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The Impact of Emission Trading Systems on Carbon Reduction and Sustainable Development

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ABSTRACT: This study examines the effectiveness of carbon markets, with a particular focus on Emission Trading Systems (ETS), in advancing global commitments to net-zero emissions by 2050. Employing a High-Dimensional Fixed Effects (HDFE) regression framework, it investigates the interplay between carbon emissions, economic dynamics, and policy interventions across diverse national contexts, including Mainland China, Hong Kong, India, Bangladesh, Cambodia, Malaysia, Indonesia, the Philippines, South Korea, Singapore, and Vietnam. The findings indicate that while ETS can contribute to CO_2 reduction, its effectiveness is highly contingent on country-specific conditions, policy design, and enforcement capacity. Results demonstrate that ETS adoption does not ensure uniform or immediate emission declines, with significant heterogeneity across income groups and institutional settings. The study further explores the nexus between carbon markets and sustainable urban development, emphasizing the integration of carbon pricing with urban planning and infrastructure investment. These insights provide critical implications for designing effective, context-sensitive ETS frameworks to support sustainable development pathways.

KEYWORDS: Emission Trading System; Carbon Emissions; Green Energy; Urbanization.
JEL Classifications: Q58, Q54, F64.

1. INTRODUCTION

Vietnam's strategic vision for a national carbon market, outlined in Decision No. 232/QD-TTg (Nguyen Hanh, 2025), highlights the country's goal to achieve net-zero emissions by 2050. This ambitious target has been analyzed by McKinsey (Agarwal, Deffarges, Delteil, Francois, & Tara, 2022) and PwC (Pham & Bang, 2025) and requires a solid plan to reduce carbon emissions. Rapid urbanization is a major contributor to greenhouse gas (GHG) emissions, making sustainable urban planning crucial for both the environment and economy. This study looks at how carbon markets can support sustainable urban development in Vietnam, focusing on market-driven strategies to reduce urban emissions while aligning with the Law on Environmental Protection 2020 and Decree No. 06/2022/ND-CP.

Research by Armeanu, Joldes, Gherghina, & Andrei (2021) highlights the complex relationship between environmental quality and economic growth. Their findings suggest that increased adoption of renewable energy can significantly reduce CO2 emissions, reinforcing the argument for integrating carbon markets with sustainable energy solutions. However, carbon leakage is a problem where pollution-heavy industries move to developing countries to avoid strict regulations, making it harder to reduce global emissions. This phenomenon complicates the effectiveness of Emissions Trading Systems (ETS) and necessitates policy coordination at both national and international levels.

The implementation of ETS varies significantly across different economic contexts. The European Union (EU) pioneered its ETS in 2005, followed by China (Ellerman, Marcantonini, & Zaklan, 2016; Verde, 2020; Guo, Ma, & Li,, 2022; Yu & Xu, 2023). However, the structure and effectiveness of these systems depend on institutional capacity and economic conditions. Developed nations such as the EU and South Korea operate fully functional ETS frameworks, whereas developing economies like Vietnam, Cambodia, and the Philippines encounter substantial institutional and economic barriers (Rahman & Velayutham, 2020; Wulandari, Laksono, & Rohmah, 2021). In contrast, India employs the Perform, Achieve, and Trade (PAT) scheme, which prioritizes energy efficiency trading over direct cap-and-trade mechanisms (Ojha, Pohit, & Ghosh, 2020). The decision to adopt ETS is influenced by international trade dynamics and climate commitments. Countries embedded in carbon-intensive supply chains may hesitate to implement ETS to maintain cost competitiveness. Hence, while ETS is a powerful tool for emissions reduction, its adoption is contingent upon each nation's economic objectives, policy landscape, and capacity to manage carbon pricing effectively.

