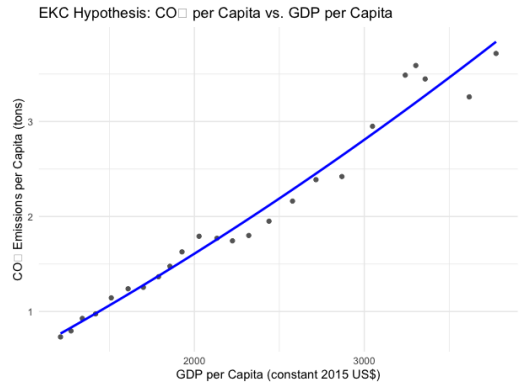
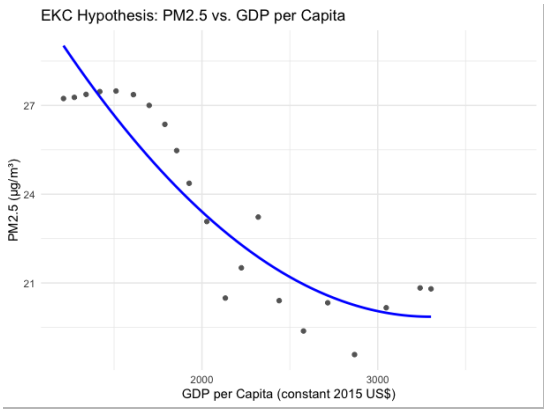
The CO_2 per capita plot in Figure 1, Panel A, displays a monotonic upward trend as GDP per capita increases from 2000 to 2023. Contrary to the EKC hypothesis, which anticipates an inverted-U shape, there is no turning point observed. This suggests that Vietnam's economic development has not yet reached the income threshold where CO_2 emissions begin to decline. The persistent upward trajectory may reflect the country's heavy reliance on fossil fuels, a rapidly expanding manufacturing base, and insufficient environmental regulation in the energy and transport sectors.

Unlike CO_2, PM2.5 concentrations in Figure 1, Panel B, show a declining trend as GDP increases. This is consistent with the downward-sloping phase of the EKC, indicating that Vietnam may be

improving air quality through localized environmental measures, such as cleaner public transport, enforcement of urban emissions standards, or improvements in residential energy use. The shape suggests early success in reducing airborne particulate pollution despite ongoing industrialization.

Similar to CO_2 per capita, the plot for total GHG emissions per capita in Figure 1, Panel C, shows a steadily rising curve without a visible turning point. This trend supports the view that broad structural decarbonization has not yet occurred in Vietnam. Although GHG emissions include methane and nitrous oxide in addition to CO_2, the trend largely mirrors CO_2 emissions, underscoring the lack of effective emission mitigation across economic sectors.

Industrial CO_2 emissions increase sharply and continuously with GDP, showing the steepest rise of all indicators, as seen in Figure 1, Panel D. This result indicates a sector-specific deviation from the EKC, where emissions from industrial processes are not only rising but accelerating. Vietnam's export-led growth model, particularly in manufacturing and textile production, likely contributes to this pattern. The absence of abatement may reflect low adoption of clean production technologies and regulatory gaps in industrial environmental governance.

<table>
<tr>
<td>Panel A: CO_2 per capita vs GDP per capita
 
</td>
<td>Panel B: PM2.5 (particulate matter) vs GDP per capita
 
</td>
</tr>
<tr>
<td>Panel C: Total GHG per Capita vs. GDP per capita</td>
<td>Panel D: Industrial CO_2 Emissions vs. GDP per capita</td>
</tr>
</table>

