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Posted Date: 9 April 2025

doi: 10.20944/preprints202504.0734.v1

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Article

The Dual Role of Foreign Direct Investment in Promoting Sustainable Development: Balancing Energy Consumption and Carbon Emissions in E-7 Economies

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Abstract: Achieving sustainable energy futures is a cornerstone of global efforts to combat environmental degradation and align with corporate social responsibility (CSR) objectives. This study examines the complex relationship between energy consumption, carbon emissions, and the moderating influence of Foreign Direct Investment (FDI) in the E-7 economies—Brazil, China, India, Indonesia, Mexico, Russia, and Turkey—from 2000 to 2022. Employing advanced panel data methodologies, including continuously updated fully modified (Cup-FM) and continuously updated bias-corrected (Cup-BC) techniques, we explore the long-term dynamics of energy use, urbanization, human capital, and FDI. Our findings reveal persistent cointegration among these variables, with energy consumption, urbanization, and human capital significantly contributing to CO₂ emissions. However, FDI emerged as a critical mitigating factor, exhibiting a negative correlation with carbon emissions and moderating the emission-enhancing effects of urbanization and human capital. These results underscore the dual role of FDI as both an engine of economic growth and a catalyst for environmental sustainability. This study advocates prioritizing green FDI inflows, particularly in renewable energy infrastructure, to harmonize economic development with global sustainability targets. By integrating CSR strategies with energy transition policies, this study provides actionable insights for policymakers and corporate leaders to foster sustainable development in rapidly industrializing economies. The findings contribute to the broader discourse on sustainable development, emphasizing the need for strategic investments and policy frameworks to achieve a low-carbon future.

Keywords: Sustainable development; Corporate social responsibility (CSR); Foreign direct investment (FDI); Carbon emissions; Energy consumption; Environmental sustainability; Renewable energy; Urbanization; Human capital

1. Introduction

Emerging countries are developing rapidly and are marked by profound transformations in multiple dimensions. These include accelerated urbanization, escalating energy consumption, investment in human capital, and sustained economic expansion [1]. Human capital, which encompasses a workforce's collective educational attainment, technical competencies, and cognitive skills, is a pivotal driver of economic development and efficient allocation of productive resources [2]. Urbanization, an integral component of socioeconomic progress, exacerbates energy consumption and carbon dioxide (CO₂) emissions through intensified resource demand; however, its agglomerative effects also enable strategic urban planning, systemic efficiencies in energy infrastructure, and economies of scale in large-scale public transportation networks, fostering pathways for low-carbon transitions [3]. Energy consumption is a critical factor in these countries. Other factors that substantially impact the environment are the type of energy consumed and its

efficiency. As these countries grow economically, energy demand increases, often resulting in increased CO₂ emissions unless there is a substantial shift towards renewable sources [4]. Economic growth is impossible without increased industrial production and consumer demand, which increases CO₂ emissions. This relationship is nonlinear and is influenced by the type of economic activity and technology used [5]. The role of Foreign Direct Investment (FDI) in this context is crucial and complex. On the one hand, FDI investments introduce capital, technologies, and practices that contribute to more efficient resource use and emission reduction. However, if not adequately regulated, FDI can also lead to an increase in environmentally harmful practices, such as exploiting natural resources and relying on carbon-intensive technologies [6]. This study aimed to dissect these relationships using empirical data and analyses. By understanding the interplay between these factors, this study provides insights into how emerging countries navigate their paths to economic growth while minimizing their environmental footprints. The findings of this study are intended to inform policymakers, business leaders, and international organizations about strategies that can lead to sustainable development in these critical regions of the world.

The motivation for this research is the urgent need to understand how various developmental factors contribute to CO₂ emissions in emerging economies. Significant changes in technological advancements, globalization, and environmental awareness represent critical windows for analysis [7]. Moreover, the role of FDI in moderating the impact of these factors on CO₂ has not been explored extensively. FDI is often regarded as a driver of economic growth and is vital for shaping sustainable development. Furthermore, the extent to which FDI mitigates the impact of these factors on CO₂ has not been widely examined in previous studies. Because FDI is generally a driver of economic development, it is critical to its influence on sustainable development [8]. However, the exact function that allows for the efficient development of strategies and plans has not been well documented. The main objective of this study is to test the impact of human capital, energy usage, urbanization, and economic growth on CO₂ emissions in emerging economies while FDI moderates this relationship. This study uses a novel panel data approach to determine the empirical relationships between these factors. Another key objective is to examine the long-run associations of these variables and assess dynamic interactions and heterogeneity within panel data. This study aims to comprehensively understand the factors influencing CO₂ emissions in emerging economies by achieving these goals. Figure 1 depicts the CO₂ emissions percentage in the E-7 countries. The percentages represent each country's contribution to the total emissions or changes in emissions over time, highlighting the environmental impacts associated with economic activities in these countries.