Despite extensive research on ETS and carbon emissions (Ellerman et al., 2016), there remains a knowledge gap concerning its interaction with urbanization and regional economic structures. This study contributes by conducting a regional-level analysis of ETS impacts, offering deeper insights into how carbon trading affects economic geography, industrial restructuring, and urban growth patterns. By addressing these gaps, the study informs policy discussions on designing ETS frameworks tailored to regional economic contexts, sector-specific needs, and local developmental disparities, thereby promoting a more equitable and effective transition to a low-carbon economy. Further, the findings highlight the significant role that different stages of economic development play in the effectiveness of Emissions Trading Systems (ETS). Variations in income levels influence how different economic groups engage with carbon markets. Findings suggest that well-designed ETS policies can stimulate urban growth by incentivizing investments in low-carbon infrastructure. Then it would enhance energy efficiency, foster innovation in low-emission technologies, and facilitate industrial transformations.

The rest of the paper is structured as follows: Section 2 provides a review of the relevant empirical literature, Section 3 outlines the data sources and econometric model, Section 4 presents the key empirical findings, and Section 5 concludes with a summary of the results and policy implications.

2. LITERATURE REVIEW

2.1 Carbon Emission Trading System (ETS) and Its Role in Sustainable Development for Asian Economies:

The effectiveness of ETS in reducing CO_2 emissions varies across studies. In China, government intervention significantly impacts emissions reduction (Gio et al., 2022; Guo et al., 2022). However, issues like permit oversupply and regulatory loopholes can undermine ETS effectiveness (Choi, 2017; Verde, 2020; Jung & Song, 2023). Diverse Asian economies integrate carbon markets, reflecting varied approaches. China's national ETS and India's compliance-based trading contrast with Hong Kong's voluntary market and Singapore's carbon tax (Rosenow, Cowart, & Thomas, 2019; Bradsher, 2021; Xinhua, 2022; Li & Gao, 2022; Ramli & Kasih, 2024). Emerging economies like Bangladesh, Cambodia, Malaysia, and Indonesia integrate carbon market elements into their strategies, reflecting adaptability (Rahman & Velayutham, 2017; Smolo, Saba, Ismail, & Mahomed, 2024; Wulandari, Laksono, & Rohmah, 2021). For instance, South Korea, a leader in carbon trading and sustainable urban development, demonstrates the successful integration of a mature, nationwide mandatory ETS alongside advanced urban planning initiatives. Its experience offers valuable insights into the long-term impacts of stringent carbon pricing on industrial innovation and urban development (Jung and Song, 2023; Zhou, Song, and Huang, 2023).

Vietnam, preparing to integrate its phased ETS implementation, stands at a critical connection in its economic development (Thang, Yen, Dung, and Cuong, 2024; Halsnæs, Some, and Pathak, 2024). The comparative analysis of these diverse Asian economies underscores the ongoing integration of carbon markets, highlighting the need for context-specific policies to navigate the trade-offs between economic growth, equity, and environmental sustainability. This sub-analysis contributes to a broader understanding of how carbon market development can be tailored to the unique challenges and opportunities presented by urbanization and industrialization across the Asian region. In general, several studies on China and the EU ETS show that regulated carbon pricing incentivizes low-carbon technology adoption and cleaner production methods (Ellerman et al., 2016; Verde, 2020). These studies confirm that ETS creates financial incentives for emissions reduction, promotes energy efficiency, and drives industrial transformation. Based on the theories and analyses above, it proposed that:

Hypotheses 1: The implementation of an Emissions Trading System (ETS) leads to a significant reduction in CO_2 emissions by creating financial incentives for emission reductions, promoting energy efficiency, and encouraging the adoption of low-carbon technologies.

2.2. The Interplay of Renewable Energy, Urbanization, Economic Growth, and Carbon Emissions:

The efficient reallocation of emission quotas through market-based mechanisms, such as Emission Trading Systems (ETS), is pivotal in shaping economic growth. Choi, Liu, and Lee (2017) applied a Computable General Equilibrium (CGE) model, that the design and implementation of the Korean ETS significantly impact economic outcomes. Specifically, they highlight the importance of sectoral coverage and quota allocation in mitigating potential negative economic effects. By channeling emission allowances to industries with higher productivity, ETS can enhance industrial efficiency and foster economic growth. Similarly, Ellerman, Marcantonini, and Zaklan (2016), evaluating the EU ETS, show that market-driven reallocation facilitates industrial adaptation without hindering GDP growth. This mechanism encourages firms to invest in cleaner, more efficient technologies, thereby reducing the long-term economic burden of carbon constraints. Then Jung and Song (2023) further underscore the role of marketized carbon trading in enabling dynamic adjustments in emissions reductions, incentivizing technological innovation, and boosting economic efficiency. These studies collectively affirm that ETS-driven quota reallocation promotes economic efficiency by directing resources towards low-carbon innovation, positively influencing GDP per capita. Moreover, the Environmental Kuznets Curve (EKC) theory suggests that emissions initially rise with economic growth but decline as countries adopt cleaner technologies (Baajike, Oteng-Abayie, Dramani, & Amanor, 2024).