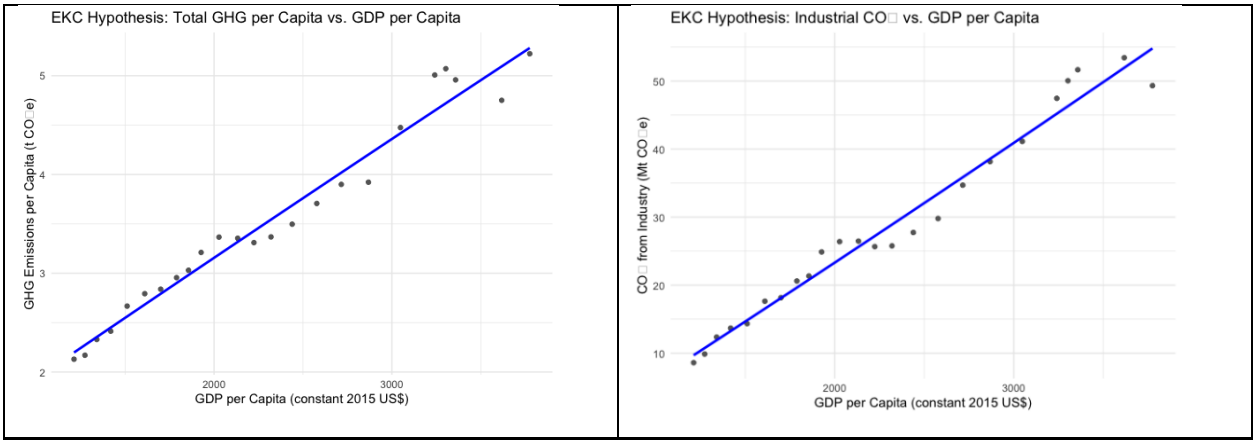


Figure 1. Environmental Kuznets Curve (Environmental Degradation vs GDP per Capita)

4.2. The Influence of the Fast Fashion Industry on EKC Dynamics

To explore the potential sectoral influence of fast fashion, I re-plotted the EKC curves for each indicator with points colored by the share of fast fashion exports in total merchandise exports.

In both CO_2 and GHG plots (Panel A and C of Fig. 2), darker points representing a higher fast fashion export share cluster predominantly along the upward slope of the GDP curve. This visual pattern suggests that fast fashion expansion is concentrated in earlier growth stages, during which emissions rise. There is no evidence that fast fashion years coincide with environmental improvement, implying that fashion-led export growth exacerbates emissions and may delay any EKC turning point.

The PM2.5 plot (Panel B of Fig. 2) shows a declining trend regardless of fast fashion share, and high-fashion years are evenly distributed across the curve. This indicates that PM2.5 emissions are less directly tied to the scale of fast fashion exports and may instead be influenced by factors such as fuel quality, traffic patterns, and residential energy use—sectors where Vietnam has made progress in pollution control.

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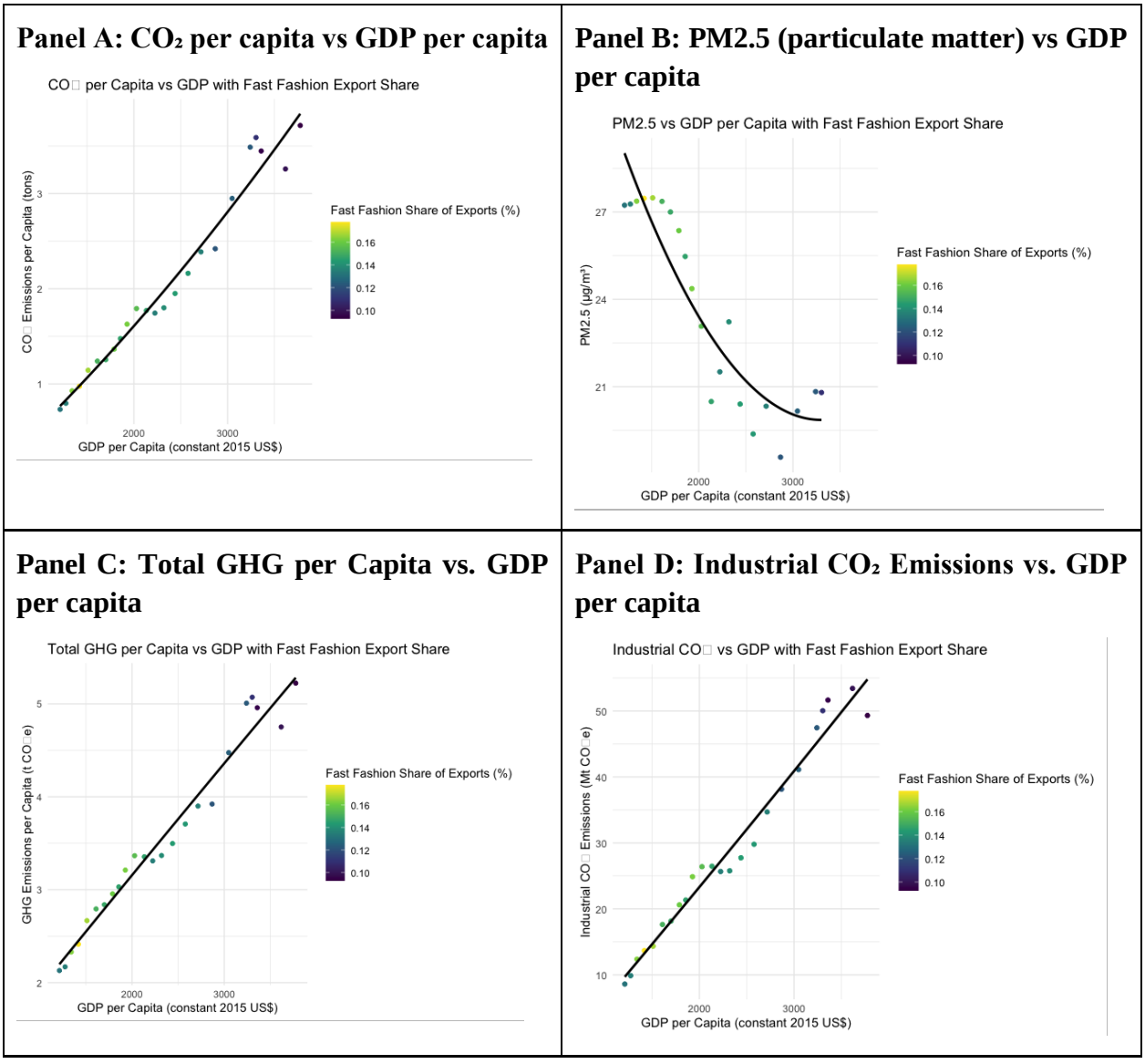