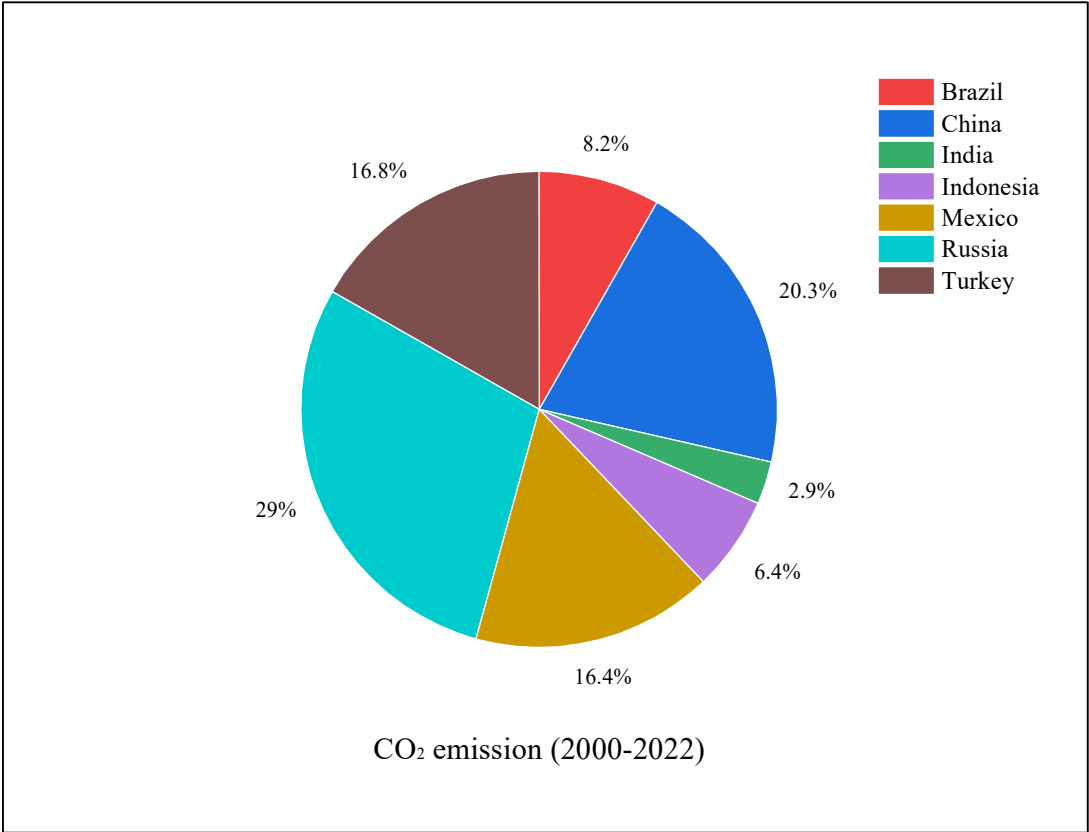


Figure 1. CO₂ emissions in the E-7 economies. Source: World Bank [9].

As a crucial source of pollution and global warming, CO₂ must be addressed because identifying its causes can improve environmental protection [10]. Therefore, this study extends several methods for environmental protection and sustainable development. First, it analyzes the effects of urbanization and human capital on CO₂ emissions in emerging economies. This group of countries is considered an essential contributor to sustainable urbanization. Second, FDI highlights its influence on reducing CO₂ emissions by considering the effects of economic development and energy usage. This study explored the role of FDI. Because the increase in FDI contributes through infrastructure to fulfill basic needs, such as water and energy, this variable is vital for environmental preservation and sustainability [11]. Third, this study stands out for its utilization of advanced econometric models, specifically Cup-FM and Cup-BC. These models offer advanced techniques to address endogeneity, unobserved heterogeneity, and bias, guaranteeing precise and reliable estimation. These models enhance the reliability and accuracy of the outcomes. This study has several important implications for policymakers and stakeholders in promoting sustainable development. These important implications should be considered. These findings can assist in developing specific policies and initiatives to promote sustainable development. The remainder of this paper is organized as follows: Section 2 presents the empirical literature. Section 3 delves into the methodology, and Section 4 presents the empirical results and a thorough analysis. Section 5 presents the conclusions, policy recommendations, and potential avenues for future research.

2. Literature Review

The literature review explores the multifaceted impacts of human capital, energy usage, urbanization, and economic growth on CO₂ emissions in emerging economies while delving into the critical role of FDI in this dynamic. Poumanyvong and Kaneko [12] proposed three theories to explain the connection between urbanization and CO₂: compact cities, ecological modernization, and urban

environmental transition theories. Ecological modernization theorists postulate that low-income people care only about their economic well-being; after reaching a certain level, they become concerned about the environment [13,14]. Based on urban environmental transition theory, urbanization is believed to involve infrastructure improvement. Initially, individuals grappled with environmental concerns and became intrigued by the repercussions of waste [15]. Compact city theorists believe that growing cities benefit citizens and the environment because they are equipped with better facilities and use resources more efficiently [16]. Empirical research has investigated the correlation between urbanization and CO₂ emissions. A positive, negative, nonlinear, or insignificant relationship may exist between variables depending on their viewpoint. The research conducted by Salahuddin et al. [17] employed second-generation panel regression techniques that incorporated heterogeneity slope coefficients and cross-sectional dependence to assess the impact of urbanization on CO₂ emissions in 44 sub-Saharan African countries between 1984 and 2016. Their results suggest that urbanization contributes to CO₂ emissions. This result was further corroborated by other studies [18–20]. Figure 2 depicts the urbanization rates across E-7 nations, measured as the percentage of the population residing in urban areas. This metric is a critical indicator of economic modernization and demographic transformation, reflecting shifts in the labor market, infrastructure development, and spatial reorganization.

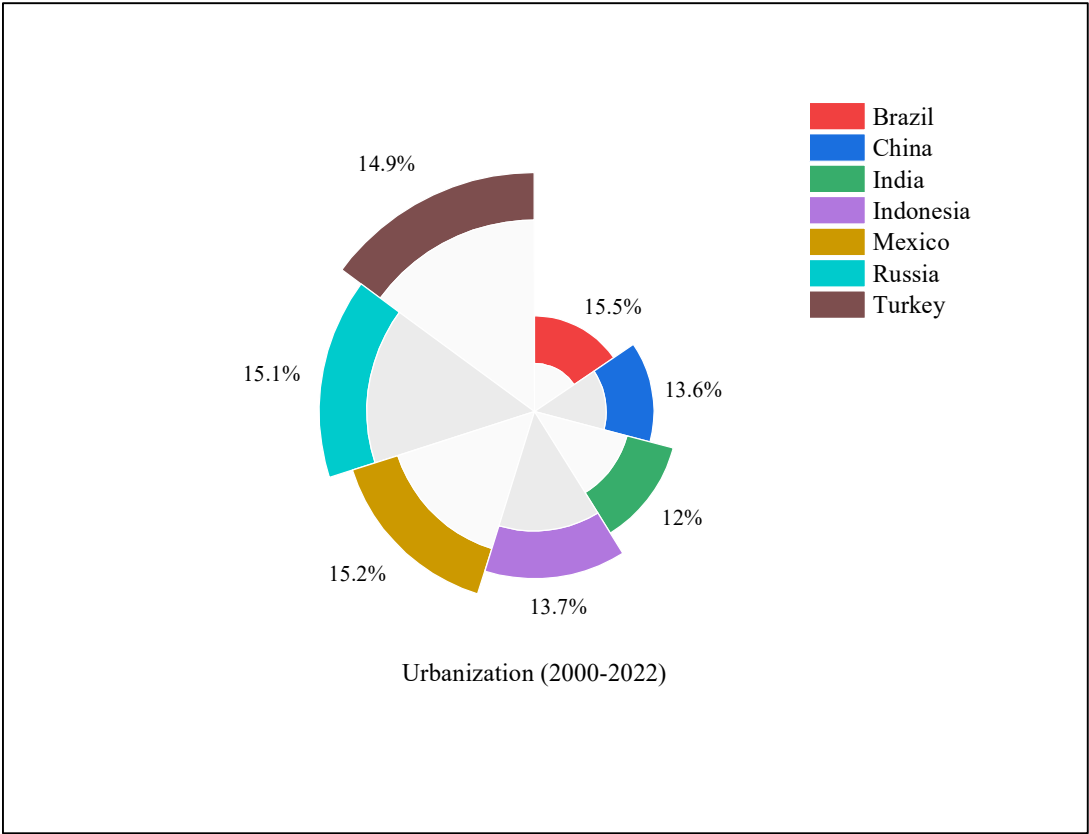


Figure 2. Urbanization in E-7 Economies. Source: World Bank [9].