Hypotheses 2: Consistent with the Environmental Kuznets Curve (EKC) hypothesis, the relationship between GDP per capita and CO_2 emissions follows an inverted U-shape, wherein CO_2 emissions initially rise with economic growth but begin to decline after reaching a certain income threshold.

The relationship between renewable energy consumption and CO_2 emissions has been extensively studied. The empirical evidence consistently demonstrates a negative association between the two at both national and regional levels (Armeanu, Joldes, Gherghina, & Andrei, 2021; Okumus, Guzel, & Destek, 2021; Chopra, Magazzino, Shah, Sharma, Rao, & Shahzad, 2022). For instance, Okumus, Guzel, and Destek (2021) employed a Cross-Sectional Autoregressive Distributed Lag (CS-ARDL) model to examine the nexus between renewable energy consumption and economic growth in G7 economies. Their findings confirm that higher renewable energy consumption leads to a statistically significant reduction in CO_2 emissions, underscoring the role of renewable energy policies in achieving emission reduction targets across both domestic and interconnected economic systems. Similarly, Armeanu et al. (2021) explored the multidimensional linkages between renewable energy, pollution, economic growth, and urbanization across economies with varying income levels. Their results indicate a consistent inverse relationship between renewable energy adoption and CO_2 emissions, reinforcing the potential of transitioning to renewable energy as an effective strategy for mitigating environmental degradation. Additionally, Chopra et al. (2022) highlighted that increased reliance on renewable energy sources lowers carbon emissions in ASEAN countries, promoting sustainable agricultural practices and highlighting regional spillover effects. Consequently, these findings strongly support the notion that renewable energy consumption plays a crucial role in reducing CO_2 emissions, emphasizing the importance of expanding renewable energy infrastructure. However, the effectiveness of renewable energy in reducing emissions varies based on economic development levels and existing energy infrastructure. Therefore, addressing technological limitations, financial constraints, and policy barriers is essential to maximizing its environmental benefits.

Hypotheses 3: Increased renewable energy consumption is negatively associated with CO_2 emissions, showing a significant contribution to emissions reduction both within a given country and in neighboring countries.

Conversely, urbanization is widely recognized as a major driver of increased CO_2 emissions. Specifically, it is associated with higher energy consumption, industrial expansion, and infrastructure development (Armeanu et al., 2021; Guo et al. 2022; Ghorbany and Hu, 2024). The urban expansion correlates with higher carbon footprints in Chinese cities (Guo et al., 2022). Their study emphasizes how regional disparities in urban planning and economic activities influence emissions patterns. Expanding on this, Armeanu et al. (2021) explored the multidimensional linkages between renewable energy, pollution, economic growth, and urbanization across economies with varying income levels. Their results indicate a consistent inverse relationship between renewable energy adoption and CO_2 emissions, reinforcing the potential of transitioning to renewable energy as an effective strategy for mitigating environmental degradation. Moreover, Wulandari et al. (2021) highlighted urban-rural disparities in Southeast Asia, where urban areas consume significantly more energy due to increased industrialization and population density. As a result, as urban populations grow, so does their per capita carbon footprint, reinforcing the link between urbanization and increased emissions.

Hypotheses 4: Urbanization leads to a significant increase in CO_2 emissions due to rising energy consumption, industrial expansion, and infrastructure development.