Figure 2. Fast Fashion Impact by Fashion Export Share in Vietnam

Similar to total CO_2, the industrial CO_2 curve (Panel D of Fig. 2) shows a strong upward trajectory, and years with high fashion share again align with rising emissions. This reinforces the view that fast fashion contributes to the accumulation of industrial pollution, possibly through energy-intensive textile production and dyeing processes.

4.3. The Statistical Test of the EKC Hypothesis and the Influence of Industrial Structure

Table 1 presents two models that test the validity of the Environmental Kuznets Curve (EKC) hypothesis in Vietnam between 2000 and 2023. The EKC posits an inverted-U-shaped relationship between environmental degradation and income: emissions increase in early stages of development

and decline after surpassing a certain income threshold.

Here, Model 1 includes only GDP per capita and its squared term, aiming to detect this nonlinear pattern, and Model 2 adds structural control variables—urban population percentage, trade openness, industry value added, FDI inflow, and regulatory quality—to assess whether these factors affect the income–emissions relationship.

The baseline EKC model (Model 1) includes GDP per capita and its square to test for a potential inverted-U relationship between income and CO_2 emissions per capita. Here, the linear term for GDP per capita is positive and statistically significant (p= .0229), indicating that CO_2 emissions per capita increase with economic growth. However, the squared term is positive but not significant (p = .2938), meaning there is no evidence of a downturn in emissions at higher income levels. Ultimately, this implies that Vietnam has not yet reached the turning point of the EKC curve in terms of CO_2 emissions, showing how the EKC hypothesis is not supported in this model. CO_2 emissions continue to rise with income, with no sign of decoupling.

Model 2 includes the same EKC terms, plus controls for Urban population (% of total) Trade openness; Industry value added (% of GDP); FDI inflow (% of GDP); Regulatory quality. Here, Both GDP per capita and its square become statistically insignificant, suggesting that the relationship between income and CO_2 emissions is not robust when accounting for other structural factors. Regulatory quality is positive and significant (p = .0288), indicating that better regulatory institutions are associated with higher CO_2 emissions. This counterintuitive result may reflect the coexistence of regulatory improvements with economic expansion, Weak enforcement despite formal regulatory improvements, or Measurement issues in perception-based governance indicators. Other controls, including urbanization, trade openness, industry structure, and FDI, are all statistically insignificant, suggesting their effects are either minimal or absorbed by other correlated predictors in this sample.

The absence of a significant inverted-U shape implies that Vietnam is still in the emission-intensive phase of development, which shows the positive trends, yet to reach its turning point. The positive effect of regulatory quality may highlight a lag between institutional reform and environmental outcomes, or a conflict between development and environmental priorities. This analysis confirms that income growth alone has not led to CO_2 reductions, and that more targeted policies are likely needed to reduce emissions and showcase the trend that adheres to the hypothesis.