According to Effiong [21], urbanization harms CO₂ emissions. These scholars employed a generalized least squares (GLS) methodology to analyze the relationship between urbanization and CO₂ emissions across OECD economies from 1996 to 2018. Their findings revealed that government effectiveness significantly moderates the positive correlation between urbanization and CO₂ levels, suggesting that enhanced institutional efficiency enables OECD countries to mitigate the environmental impact of urban expansion. Furthermore, this study explores the nonlinear dynamics between urbanization and CO₂ emissions using the environmental Kuznets curve (EKC) theoretical

lens, offering nuanced insights into decoupling economic growth from ecological degradation. The EKC is a method for evaluating environmental performance. The EKC was derived from the inverted U-shaped graph developed by Kuznets in 1955 [22]. The EKC represents the connection between CO₂ and its influencing factors. From Kuznets' perspective, the environment suffers from economic growth, but this relationship eventually improves as economic growth continues. According to the EKC hypothesis, income and environmental quality have an inverted U-shaped relationship. According to the EKC, environmental degradation is caused by economic development. However, once a specific threshold of economic growth is reached, ecological quality improves as the per capita income increases. The shape of this curve indicates that environmental pollution initially increases with rising income but then begins to decline. The first introduced an inverted U-shaped relationship, and the term 'Environmental Kuznets Curve' was formulated by Grossman and Krueger [23]. Xiaoman et al. [24] posited that rising per capita income triggers heightened demand for environmental quality, incentivizing the adoption of cleaner, sustainable technologies to mitigate ecological degradation.

Several empirical studies support the GDP growth and environmental quality EKC hypotheses [25–27]. This inverted U-shaped relationship was confirmed by Al-Mulali & Ozturk, Majeed et al. [28,29] confirmed this inverted-U-shaped relationship. Using data from 1995 to 2019, Saqib et al. [30] explored the possibility of extending the traditional Kuznets curve to growing, industrialized economies. According to this study, income expansion precedes environmental sustainability in these economies. Furthermore, technological modernization contributes to pollution mitigation. Using 54 African nations as case studies, Hussain et al. [31] examined the heterogeneous effects of urbanization and non-renewable energy usage on the environment. Research indicates that urbanization and the utilization of non-renewable energy sources in Africa have detrimental environmental effects. The relationship between economic development and CO₂ emissions follows an inverted U-shaped curve, consistent with the EKC theory. By examining the Middle Eastern and North African economies, Kostakis et al. [32] proved the EKC hypothesis and suggested that energy use adversely affects environmental quality. According to Kaya Kanlı and Küçükefe [33], although the EKC theory addresses the connection between the environment and income, it cannot be applied globally. Thus, regardless of income level, all countries must work to limit CO₂ emissions in different ways. Researchers have investigated the relationship between human capital and pollution from this perspective. Iorember et al. [34] conducted a study on the impact of renewable energy usage, human capital, and trade on the ecological footprint in South Africa; multiple structural breaks cointegration tests were employed and found that human capital is key to enhancing a nation's environmental sustainability. Consequently, they can regulate and reduce CO₂ emissions [35–37]. Figure 3 shows human capital development in the E-7 economies, measuring education levels and returns on education. It is crucial to understand how these nations invest in their populations to drive economic growth and competitiveness.

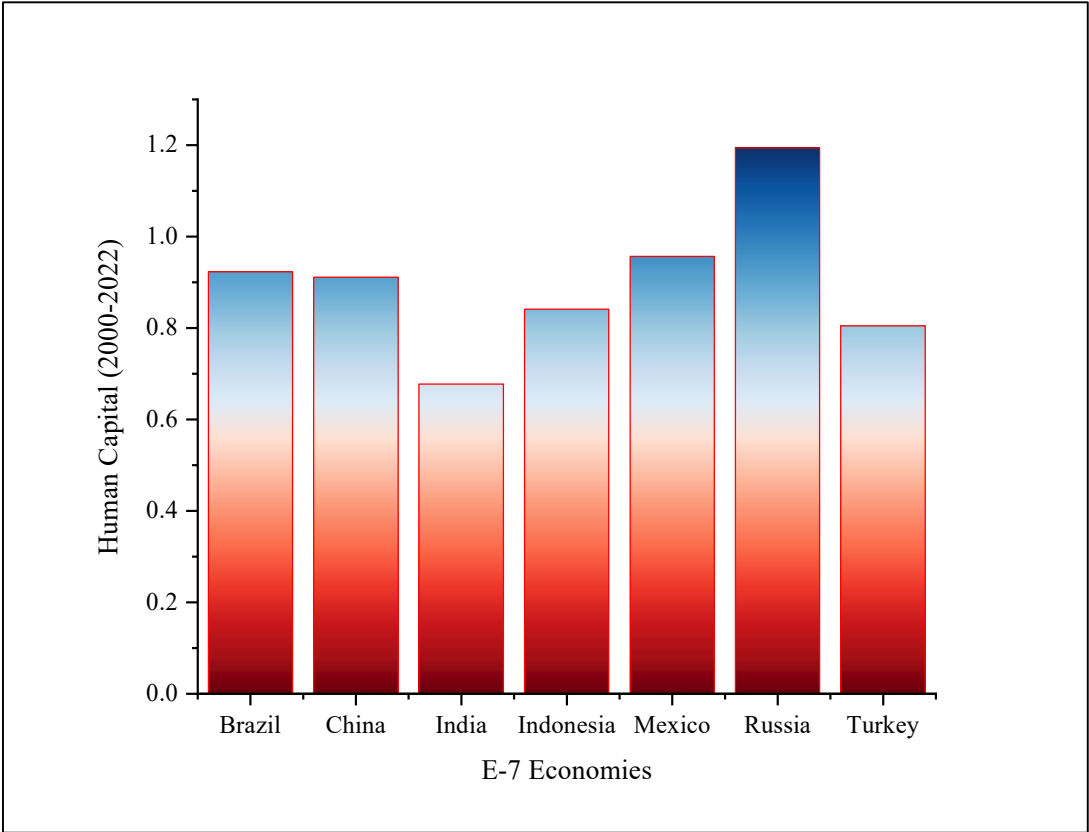


Figure 3. Human Capital in the E-7 Economies. Source: Penn World Table [38].