3. METHODOLOGY

3.1. Data Collection:

This study examines the interplay of Emission Trading Systems (ETS), carbon emissions (CO_2), gross domestic product per capita (GPC), renewable energy consumption (REC), and urbanization (UP) across eleven diverse Asian economies from 2010 to 2023, using World Bank data. These economies include Mainland China, Hong Kong, India, Bangladesh, Cambodia, Malaysia, Indonesia, the Philippines, South Korea, Singapore, and Vietnam. The period is based on important policy changes, noticeable economic trends, and the availability of complete data. The economies are selected due to their varying economic development, urbanization levels, and ETS frameworks. Consequently, this diversity allows for a robust analysis of the complex relationships between these factors. For example, South Korea, Hong Kong, and Singapore supported high-income status, while others experienced significant economic transitions. Furthermore, the study highlights the dynamic economic progress of several nations. Indeed, India, Bangladesh, Indonesia, Vietnam, the Philippines, Cambodia, and Mainland China all underwent transitions in their income classifications, reflecting substantial economic reforms and growth. Moreover, these transitions, as classified by the World Bank, illustrate the diverse development trajectories within the region.

Subsequently, the analysis employs log-transformed World Bank data to examine the impact of Emission Trading System (ETS), carbon emissions (CO_2), gross domestic product per capita (GPC), renewable energy consumption (REC), and urbanization (UP) across 11 economies. In Table 1, Descriptive statistics reveal significant heterogeneity in carbon emissions across the economies. For instance, Mainland China exhibits the highest mean CO_2 emissions (9.52), while Cambodia reports the lowest (3.69). Additionally, advanced economies like South Korea and

Singapore show stable emission trends (0.04 and 0.08, respectively), whereas emerging economies display greater variation. Moreover, the dataset captures diverse economic development levels. For instance, Singapore demonstrates the highest GDP per capita (11.05), while Bangladesh and Cambodia represent lower-income economies (7.32 and 7.42, respectively). Likewise, renewable energy adoption varies significantly. Specifically, Cambodia and Bangladesh have high renewable energy shares, while Hong Kong and Singapore show negative values, indicating heavy reliance on fossil fuels. Furthermore, urbanization levels also exhibit significant variation. For instance, Mainland China and India lead in urban population size (20.49 and 19.93, respectively), while Cambodia and Bangladesh have lower levels (15.10 and 17.86, respectively). Therefore, industrialized nations with high GDP per capita often show high carbon emissions and lower renewable energy reliance, reflecting their energy-intensive industries. Conversely, developing countries tend to rely more on renewable energy and exhibit lower carbon emissions. Urbanization significantly influences emissions and energy use, displaying diverse strategies for sustainable urban development.

Table 1: Descriptive statistics of variables.

Country	Variable	Obs	Mean	Std. dev.	Min	Max
Bangladesh	CO2	14	5.471204	0.114351	5.298959	5.639708
Bangladesh	GPC	14	7.323829	0.45989	6.629872	7.907094
Bangladesh	REC	12	3.455337	0.170301	3.218876	3.696352
Bangladesh	UP	14	17.85899	0.128741	17.65203	18.05537
Cambodia	CO2	14	3.688625	0.152188	3.486347	3.887214
Cambodia	GPC	14	7.417943	0.3036	6.858853	7.795543
Cambodia	REC	12	4.079192	0.08859	3.939638	4.174387
Cambodia	UP	14	15.10437	0.133036	14.89486	15.3096
China	CO2	14	9.517719	0.093298	9.32927	9.676837
China	GPC	14	9.048713	0.313017	8.422987	9.446406
China	REC	12	2.549082	0.102776	2.424803	2.721295
China	UP	14	20.48639	0.106821	20.30547	20.62994
Hong Kong SAR	CO2	14	3.843676	0.108896	3.638278	3.963444
Hong Kong SAR	GPC	14	10.66912	0.142077	10.39054	10.83036
Hong Kong SAR	REC	12	-1.4655	0.413488	-2.30259	-0.69315
Hong Kong SAR	UP	14	15.80523	0.022436	15.76487	15.83522
India	CO2	14	8.126534	0.114392	7.918489	8.326893
India	GPC	14	7.485821	0.202354	7.206021	7.816333
India	REC	12	3.533336	0.035979	3.48124	3.589059
India	UP	14	19.92538	0.099039	19.76774	20.07498
Indonesia	CO2	14	6.882119	0.12585	6.661842	7.090243
Indonesia	GPC	14	8.242284	0.131127	8.028026	8.492145