Table 2 presents results from specifications that test whether the fast-fashion industry moderates the relationship between economic growth and CO_2 emissions, i.e., whether it shifts or distorts the

EKC curve. This is done by including interaction terms between GDP per capita and the two fast fashion variables (log export volume and export share). Here, Models 1 and 2 test the interaction without controls and Models 3 and 4 add controls to assess whether observed effects are robust to broader structural variables.

In Model 1, GDP per capita shows a positive though near-significant effect ($p = .13$), implying that emissions may rise as income increases. However, the squared GDP term is negative yet insignificant, providing no evidence of a turning point. This indicates that the Environmental Kuznets Curve (EKC) hypothesis is not supported in this context. Turning to the fast fashion sector, log(fashion exports) is negative and marginally significant ($p = .11$), hinting at a possible inverse relationship with emissions. Still, this effect is likely driven by confounding macroeconomic or trade trends rather than a genuine decoupling mechanism. Similarly, the interaction term between GDP and fashion exports is negative but not statistically significant, suggesting that the growth of fast fashion does not moderate the income–emissions relationship in any meaningful way. Overall, fast fashion growth does not statistically alter either the shape or the strength of the GDP–CO_2 relationship.

Table 1. EKC Regression Models (Baseline vs. With Controls) Dependent variable: CO_2 per Capita

	(1) Baseline	(2) With Controls
GDP per Capita	0.001**	0.001
	(0.0003)	(0.002)
GDP per Capita²	0.00000	-0.000
Urban Population (%)	(0.00000)	(0.00000)
		-0.036
		(0.228)
Trade Openness	—	-0.006
		(0.005)
Industry Value Added	—	0.024
		(0.041)
FDI Inflow	—	0.028
		(0.031)
Regulatory Quality	—	1.629**
		(0.674)
Constant	-0.346	0.810
	(0.384)	(3.549)
Observations	24	23
R^2	0.968	0.979
Adjusted R^2	0.965	0.969
Residual Std. Error	0.177	0.165
F Statistic	320.9***	98.33***

*Signifiance codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

Table 2. EKC Models with Interaction Between GDP and Fast Fashion Dependent variable: CO_2 per Capita

	(1) Log FF × GDP	(2) Share FF × GDP	(3) Full + Log FF × GDP	(4) Full + Share FF × GDP
GDP per Capita	0.008885	0.00033	0.00628	0.00537
	(0.00559)	(0.00129)	(0.00638)	(0.00483)
GDP per Capita²	-0.000000492	0.000000151	-0.000000566	-0.000000369
	(0.000000313)	(0.000000170)	(0.000000463)	(0.000000448)
Log(Fashion Export)	-0.854	—	-0.958	—
	(0.515)		(0.782)	
Fashion Export Share	—	-0.445	—	13.57
		(8.511)		(14.23)
GDP × Log(Fashion Export)	-0.000166	—	-0.000047	—
	(0.000204)		(0.000239)	
GDP × Fashion Export Share	—	0.00158	—	-0.00755
		(0.00474)		(0.00771)
Urban Population (%)	—	—	-0.00551	-0.2697
			(0.2318)	(0.3366)
Trade Openness	—	—	-0.00681	-0.00665
			(0.00603)	(0.00637)
Industry Value Added	—	—	0.041	0.00073
			(0.0487)	(0.0543)
FDI Inflow	—	—	0.0372	0.0266
			(0.0487)	(0.0334)
Regulatory Quality	—	—	1.252†	1.600*
			(0.719)	(0.702)
Constant	13.27	-0.075	15.75	2.41
	(9.30)	(1.70)	(13.19)	(4.02)
Observations	24	24	23	23
R^2	0.974	0.969	0.982	0.980
Adjusted R^2	0.968	0.962	0.969	0.966
Residual Std. Error	0.169	0.184	0.164	0.172
F Statistic	177.0***	148.7***	77.85***	71.31***

*Significance codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

In Model 2, which includes GDP interacted with the fashion export share, none of the estimated coefficients are statistically significant. Neither GDP nor GDP² supports the EKC hypothesis. The interaction term is positive but highly insignificant with a p-value of 0.742, suggesting that the relative size of the fashion export sector does not moderate the income–emissions relationship.

Although the model fit remains strong ($R^2 = 0.969$), the inclusion of the fashion export share and its interaction with GDP does not improve the model's explanatory power. In essence, showing that Fast fashion export share does not significantly shape the income–emissions relationship.