Conversely, Gu et al. [39] employed a nonlinear panel autoregressive distributed lag method to assess the impact of human capital on CO₂ emissions in BRICS economies and found that a reduction in education increases CO₂ emissions. They believe that human capital accretion is vital for reducing environmental degradation by lowering CO₂ emissions [40]. However, according to Hill and Magnani [41], more education leads to greater consumption of non-renewable energy sources. Although analyses of urbanization, CO₂, human capital, and CO₂ nexus have been conducted, a gap remains in emerging countries. As highlighted above, FDI has been overlooked in previous studies as a conditional factor that moderates the connection between urbanization, CO₂, human capital, and CO₂ in emerging countries. Hence, this analysis attempts to fill this gap by first considering the role of FDI in the nexus of urbanization and human capital in emerging countries. Our objective is to contribute to the analysis of sustainable urbanization and development by considering new policies that mitigate pollution. Second, the importance of FDI in implementing sustainable development shows that it can be a key instrument in the fight against pollution, particularly in emerging countries. According to FDI theory, various countries strive to attract FDI because of its potential economic benefits. International production networks, knowledge transfer, and productivity increase through FDI [42]. Figure 4 compares the FDI levels in the E-7 economies. It shows FDI as a percentage of GDP inflows, illustrating how these economies have attracted foreign investments over the past two decades.

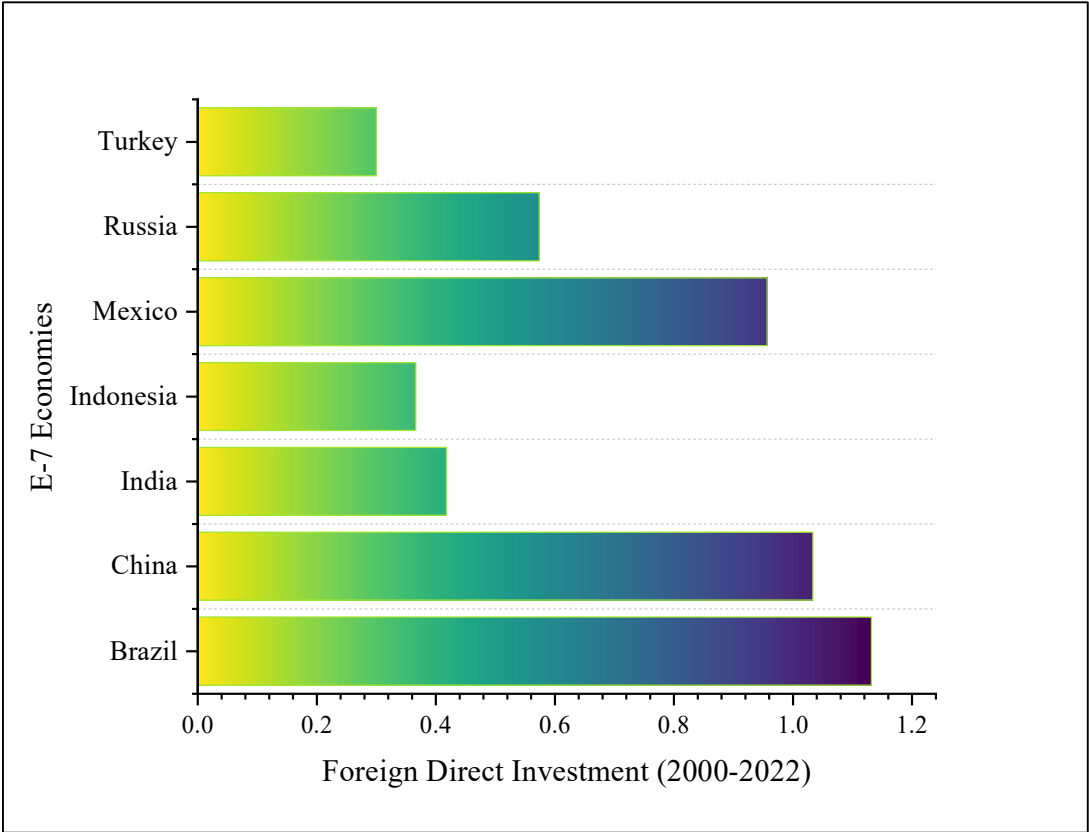


Figure 4. FDI in E-7 Economies. Source: World Bank [9].

Hence, FDI contributes significantly to economic growth compared to national investment [43]. Wang [44] examined FDI’s contribution of FDI to reducing CO₂ emissions and found that FDI combined with human capital has a positive environmental impact in China. Foreign firms must introduce technologies tailored to the educational level of host countries because FDI inflows in countries with reasonable academic levels will reduce CO₂. However, Ahmad et al. [45] considered that the innovative and cleaner technologies provided by FDI reduce CO₂ emissions in host economies. The existing literature provides an understanding of the individual effects of human capital, energy usage, urbanization, and economic growth on CO₂ emissions in emerging nations. However, there is a gap in the studies that comprehensively analyze these factors in conjunction with the moderating role of FDI. Furthermore, the dynamics of these relationships may vary across different regions and developmental stages, suggesting a need for more nuanced studies. This study investigated the mitigation of sustainable development and climate change in emerging economies.

3. Model Description, Data, and Methodology

3.1. Model Description

This study evaluated the impact of human capital, urbanization, FDI, energy use, and gross domestic product on CO₂ emissions in E-7 economies from 2000 to 2022. The variables were log-transformed as logarithmic transformations utilized in regression models to stabilize the variance, linearize relationships, and provide better interpretability, particularly for multiplicative impacts. Thus, the analysis was more comprehensive [46]. The generalized empirical relations are as follows:

$$CO_2 = f (HC, URB, FDI, EC, GDP, GDP^2) \tag{1}$$

Equation (1) represents the regression as follows:

$$CO_2 = \beta_0 + \beta_1 HC_{i,t} + \beta_2 URB_{i,t} + \beta_3 FDI_{i,t} + \beta_4 EC_{i,t} + \beta_5 GDP_{i,t} + \beta_6 GDP^2_{i,t} + \mu_{i,t} \quad (2)$$

Where β_0 is the constant term, and $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6$, the coefficients of the variables HC, URB, FDI, EC, GDP , and GDP^2 , respectively. The variable $\mu_{i,t}$ signifies the error term. The subscripts i ($i=1, 2, \dots, n$), and t ($t=1, 2, \dots, T$) denote economies, and time, respectively. The influence of FDI on urbanization and human capital is shown in Equations 3 and 4.