Indonesia	REC	12	3.272206	0.194341	2.985682	3.583519
Indonesia	UP	14	18.78264	0.094198	18.62721	18.91963
Korea, Rep.	CO2	14	6.550474	0.037938	6.482872	6.608211
Korea, Rep.	GPC	13	1.09841	0.369846	0.30508	1.917632
Korea, Rep.	REC	6	0.408478	0.150603	0.219436	0.639043
Korea, Rep.	UP	14	17.54509	0.012627	17.51934	17.55798
Malaysia	CO2	14	5.664346	0.071048	5.547352	5.785073
Malaysia	GPC	14	9.251208	0.077385	9.093733	9.371446
Malaysia	REC	12	1.354096	0.454631	0.693147	2.014903
Malaysia	UP	14	16.99135	0.100715	16.82714	17.13514
Philippines	CO2	14	5.33281	0.161924	5.089847	5.545752
Philippines	GPC	14	8.004214	0.156578	7.679212	8.244038
Philippines	REC	12	3.411139	0.088308	3.292126	3.529297
Philippines	UP	14	17.7227	0.076457	17.59221	17.83149
Singapore	CO2	14	4.186397	0.076762	4.061332	4.307978
Singapore	GPC	14	11.04626	0.182228	10.76293	11.38995
Singapore	REC	12	-0.37581	0.257825	-0.69315	0.09531
Singapore	UP	14	15.52252	0.040504	15.44018	15.59345
Viet Nam	CO2	14	5.950506	0.222208	5.68481	6.261746
Viet Nam	GPC	14	7.954027	0.280046	7.42843	8.362196
Viet Nam	REC	12	3.356908	0.24341	2.939162	3.634951
Viet Nam	UP	14	17.30483	0.129891	17.09647	17.49482

Source: Data are collected from the World Bank's World Development Indicators. All variables are logarithmic transformations. Descriptive statistics and subsequent calculations were performed by the author.

3.2. Model Specification:

The High-Dimensional Fixed Effects (HDFE) regression is employed to examine the determinants influencing national carbon emissions, incorporating theoretical foundations from the Environmental Kuznets Curve (EKC) hypothesis and the Cobb-Douglas production function (Chopra, Magazzino, Shah, Sharma, Rao, & Shahzad, 2022). The study investigates the relationship between GDP, carbon emissions, urbanization, and renewable energy consumption, acknowledging that carbon-related environmental policies, including the launch of Emission Trading Systems (ETS), serve as external shocks to emissions trends. This research focuses on assessing the shifts in carbon emissions before and after the introduction of these policies. Given that most economies in the dataset have recently adopted ETS, applying a Difference-in-Differences (DiD) approach faces challenges due to collinearity issues. Because all treated countries eventually adopted ETS, it might lead to insufficient variation between treatment and control groups (De Chaisemartin & d'Haultfœuille, 2020). Instead, the study employs an interaction-based approach, leveraging heterogeneity in income levels to capture differences in ETS effectiveness across economic classifications.

$$LnCO2_{i,t} = \alpha_0 + \alpha_1(Post_{i,t}*Income\_Group_{i,t}) + \alpha_2 LnGDP_{i,t} + \alpha_3 LnGDP2_{i,t} + \alpha_4 LnUR_{i,t} + \alpha_5 LnNREC_{i,t} + V_t + F_i + \varepsilon_{i,t} \quad (1)$$