In Model 3, which includes full controls alongside the GDP × log(fashion exports) interaction, the results remain unchanged. The interaction term is highly insignificant ($p = .85$), offering no evidence that fast fashion alters the income–emissions relationship. The EKC terms (GDP and GDP^2) remain insignificant, reinforcing the absence of the Environment Kuznets curve dynamic in this specification. Among the controls, regulatory quality emerges as marginally significant ($p = .105$), suggesting that governance capacity may be a more relevant moderator of emissions than sectoral export growth. Overall, once controls are introduced, fast fashion export growth remains statistically irrelevant for shaping the EKC trajectory, showing no support to the findings.

As in Model 3, in Model 4 the interaction between GDP and fashion share is not significant ($p = .345$). Regulatory quality is now statistically significant ($p = .0401$), making it the only consistent predictor across models. All other variables, including GDP terms, controls, and interaction, are not significant.

To refine our analysis of the relationship between economic growth, fast fashion, and environmental degradation in Vietnam, we incorporated a year variable and applied Newey-West robust standard errors to address time-related estimation issues (Table 3). Controlling for year accounts for unobserved, systematic changes over time that may affect CO_2 emissions regardless of income or sectoral structure. These include technological advancements, changes in global market dynamics, and the gradual implementation of environmental policies. Without this temporal control, the model may incorrectly attribute emissions trends to economic or sectoral variables rather than to underlying time-related effects. Additionally, I applied Newey-West standard errors to correct for potential autocorrelation and heteroskedasticity, which are common in macroeconomic time series. Since annual CO_2 emissions are likely correlated across years and may exhibit changing variance over time, using standard OLS errors could lead to underestimated standard errors and inflated significance levels.

In the model with the interaction term between log(fashion export) and GDP, the EKC hypothesis is not supported. Neither GDP per capita nor its squared term are statistically significant, suggesting that Vietnam has not yet reached a turning point in its emissions trajectory. The expected inverted-U shape of the EKC is thus not observed. Interestingly, log(fashion_export) is statistically significant and negative ($p < .05$), indicating that increases in fashion export volume

are associated with lower CO_2 emissions per capita, even after accounting for income and other structural factors. While initially counterintuitive, this finding may reflect a shift toward more efficient production technologies in the export sector; Structural upgrades in manufacturing due to global buyer standards; or a coincidental overlap between the rise of fashion exports and broader emissions stabilization policies post-2015.

The interaction term between GDP and log(fashion_export) is not significant, suggesting that fast fashion growth does not moderate the GDP–emissions relationship. However, regulatory quality remains a statistically significant and positive predictor of CO_2 emissions, reinforcing the idea that stronger institutions are associated with better environmental outcomes. Other controls, such as urban population, trade openness, and FDI inflows, were not significant in this model.

Table 4. EKC Models with Year Control and Newey-West Robust Standard Errors Dependent variable: CO_2 per Capita

	(1) Log FF × GDP + Year + Controls	(2) Share FF × GDP + Year + Controls
GDP per Capita	–0.0140 (0.0147)	0.00881 (0.00553)
GDP per Capita²	–0.00000038 (0.00000043)	–0.00000080 (0.00000067)
Log(Fashion Export)	–2.7298* (1.059)	—
Fashion Export Share	—	21.34 (14.77)
Year	1.8489 (1.279)	–0.4808 (0.598)
Urban Population (%)	–2.596 (1.949)	0.324 (0.730)
Trade Openness	–0.00521 (0.00356)	–0.00934** (0.00266)
Industry Value Added	0.0280 (0.0346)	0.0111 (0.0277)
FDI Inflow	0.0264 (0.0161)	0.0443* (0.0163)
Regulatory Quality	1.708*** (0.319)	1.368** (0.432)
GDP × Log(Fashion Export)	0.000733 (0.000571)	—
GDP × Fashion Export Share	—	–0.0116 (0.00848)
Constant	–3576.3 (2489.1)	945.3 (1172.1)
Observations	23	23
Adjusted R^2	—	—

*Significance codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

When replacing fashion export volume with its share of total merchandise exports in Model 2, the results similarly reject the EKC hypothesis: GDP and GDP² remain insignificant. Both the main effect of fashion export share and its interaction with GDP are statistically insignificant, indicating that the relative size of the fashion sector within exports does not explain changes in CO_2 emissions. However, trade openness emerges as a significant, negative predictor of emissions ($p < 0.01$), suggesting that Vietnam's integration into global trade may have contributed to cleaner production practices or technological spillovers. FDI inflow is also positive and significant ($p < 0.05$),

suggesting that foreign investment may still be contributing to emission-intensive industrial activity. Importantly, regulatory quality remains a robust predictor ($p < 0.01$) in this model as well, underscoring the role of institutional effectiveness in managing environmental degradation. This consistent finding across models highlights the importance of governance capacity in mediating the environmental impacts of growth.