$$CO_2 = \beta_0 + \beta_1 HC_{i,t} + \beta_2 URB_{i,t} + \beta_3 FDI_{i,t} + \beta_4 FDI * URB_{i,t} + \beta_5 EC_{i,t} + \beta_6 GDP_{i,t} + \beta_7 GDP^2_{i,t} + \mu_{i,t} \quad (3)$$

The moderating effect between FDI and urbanization $\beta_4 FDI * URB_{i,t}$ is described by using interaction terms. In this analysis, we verify the EKC hypothesis and expect the coefficient of the GDP square to be significant and negative. This study confirms the EKC hypothesis by anticipating that the GDP square coefficient will be significant and negative.

$$CO_2 = \beta_0 + \beta_1 HC_{i,t} + \beta_2 URB_{i,t} + \beta_3 FDI_{i,t} + \beta_4 FDI * HC_{i,t} + \beta_5 EC_{i,t} + \beta_6 GDP_{i,t} + \beta_7 GDP^2_{i,t} + \mu_{i,t} \quad (4)$$

The moderating effect between foreign direct investment and human capital $\beta_4 FDI * HC_{i,t}$ is explained by employing interaction terms. This study confirms the EKC hypothesis by anticipating a significant negative coefficient for the GDP square.

3.2. Data

This study examines the impact of human capital, foreign direct investment (FDI), urbanization, energy consumption, and economic growth on CO₂ emissions in the E-7 emerging economies (Brazil, China, India, Indonesia, Mexico, Russia, and Turkey) using data from 2000 to 2022. CO₂ was computed in metric tons per capita, indicating the pollution level per person. Data were gathered from the World Development Indicators (WDI) [9]. The human capital index (HC) uses years of schooling and educational returns to measure human capital. The data source is the Penn World Table (PWT) [38]. Economic growth (GDP) was computed as GDP per capita and the growth of domestic products per inhabitant. The data were derived from the WDI. Energy consumption (EC) was quantified as kilograms of oil equivalent per capita consumed by each inhabitant. Data were obtained from WDI. Urbanization (URB) is the ratio of people living in cities or towns to the total population. Data were acquired from the WDI. Foreign direct investment (FDI) inflow was quantified as a percentage of the gross domestic product (GDP). Data were obtained from WDI.

3.3. Methodology

3.3.1. Cross-Sectional Dependency Test

The primary objective of the slope heterogeneity test was to assess whether heterogeneity existed among the gradients of the different variables in the dataset. Conversely, cross-sectional dependence (CD) allows for the identification of interconnectedness between cross-sectional observations [47]. The test statistics are derived using the following equation:

$$y_{it} = \alpha_i + \beta_i x_{it} + u_{it} \quad i = 1 \dots N, t = 1 \dots T \quad (5)$$

$$LM = T \sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\rho}_{IJ} \rightarrow \vec{d} X^2_{N(N+1)/2} \quad (6)$$

$$CD_{lm} = \sqrt{\frac{N}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^N (T \hat{\rho}_{ij} - 1) \quad (7)$$

$$CD_{lm} = \sqrt{\frac{2T}{N(N-1)}} \sum_{l=1}^{N-1} \sum_{j=i+1}^N (\hat{\rho}_{ij}) \quad (8)$$

$$CD_{lm} = \sqrt{\frac{2}{N(N-1)}} \sum_{l=1}^{N-1} \sum_{j=i+1}^N \left(\frac{(T-K)\hat{\rho}_{ij}^2 - u_{Tij}}{v_{Tij}^2} \right) \vec{d}(N, 0) \quad (9)$$

3.3.2. Panel Unit Root Tests

Panel data analysis frequently utilizes second-generation panel unit root testing, CIPS, and CADF. A characteristic of second-generation panel unit root tests is their ability to reject the null hypothesis of the CD. Therefore, these methods consider the relationships among cross-sections to overcome this issue [48]. The CIPS assessment is determined by the IPS approach, which presents the regression equation of the CADF in Equations (10) and (11).

$$\text{For CIPS: } \Delta Y_{it} = \alpha_i + \beta_i i + \gamma_i Y_{it} - 1 + \delta_i Z_{it} + \varepsilon_{it} \quad (10)$$

$$\text{For CADF: } \Delta Y_{it} = \alpha_i + \beta_{it} i + \gamma_i Y_{it} - 1 + \sum_j = 1 p \delta_{ij} \Delta Y_{it} - j + \varepsilon_{it} \quad (11)$$

3.3.3. Panel Cointegration Test

Panel cointegration tests assess whether a stable and long-lasting connection exists between time-series data. Panel data analysts commonly use error correction-based tests developed by Kao [49] and Pedroni [50]. The error correction-based method is a pioneering cointegration technique for analyzing panel data [51]. The Kao and Pedroni cointegration tests operate under the null hypothesis of no cointegration among the variables, with the alternative hypothesis asserting that cointegration exists across all the panels. In this study, we employ the Westerlund cointegration test, which extends this framework by evaluating the alternative hypothesis that cointegration is present in at least one panel, thereby offering a more nuanced assessment of cross-sectional dependencies and heterogeneous panel structures [51].

3.3.4. CUP-FM and CUP-BC Approaches

The selection of an appropriate estimation method is critical, as it directly affects the accuracy, reliability, and interpretability of the empirical findings. Among the widely used estimators in panel data analysis are the “Continuously Updated Fully Modified” (Cup-FM) and “Continuously Updated Bias-Corrected” (Cup-BC) approaches. These methods offer significant advantages, particularly in addressing endogeneity concerns and reducing estimation bias, thereby enhancing the robustness of dynamic panel data models. The Cup-FM estimator represents a sophisticated advancement in estimating dynamic panel data and provides improved efficiency and consistency in the presence of cross-sectional dependence and heterogeneous dynamics. Bai and Kao [52] draw advantages from both fixed effects and instrumental variable methods. An effective solution to the endogeneity issue caused by unobserved heterogeneity constraints and simultaneity bias is achieved through structural means. A distinctive feature of the Cup-FM method is its ability to continuously update estimates with new information, enabling real-time analysis and supervision of dynamic relationships. The Cup-FM estimator has proven effective in integrating fixed effects to control for unobserved heterogeneity that is time-invariant over individuals or entities in panel data. The endogeneity issue has been effectively mitigated by applying instrumental variable (IV) techniques, which facilitate the derivation of unbiased and statistically consistent estimators. These estimators are particularly advantageous in dynamic panel models, especially when lagged dependent variables are incorporated as regressors to address autocorrelation and simultaneity bias. The methodological framework for the (Cup-FM) and (Cup-BC) estimators is formally represented by the following equation:

$$\widehat{\beta_{cup}} = \left[\sum_{i=1}^N \left(\sum_{t=1}^T \hat{y}_{it} + (\hat{\beta}_{cup}) \times (x_{it} - \bar{x}_t) - T(\gamma_i' \hat{\beta}_{cup}) \Delta f_{et} + (\hat{\beta}_{cup}) \Delta \mu_{el} + (\hat{\beta}_{cup}) \right) \right] \times \left[\sum_{i=1}^N \sum_{t=1}^T (x_{it} - \bar{x}_t)(x_{it} - \bar{x}_t) \right]^{-1} \tag{12}$$