where $LnCO2_{i,t}$ represents the total greenhouse gas emissions of economy i in year t, $LnGDP_{i,t}$ represents the gross domestic product per capita of economy i in year t, $LnUR_{i,t}$ represents the urban population of economy i in year t, and $LnNREC_{i,t}$ represents the renewable energy consumption scaled by total energy consumption of economy i in year t, respectively. Post is dummy binary variables which indicate the post-ETS adoption period. Income Group is a categorical variable classifying countries into different income levels (Low-Income, Lower-Middle, Upper-Middle, High-Income) according to World Bank Classification. The interaction term, $Post_{i,t}$*Income_Group, estimates how the effect of ETS adoption varies across income groups. This allows for testing whether ETS is more effective at different income levels, aligning with studies on carbon mitigation pathways (Armeanu et al., 2021). Further, the interaction captures heterogeneous treatment effects, acknowledging that higher-income nations may implement stricter ETS enforcement, while lower-income countries face weaker regulatory capacity (Ren, Yang, Hu, & Chevallier, 2022). t denotes the year, i denotes the economy, and ε is the error term. Time (V) and individual (F) fixed effects are included to control for unobserved heterogeneity. High-dimensional fixed effects (HDFE) regression is preferred over alternatives like random effects, first-differencing, and GMM due to its robust handling of unobserved heterogeneity and endogeneity. HDFE efficiently absorbs country and year effects, mitigating omitted variable bias. Random effects are unsuitable due to unrealistic assumptions, while first-differencing fails to control global shocks. GMM is inappropriate given the limited time span and potential serial correlation. HDFE's ability to manage multi-dimensional fixed effects ensures a rigorous analysis of complex panel data.

3.3. Methods of the robustness checks:

To assess the impact of Emission Trading System (ETS) implementation, this study employs a Difference-in-Differences (DID) model, treating ETS launch as an external shock. DID effectively distinguishes pre- and post-shock changes, comparing experimental (ETS-affected) and control (unaffected) groups (Wing, Simon, & Bello-Gomez, 2018). Significant trend differences between groups, validated through thorough tests, confirm the policy's effect. This method provides robust evidence of ETS influence on carbon emissions:

$$LnCO2_{i,t} = \alpha_0 + \alpha_1(Post_{i,t}*Treat_{i,t}) + \alpha_2 LnGDPi,t + \alpha_3 LnGDP2_{i,t} + \alpha_4 LnUR_{i,t} + \alpha_5 LnNREC_{i,t} + V_t + F_i + \varepsilon_{i,t} \quad (2)$$

where Post and Treat are both dummy binary variables which are introduced to represent the impact of the ETS.

Further, a placebo test serves as another robustness check. It aims to address time and region confounding variables, (Eggers, Tuñón, & Dafoe, 2024). By randomly generating experimental groups and repeating the DID model 500 times, significant estimates across samples suggest confounding variables. Conversely, a distribution centered around zero indicates their elimination.

4. RESULTS ANALYSIS

4.1. Impact of ETS, Renewable Energy, and Urbanization on CO2 Emissions:

Table 2 presents the regression results examining the impact of the Emission Trading System (ETS), CO_2, renewable energy consumption, and urbanization, with CO_2 as the dependent variable. All models utilize linear regressions with high-dimensional fixed effects and clustered standard errors to account for within-country correlation, ensuring robust inference. Fixed effects control for unobserved heterogeneity, such as time-invariant country differences and year-specific shocks. Column (1) represents the baseline model, incorporating year and country fixed effects to control for time-invariant country-specific factors and global temporal shocks. Columns (2) to (5) provide robustness tests: Column (3) employs the Difference-in-Differences (DID) approach; Column (4) conducts placebo tests to assess the ETS effect's reliability; and Column (5) uses clustered standard errors at the income-group level and country fixed effects.

In Column (1), without country fixed effects, the Post ETS variable is insignificant, indicating potential omitted variable bias due to other country-specific factors. However, Column (2), with country fixed effects, shows a significant negative effect of Post ETS (-0.0581), suggesting emissions decreased after ETS adoption. Conversely, the DID approach in Column (5) finds no significant interaction term (Post x Treat), implying the ETS's impact varies across countries. Country-specific effects reveal that Malaysia and Vietnam exhibit significant positive effects on CO_2 emissions, suggesting higher emissions levels compared to others. This aligns with Fowlie & Reguant (2018), who noted firms delaying compliance investments, and Ahmed et al. (2021), who highlighted Malaysia's fossil fuel reliance.