5. DISCUSSION

This study examined whether the Environmental Kuznets Curve (EKC) hypothesis applies to Vietnam's growth from 2000 to 2023 with the particular focus on the role of fast fashion exports in shaping environmental outcomes. Using visual evidence and regression models with interaction terms, year controls, and robust error corrections, the findings provide little support for the EKC's predicted inverted-U, as most carbon-based indicators rise monotonically with income. Fast fashion exports do not consistently shift this trajectory, while institutional quality and trade dynamics emerge as more influential determinants. The discussion that follows addresses four themes in turn: first, whether the EKC is supported in Vietnam; second, whether the fashion sector alters EKC dynamics; third, the broader role of governance, trade, and foreign investment; and fourth, the theoretical and policy implications these results hold for environmental governance and green growth.

Overall, the empirical evidence does not support the EKC hypothesis for Vietnam during the study period, showing the upward trend but no turning point. Across multiple model specifications, including baseline EKC models, full control models, and those incorporating time effects, the squared term of GDP per capita remained statistically insignificant. Visual plots also revealed continuously rising trends in CO_2 emissions per capita, total greenhouse gas emissions, and industrial CO_2 emissions as income increased, with no observable turning point. These findings suggest that Vietnam is still in the early or mid-phase of environmental degradation, where emissions rise with economic expansion.

The only partial exception is PM2.5 air pollution, which shows a declining trend relative to GDP per capita, an observation consistent with the EKC's downward-sloping phase. However, since this pattern was not mirrored in carbon-based indicators, the PM2.5 result likely reflects local air quality interventions rather than structural decoupling of pollution from growth. This reinforces prior findings that the EKC is pollutant-specific and does not uniformly apply across environmental domains (Dinda, 2004).

Overall, the analysis of whether the fashion industry influences EKC dynamics shows no

significant effect. The inclusion of fast-fashion export indicators, both as log-transformed export volume and as a share of total merchandise exports, did not reveal a consistent or statistically significant effect on the EKC relationship. In most models, neither the main effects nor the interaction terms between fast fashion and GDP per capita were significant. This suggests that the fast fashion sector, as measured by trade data, does not fundamentally shift the structure of the GDP–emissions relationship.

However, some models, particularly those using log-transformed fast-fashion export data, showed a statistically significant negative relationship with CO_2 per capita. While initially counterintuitive, this result may indicate that Vietnam's fashion sector has adopted relatively cleaner or more energy-efficient production technologies, possibly due to pressure from global buyers, environmental audits, or participation in green trade initiatives. Still, this effect disappears when fashion exports are measured relative to total exports (as a share of total exports), suggesting that absolute export growth matters more than sectoral composition. In short, the fashion industry's role appears to be weakly associated with emissions, but not as a driver of EKC transformation.

It is worth noting that regulatory quality is a strong predictor of environmental outcomes, with significant implications for policy. Across all models, regulatory quality consistently emerged as the most robust and significant predictor of environmental performance. Countries with better governance, including stronger regulatory institutions, tend to have lower emissions—an outcome that aligns with institutionalist theories of environmental performance (Knill et al., 2012; Dasgupta et al., 2001). This finding reinforces the idea that institutional capacity may be more important than income alone in shaping sustainable outcomes, particularly in developing economies.

Additionally, trade openness showed a significant and negative effect on emissions in the final model, suggesting that integration into global markets may facilitate access to cleaner technologies or incentivize greener production for export. Conversely, foreign direct investment (FDI) inflow was positively associated with emissions, lending some support to the pollution haven hypothesis—the idea that multinationals may relocate polluting activities to countries with weaker environmental standards.

Other variables, such as urbanization and industrial structure, did not exhibit significant effects, possibly because their effects overlapped with those of GDP or governance indicators. While the empirical results of the study contradict the theories that underpin the study's hypothesis, including the EKC hypothesis, other theoretical perspectives, such as institutionalist environmental governance theories and trade theories, are supported by the results.