This study employs a novel method called dynamic seemingly unrelated cointegrating regression (DSUR), introduced by Mark et al. [53]. The SUR model expands on the conventional SUR model by incorporating dynamics. It is utilized when there is a group of equations with internal variables that change over time, and the parameters of these equations are determined, considering any potential correlations and fluctuations between them. The SUR model for each Equation j is displayed for cross-sectional unit i and period t as follows:

$$y_{ijt} = \alpha_j + \sum_{k=1}^p \beta_{jk} y_{ijt-k} + \sum_{m=1}^p \beta_{jm} y_{ijt-m} + \varepsilon_{ijt} \tag{13}$$

4. Results and Discussion

The outcomes of the CD and slope heterogeneity analyses are presented in Table 1. The findings suggest that the research units have diverse properties and exhibit cross-sectional dependence and a shared dynamic. The results in Table 1 are statistically significant at the 1% level, indicating differences between units.

Table 1. Outcomes of CD and slope heterogeneity test.

	Breusch-Pagan LM Test	Pesaran Scaled LM Test	Adjusted LM Test	Pesaran CD Test	Δ	Adj. Δ
CO ₂	315.302 ^a	17.833 ^a	127.934 ^a	12.582 ^a	29.87 ^a	103.109 ^a
HC	235.733 ^a	18.356 ^a	224.55 ^a	42.186 ^a	70.144 ^a	138.655 ^a
URB	179.885 ^a	37.878 ^a	138.041 ^a	54.954 ^a	57.97 ^a	126.852 ^a
FDI	244.548 ^a	27.477 ^a	109.788 ^a	21.012 ^a	49.767 ^a	122.94 ^a
EC	406.663 ^a	26.557 ^a	123.517 ^a	53.829 ^a	59.177 ^a	55.843 ^a
GDP	169.386 ^a	31.385 ^a	213.025 ^a	30.683 ^a	33.853 ^a	87.594 ^a

LM signifies Lagrange Multiplier, Δ shows Delta and Adj. Δ exhibits Adjusted Delta. Note: c, b, and a are significant at the 10, 5, and 1% levels.

As shown in Table 2, the test statistics for CADF and CIPS are statistically significant at the 1% level after making the first difference in the constant and trend. It suggests that these results support the notion that all variables are integrated in the first order, specifically, $I(1)$. Table 3 presents the results of the panel cointegration tests. Kao and Pedroni [49,50] and Westerlund [51] conducted a panel cointegration test to determine whether the dependent and independent variables cointegrated in the long run. The analysis revealed a long-term relationship in the empirical equation, as assessed through panel cointegration test results.

Table 2. Panel unit root test results.

Variables	CADF statistic		CIPS statistic		CADF statistic		CIPS statistic	
	Constant		Constant		Constant and trend		Constant and trend	
	Level	1 st difference	Level	1 st difference	Level	1 st differences	Level	1 st difference
CO ₂	-2.005	-4.048 ^a	-1.821	-6.149 ^a	-2.634	-7.823 ^a	-1.14	-3.253 ^a
HC	-1.527	-4.299 ^a	-1.209	-6.532 ^a	-1.808	-4.677 ^a	-2.531	-2.973 ^a
URB	-2.923	-2.868 ^a	-2.932	-3.473 ^a	-2.052	-3.786 ^a	-2.463	-4.604 ^a
FDI	-1.886	-3.007 ^a	-1.851	-2.094 ^a	-1.851	-3.191 ^a	-2.782	-7.095 ^a
EC	-2.827	-7.876 ^a	-2.069	-4.573 ^a	-1.413	-4.898 ^a	-1.918	-7.423 ^a
GDP	-1.471	-6.487 ^a	-2.304	-5.759 ^a	-2.956	-3.241 ^a	-2.635	-4.775 ^a

c, b, and a denote significance at the 1%, 5%, and 10% levels.

Table 3. Panel Cointegration Analysis Outcome.

Pedroni [50]					
Within-dimension	Statistics	Prob.	Between-dimension	Statistic	Prob.
Panel v-Statistic	1.788 ^b	0.038	Group rho-Statistic	1.313	0.904
Panel rho-Statistic	0.648	0.742	Group PP-Statistic	-2.228 ^b	0.014
Panel PP-Statistic	-2.328 ^b	0.010	Group ADF-Statistic	-2.315 ^b	0.010
Panel ADF-Statistic	-2.418 ^a	0.008			
Kao [49]	t-Statistic	Prob.	Westerlund [51]	Z-Value	P-Value
ADF	-2.175 ^b	0.014	G _t	-4.069 ^a	0.000
			G _a	1.658	0.951
			P _t	-3.145 ^a	0.000
			P _a	-0.862	0.194

The significance levels are c at 1%, b at 5%, and a at 10%.

Table 4. Results from CUP-FM, CUP-BC, and DSUR.

Variables	CUP-FM			CUP-BC			DSUR		
	Coeff.	Std. error	t-stat	Coeff.	Std. error	t-stat	Coeff.	Std. error	t-stat
HC	0.105 ^a	0.036	3.052	0.149 ^a	0.039	3.858	0.121 ^a	0.018	7.989
URB	0.191 ^b	0.038	2.414	0.120 ^a	0.023	5.956	0.170 ^a	0.027	6.543
FDI	-0.092 ^a	0.023	-3.693	-0.080 ^b	0.037	-2.131	-0.131 ^a	0.016	-7.707
EC	0.158 ^a	0.022	7.254	0.151 ^a	0.022	7.189	0.102 ^a	0.018	5.655
GDP	0.168 ^a	0.026	6.151	0.151 ^a	0.033	5.006	0.133 ^a	0.022	6.377
GDP ²	-0.077 ^b	0.035	-2.148	-0.101 ^a	0.020	-4.871	-0.131 ^a	0.026	-4.672
C	11.238 ^a	0.242	46.797	10.843 ^a	0.241	45.151	16.942 ^a	0.242	70.548
R ²	0.889			0.898			0.906		
Adj R ²	0.951			0.937			0.945		

Note: c, b, and a are significant at the 10%, 5%, and 1% levels.