For ETS-adopting countries (China, Hong Kong, Malaysia, Singapore, South Korea), the interaction terms between Post ETS and country dummies show increased emissions in China, South Korea, and Singapore. This contradicts expectations and suggests initial ETS programs, reliant on free allocation, were less effective (Lee et al., 2022; Lin & Xu, 2023; Jung & Song, 2023; Xie et al., 2023). These countries' industrial growth outpaced emissions reductions, and they face challenges like coal reliance and emissions offshoring (Yin, Liu, & Gu, 2022). Income group dummy variables reveal significant variation in CO_2 emissions. Low and lower-middle-income countries have lower emissions, aligning with the Environmental Kuznets Curve (EKC) hypothesis. The positive interaction term (Post ETS × Lower-Middle-Income) supports the EKC, showing emissions rise during early industrialization and decline later. Lower-middle-income countries show high pollution elasticity, while upper-middle-income countries' marginal impact of ETS is weaker.

The coefficients for GDP per capita and its squared term are insignificant, contradicting the EKC and suggesting ETS and renewable energy policies have a greater impact. This aligns with Armeanu et al. (2021) and Chopra et al. (2022), who highlight renewable energy's importance, but its effect weakens with more controls. Urbanization shows a significant positive relationship with emissions, consistent with Shahbaz et al. (2016) and others, indicating urban growth drives emissions. The insignificant GDP per capita and squared term coefficients challenge the EKC, emphasizing ETS and renewable energy's roles. Renewable energy's mitigating effect diminishes with more controls, suggesting stronger policies are needed. Urbanization's positive association with emissions underscores the need for integrated urban planning and clean energy strategies. Therefore, ETS's impact varies, and initial programs were less effective. Income levels influence emissions, supporting the EKC. Renewable energy policies are crucial, but stronger interventions are needed. Urbanization drives emissions, requiring integrated planning and clean energy solutions.

4.2. Robustness Tests: DID, Placebo, and Clustering:

Models (3), (4), and (5) provide robustness tests for the baseline model. Model (3) uses a Difference-in-Differences (DiD) approach, comparing ETS-adopting (treatment) and non-adopting (control) countries. The insignificant post-ETS and treatment variables suggest no immediate emissions impact. This aligns with Ellerman, Marcantonini, & Zaklan (2016), who noted initial ETS phases, like the EU's, had limited effectiveness. The Carbon Leakage Hypothesis (Verde, 2020) further explains this, where firms relocate emissions-intensive production to avoid compliance costs. Model (4) employs a placebo test, randomly assigning ETS adoption years to check if the estimated ETS effect is spurious (Eggers et al., 2024). The insignificant placebo effect suggests that observed reductions are likely policy-driven. Model (5) clusters standard errors by income group, acknowledging potential correlations among countries with similar economic characteristics (Cameron & Miller, 2015). This approach addresses limitations of country-level clustering. The robust urbanization effect (1.5043***) across these models highlights urban growth's impact on emissions, independent of ETS policies. This test reinforces the need to consider income-driven differences in future policy assessments, despite the statistically weak ETS effect.

Table 2: The Effect of ETS, Renewable Energy, and Urbanization on CO2 Emissions in 11 Economies

	(1)	(2)	(3)	(4)	(5)
Variables	**Baseline**	**Country Fixed Effects**	**DID Test**	**Placebo Test**	**Cluster standard errors at Income-group level**
Post Emission Trading System	-.04380	-0.0557	-0.1649	-0.0453	-0.0581***
	(0.120)	(0.0304)	(0.177)	(0.0246)	(0.0084)
Countries without FE: Cambodia, China, Hong Kong, India, Indonesia, South Korea and Singapore.					
Malaysia		1.407**			1.419**
		(0.594)			(0.314)
Philippines					0.1034***
					(0.0170)
Vietnam		1.337***			1.335***
		(0.336)			(0.145)
Interaction Terms					