Institutionalist environmental governance theories are a set of ideas in environmental policy and political science that focus on the quality, design, and capacity of institutions, especially formal rules, laws, and enforcement bodies that further shape environmental outcomes. Here, environmental governance refers to the institutional arrangement that attempts to control individual or organizational use of natural resources, ecological systems, and sinks for wastes in order to meet objectives such as sustainable use, protection of public health, and protection of valued species or places." (NRC, 2005)

In the case of Vietnam, Institutionalist environmental governance theories find strong support where improvements in institutional quality, regulatory frameworks, and enforcement capacity have been shown to enhance environmental outcomes. Empirical evidence covering 1996–2022, close to our set time of 2000-2023, demonstrates that, in the short term, renewable energy and institutional quality have positive impacts on green growth and that in the long term, green innovation, renewable energy, industrialization, and institutional quality have positive impacts on Vietnam's green growth (Nguyen et al., 2024). Following, a 30-year critical review of Vietnam's environmental policy similarly notes that the country "has demonstrated a clear commitment to environmental policy by establishing a substantial body of regulations aimed at achieving environmental protection objectives," driven by political attention, international integration, and public demand for a cleaner environment (Do & Thi, 2023), reflecting the continuous efforts for growth and sustainability.

Moreover, Mahmood et al. (2022) and Stef et al. (2023) reveal that effective climate change policies must be associated with improvements in key institutional dimensions, such as citizens' participation and control of corruption, and that political stability and regulatory quality positively influence environmental performance at the national level. Recent legal reforms, such as those under the new environmental protection law, require businesses "to actively employ technologies to control pollution" and impose "recycling or monetary compensation obligations for certain products and packaging" (IFC, 2022). Further, institutional quality has been shown to moderate the relationship between informal economic activity and environmental degradation, underscoring the role of institutional reform policies in controlling CO_2 emissions (Tran, 2022). Together, these findings affirm that, as Institutionalist theory predicts, in Vietnam, robust governance structures and strong rule enforcement are critical to achieving sustainable environmental performance and making a national impact.

Furthermore, trade theories posit that trade openness can serve as a channel for green growth by facilitating the transfer of green technologies between countries, the diffusion of environmental

standards, and access to green investment (Feng et al., 2024). The underlying theory suggests that by engaging in international trade, countries can modernize their production structures, shift toward less-polluting sectors, and adopt more efficient practices through exposure to foreign markets and competition while reducing CO2. (Almulhim et al., 2022).

In the Vietnamese context, this channel is partially supported. Liberalization and increased trade have boosted economic growth and technology inflows, but their environmental gains depend on complementary regulatory capacity.

However, trade's tendency to generate scale effects —a concern that trade and higher production and transport activity are likely to increase greenhouse gas emissions by stimulating growth (Copeland et al., 2004) —remains. ARDL study finds that "a 1 percent increase in trade openness leads to a 0.191 percent increase in CO_2 emissions" in the long run, with effects "revers[ing] from negative to positive after a two-year period," implying mixed environmental outcomes without strong safeguards (Tran et al., 2019). "Trade openness has a negative and insignificant effect on green growth in the short run but a positive and significant impact in the long run" (Teklie & Yağmur, 2024). Overall, Vietnam's experience shows that openness can support green growth when paired with institutional strengthening. (Tran et al., 2019; Le et al., 2025).

Similarly, Le et al. (2025) report that "international trade contributes to air pollution, but becoming a full member of WTO brings a positive effect to the Vietnamese environment," as WTO accession catalyzed regulatory upgrades. This institutional channel is also visible under the EVFTA: Vietnam's legal gap review notes that Chapter 7 on non-tariff barriers for renewable energy requires domestic alignment, with about 15 laws already governing the area and a call to appoint a lead agency, steps that can lower trade-related frictions for clean investment (World Bank, 2020). As integration has deepened, Vietnam has rapidly scaled clean power, with wind and solar supplying about 13 percent of electricity in 2024 and low-carbon sources accounting for 44 percent overall, demonstrating trade-enabled technology diffusion but also the need for grid and regulatory reforms to lock in gains (Ember, 2025).

Furthermore, the role of specific sectors in changing the EKC dynamic is also not clearly confirmed in the results. As discussed, in theory, economies that reduce the dominance of heavy manufacturing or polluting industries, adopt cleaner production in key sectors should see earlier decoupling of emissions from GDP, slowly following the trend of EKC, decreasing their emission. However, in Vietnam sectoral trends and shifts show little evidence to support this mechanism. Nguyen and Le (2022) find that "manufacturing and construction sectors remain the largest

contributors to CO_2 emissions, with limited improvement in emissions intensity over the past decade.