This study utilized novel panel data evaluation techniques, such as Cup-FM, Cup-BC, and DSUR. Tables 4, 5, and 6 present the estimation results, respectively. Table 4 shows that a 1% increase in human capital leads to a 0.105% increase in CO₂, while a 1% increase in the urban population leads to a 0.191% increase in CO₂. In addition, FDI has a negative effect on CO₂ emissions. Thus, a 1% increase in FDI decreases CO₂ emissions by 0.092%. Hence, an increase in FDI decreases CO₂ emissions in emerging economies. Furthermore, a 1% increase in energy usage resulted in a 0.158% increase in CO₂. GDP positively affected CO₂, indicating that a 1% increase contributed to CO₂ by 0.168%. GDP² negatively affects CO₂ emissions, confirming the environmental Kuznets curve. A 1% increase in GDP² decreased CO₂ emissions by 0.077%. The Cup-FM outcomes were aligned with the Cup-BC and DSUR findings. The positive influence of human capital on CO₂ in E-7 countries is linked to multiple factors, such as improvements in human capital, education, and skills that drive economic growth and industrialization. It often leads to increased energy consumption, much of which is based on fossil fuels, thereby increasing CO₂ emissions. As human capital leads to better job opportunities and income, there is an increase in living standards, which increases the need for energy-intensive goods and services, further contributing to CO₂ emissions [54]. Figure 5 presents the findings in Table 4.

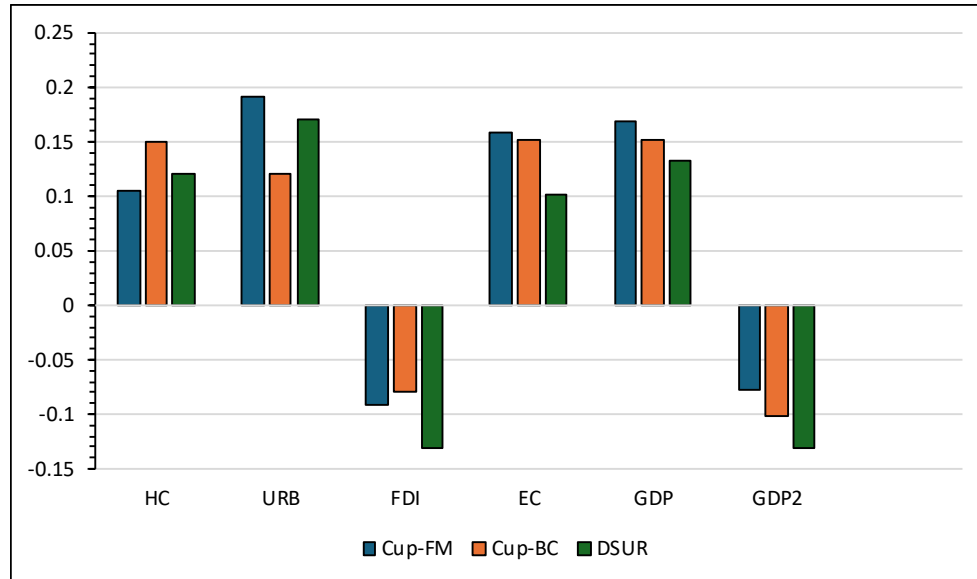


Figure 5. Findings from CUP-FM, CUP-BC, and DSUR. Source: Author's calculation.

Urbanization increases CO₂ emissions in E-7 countries because urban regions have larger energy demands owing to the population, extensive industrial and commercial activities, and the need for transportation, heating, and cooling, which often rely on fossil fuels. Urbanization leads to more vehicles on the road as people commute to work and for personal needs, increasing fuel usage and CO₂. The proliferation of urban regions involves significant construction activity, which consumes energy and often uses materials such as cement and steel, the production of which is carbon-intensive [18]. FDI negatively impacts CO₂ emissions in E-7 economies, primarily through technology transfer and efficiency improvements. FDI facilitates the transfer of advanced and efficient technologies from developed to developing countries, promotes sustainable development, and reduces environmental pollution in the E-7 countries. The implementation of greener production methods and renewable energy sources has reduced the reliance on fossil fuels and lowered CO₂ emissions. FDI plays a pivotal role in driving economic modernization by facilitating the transition towards service-oriented and high-technology industries, which are generally characterized by lower carbon intensity than conventional manufacturing and industrial sectors [55].

The dependence on fossil fuels for energy in E-7 countries contributes to the positive impact of EC on CO₂ emissions. As these emerging economies grow, their demand for energy, fuel, industrialization, transportation, and urban development increases. This energy demand is primarily met through coal, oil, and natural gas, which leads to higher CO₂ emissions because these energy sources release carbon dioxide when burned. Moreover, E-7 countries in various developmental stages have not fully transitioned to cleaner renewable energy sources. Therefore, as EC increases, CO₂ also increases because of the carbon-intensive nature of the primary energy sources.

The reliance on fossil fuels for energy in the E-7 nations amplifies the positive relationship between EC and CO₂ emissions. As these emerging economies expand, their escalating energy demands, driven by industrialization, transportation, and urban development, are predominantly met through coal, oil, and natural gas. The combustion of these carbon-intensive energy sources releases significant quantities of CO₂, exacerbating emissions. Furthermore, the E-7 countries, at varying stages of development, have yet to achieve a comprehensive transition to cleaner, renewable energy alternatives. Consequently, rising EC levels correlate with increased CO₂ emissions, reflecting the persistent carbon dependency of energy systems [56]. GDP's positive effect of GDP on CO₂ emissions in E-7 economies is linked to economic growth and its associated increases in industrial, transportation, and energy activities. As GDP grows, it typically signifies higher industrial output, more vehicles on the roads, and greater energy consumption across various sectors, including

residential and commercial sectors. In the early phases of development, they often relied on carbon-intensive energy sources derived from fossil fuels, such as coal, natural gas, and oil. The combustion of these fuels for energy and transportation leads to increased CO₂ emissions [57]. Figure 6 illustrates how human capital, energy use, GDP, and urbanization are linked to CO₂ emissions, which is the central focus of this study. Adorned with a plus sign, it suggests that these factors positively affect CO₂, except for FDI, highlighting the multifaceted influences on environmental sustainability in E-7 economies.