Post x China		0.0716***			0.0716**
		(0.0187)			(0.0163)
Post x South Korea		0.103*			0.1028***
		(0.0521)			(0.0132)
Post x Singapore		0.212***			0. 1044 ***
		(0.0632)			(0.0341)
GDP per capita	-0.0255	-0.057	-0.0392	-0.0252	-0.0573
	(0.0207)	(0.0937)	(0.0592)	(0.0518)	(0.0524)
Square of GDP per capita	0.036	-0.0027	0.0815	0.0044	-0.0027
	(0.0374)	(0.0099)	(0.0442)	(0.0093)	(0.0034)
Renewable Energy Consumption	-0.352**	-0.125**	0.2844	-0. 0874	-0.126
	(0.116)	(0.0552)	(0.0885)	(0.0520)	(0.0689)
Urban Population	0.936***	1.489**	1.045***	1.061*	1.489 ***
	(0.0429)	(0.581)	(0.102)	(0.565)	(0.3011)
Country Income Group: No Fixed Effect					
Post ETS x Country Income Group: No Interaction					
Treat (ETS adopted country)			0.0719 (0.3719)		
Post x Treat			0.062 (0. 1843)		
Constant	-9.956***	-20.30*	-11.48***	-12.816	-19.49**
	(0.734)	(10.35)	(2.071)	(9.804)	(5.489)
Observations	126	126	126	126	126
R-squared	0.9692	0.999	0.934	0.999	0.999
Adj R-squared	0.9629	0.9991	0.9361	0.9991	0.9991
Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1					

Source: Author's calculation

5. CONCLUSION

This study examines the impact of Emissions Trading Systems (ETS) on national carbon emissions, employing High-Dimensional Fixed Effects (HDFE) regression. The analysis reveals that ETS effectiveness varies significantly across economic contexts. For instance, ETS adoption does not uniformly result in immediate emissions reductions. While emissions increased in some countries, particularly in the early phases of implementation in China, South Korea, and Singapore, potentially due to permit oversupply and regulatory loopholes, lower-middle-income countries saw significant reductions, aligning with the Environmental Kuznets Curve (EKC) hypothesis. However, upper-middle-income countries showed no statistically significant ETS impact, suggesting diminishing returns with increased wealth.

Additionally, control variables provide more insight into emissions dynamics. The insignificant negative effect of GDP per capita challenges the conventional EKC, implying that income alone does not guarantee emissions reduction, as fossil fuel dependence persists in developing economies. The mitigating effect of renewable energy diminishes with additional controls, suggesting it often supplements, rather than replaces, fossil fuels. Conversely, urbanization's strong positive effect underscores the need for integrated urban planning alongside carbon pricing. These findings emphasize that ETS success is contingent upon economic structure, energy policies, and urban development strategies. These findings highlight that while ETS can play a role in emissions reduction, economic structure, energy policies, and urban development must be considered to achieve meaningful and sustained environmental benefits.

To guide Vietnam's 2025 ETS implementation, a phased approach is recommended, beginning with pilot programs in key sectors, followed by gradual expansion. A robust carbon pricing strategy, including a floor price and potential carbon tax integration, is essential. Institutional reforms, such as strong Monitoring, Reporting, and Verification (MRV) systems and cross-border carbon trade mechanisms, are crucial for market integrity. Urban sustainability should be prioritized by incentivizing green buildings and public transport within the ETS. International collaboration, learning from South Korea, Singapore, and China, and participation in ASEAN carbon market initiatives, will enhance policy design and regional governance. This sophisticated strategy aims to optimize ETS effectiveness and minimize economic disruption.

Based on these findings, the study offers targeted policy recommendations aimed at enhancing the effectiveness of carbon markets as a tool for urban sustainability and regional industrial advancement. They include optimizing carbon emission quota allocation, enhancing market vitality through financial innovation, and strengthening integrated management frameworks. These interventions aim to maximize carbon markets' potential for urban sustainability and regional industrial advancement, informing Vietnam's development of a robust and equitable carbon market. These policy interventions are essential for maximizing the potential of carbon markets to drive sustainable urban development and contribute to Vietnam's broader climate change mitigation goals.

Despite the robustness checks, several limitations remain. The study's reliance on short-term ETS data may underestimate long-term effects. Future research should employ Instrumental Variable (IV) approaches to address endogeneity and pre-treatment trends, conduct sectoral analysis to identify industry-specific impacts, and evaluate long-term ETS effectiveness to capture policy adjustments and market maturity.

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