Vietnam's manufacturing remains to occupy a large share of GDP, 16.7% in 2022, up from 15.3% in 2010, and the country remains a major hub for water and carbon-intensive industries like textiles, apparel, and footwear industries (General Statistics Office of Vietnam, 2023). Moreover, with the increasing trend of fast fashion, Vietnam's textile and garment exports reached US$37.6 billion in 2022, more than double the 2010 figure, and the sector is estimated to contribute 8–10% of national industrial wastewater and a significant share of industrial CO_2 emissions (VITAS, 2023; World Bank, 2019), worsening the environmental condition.

Consequently, Vietnam's aggregate emissions profile continues to be driven by energy and resource-intensive production linked to global supply chains, especially in fast fashion. The prominence of the highly polluting industry's contribution to the country's economy and growth over time underscores that the structural shift of such industries toward following the EKC is insufficient, and that shifts from pollution-intensive industries toward cleaner sectors are thus showing little support for this relationship.

The results of the statistical analysis and the literature review carry several important implications for environmental policy and future research in Vietnam. Firstly, Vietnam should not expect economic growth alone to deliver reductions in emissions. The rejection of the Environmental Kuznets Curve in this context shows that a sustained decoupling from environmental degradation has not accompanied higher GDP per capita; instead, emissions have continued to rise alongside income, due to the highly polluting industries and their sectoral dominance. This finding underscores the need for targeted interventions in high-emission sectors such as energy, transport, and manufacturing, where industrial expansion has driven much of the increase in CO_2 output. Without sector-specific regulations and efforts to mitigate emissions, such as subsidizing clean energy and improving fuel-efficiency standards, to both optimize efficiency and environmentally friendly production, the structural drivers of emissions —thereby deviating from the EKC —will likely remain intact despite economic progress in Vietnam.

In addition, one important aspect policymakers should focus on is prioritizing institutional strengthening. Throughout the analysis, regulatory quality and governance indicators emerged as stronger and more consistent predictors of environmental outcomes than purely economic variables, lending empirical support to Institutionalist environmental governance theory. In practice, this means that reforms aimed at improving the enforcement of environmental regulations,

reducing opportunities for corruption, and building state capacity to monitor compliance can yield more reliable environmental gains than relying solely on market forces, which primarily leads to growth in more profitable and stronger industries. Vietnam's experience with trade openness reinforces this point: while integration into global markets has facilitated technology transfer and green investment, the environmental benefits have materialized only where governance frameworks have been able to enforce environmental standards. Otherwise, the global supply chain was used in a way that is financially beneficial, leading to growth in high-polluting industries.

Further research is needed to unpack the sector-specific environmental profiles of Vietnam's export industries, going beyond aggregate trade values to assess their true ecological footprint. The use of micro-level firm data and input–output environmental modeling would enable more precise estimates of the environmental impacts of key sectors, such as textiles, apparel, and electronics, particularly given the prominence of the global fast-fashion industry in Vietnam's export mix. Moreover, comparative studies across ASEAN and other lower-middle-income economies, such as Thailand, Myanmar, and Cambodia, could determine whether Vietnam's emissions–growth trajectory is typical for the region or an anomaly, offering valuable insight into how structural and institutional differences influence environmental outcomes in similar development contexts.

6. CONCLUSION

This study shows that Vietnam's path of growth from 2000 to 2023 does not align with the Environmental Kuznets Curve. While PM2.5 concentrations have declined, carbon-based pollutants such as CO_2 and total greenhouse gases have continued to rise steadily with income, signaling that structural decoupling has not yet occurred. The expansion of fast fashion exports, though central to Vietnam's economy, did not fundamentally reshape the income–emissions relationship. By contrast, institutional quality and governance capacity emerged as far stronger predictors of environmental outcomes, with trade openness linked to cleaner practices and foreign direct investment associated with higher emissions. Taken together, these findings suggest that growth by itself is insufficient to deliver environmental improvements. An economy's ability to reach a sustainable trajectory depends on strengthening institutions, enforcing environmental standards, and guiding high-emission industries such as textiles toward cleaner production. Building on localized successes in air quality management, future policies can draw on targeted regulation and sector-specific interventions to align industrial growth with the country's long-term climate commitments.

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