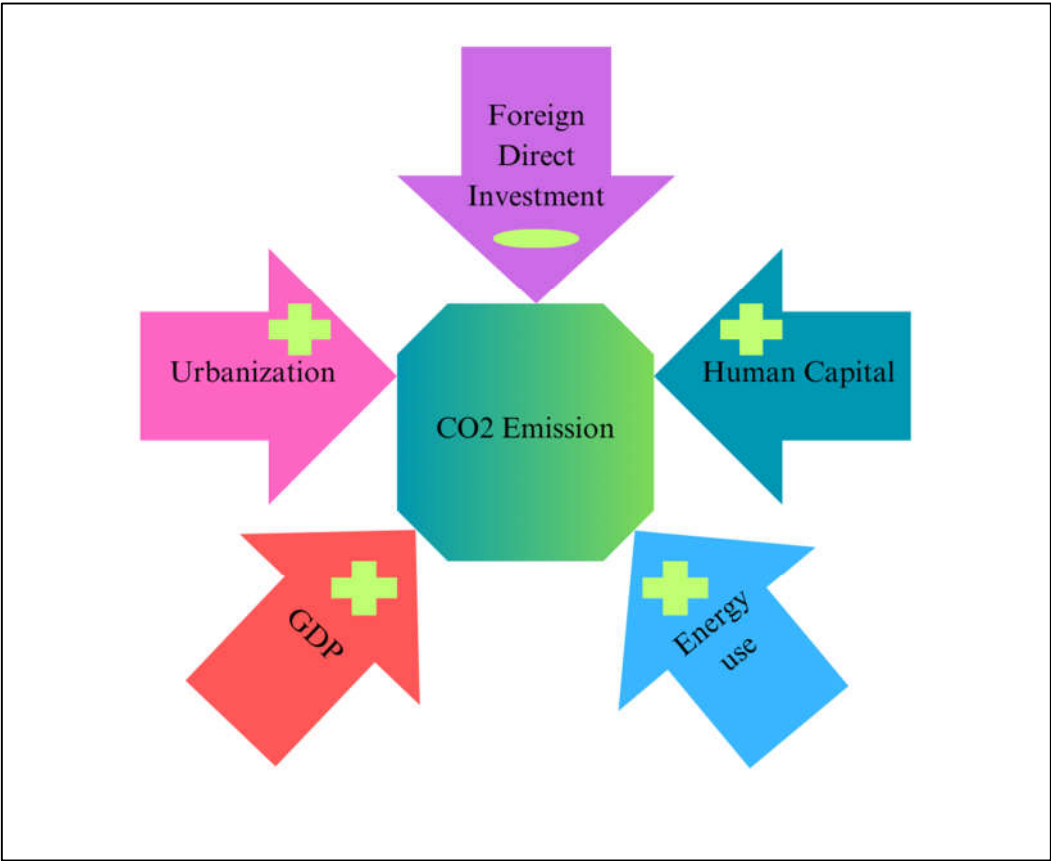


Figure 6. Findings for Cup-FM, Cup-BC, and DSUR. Source: Author’s calculation.

The squared GDP term and the EKC hypothesis negatively impacted CO₂ emissions in the E-7 countries. The EKC hypothesis demonstrates an inverse relationship between CO₂ and economic growth (measured by GDP) that follows an inverted U-shape. As GDP increases, CO₂ emissions also increase because economic growth is typically driven by industrialization and increased energy consumption, often from the use of fossil fuels [58]. However, beyond a certain point of economic development, further increases in GDP lead to decreased CO₂, where the “GDP squared” term comes into play with a negative coefficient. As countries expand and mature, they prefer to adopt advanced, efficient, and cleaner technologies that reduce CO₂ emissions per unit of economic output. Economic growth often raises public awareness and demand for environmental protection, leading to better regulations, pollution control measures, and investments in sustainable practices and technologies [59].

Table 5. CUP-FM, CUP-BC, and DSUR results; mediating effect of FDI & urbanization.

Variables	CUP-FM			CUP-BC			DSUR		
	Coeff.	Std. error	t-stat	Coeff.	Std. error	t-stat	Coeff.	Std. error	t-stat
HC	0.080 ^a	0.016	3.665	0.078 ^a	0.004	27.808	0.172 ^a	0.005	27.125
URB	0.118 ^a	0.018	11.128	0.068 ^a	0.008	12.505	0.028 ^a	0.012	2.624
FDI	-0.025 ^a	0.007	-3.493	-0.043 ^a	0.005	-7.927	-0.092 ^a	0.009	-9.408
FDI*URB	-0.032 ^a	0.013	-2.661	-0.054 ^a	0.008	-24.456	-0.012 ^a	0.009	-22.654
EC	0.088 ^a	0.009	9.436	0.100 ^a	0.003	25.743	0.173 ^a	0.011	17.362
GDP	0.068 ^a	0.008	22.654	0.078 ^a	0.009	10.202	0.082 ^a	0.007	10.505
GDP ²	-0.055 ^a	0.007	-13.133	-0.022 ^a	0.005	-3.656	-0.112 ^a	0.003	-23.664
C	10.365 ^a	0.360	42.568	11.324 ^a	0.356	42.453	18.467 ^a	0.356	77.678
R ²	0.901			0.910			0.920		
Adj R ²	0.961			0.957			0.967		

Note: c, b, and a are significant at the 10%, 5%, and 1%, respectively.

Moreover, the findings in Table 5 are significant, with the results in Table 4 for the Cup-FM, Cup-BC, and DSUR methods. The interaction term FDI*URB has a negative effect on CO₂ in E-7 economies, indicating that FDI moderates the relationship between urbanization and CO₂. FDI introduces cutting-edge technologies and managerial techniques to the host nation. When these investments are directed towards urban areas, they introduce more energy-efficient infrastructure, green technologies, and sustainable urban planning practices. It mitigates the typical increase in CO₂ emissions associated with urbanization [60]. FDI also includes investments in renewable energy projects and environmentally friendly technologies in urban areas. These investments help offset the carbon footprint of growing cities by reducing their dependence on fossil fuels [61]. FDI stimulates less carbon-intensive sectors, such as services and high-tech industries, within urban regions. This diversification shifts economic activities in cities away from heavy industries, which are major contributors to CO₂ emissions. Consequently, the negative effect of the FDI*URB interaction on CO₂ indicates the critical importance of foreign investments in enabling sustainable urban development in E-7 countries, leading to a more environmentally friendly urbanization process [60]. Figure 7 presents the findings in Table 5.

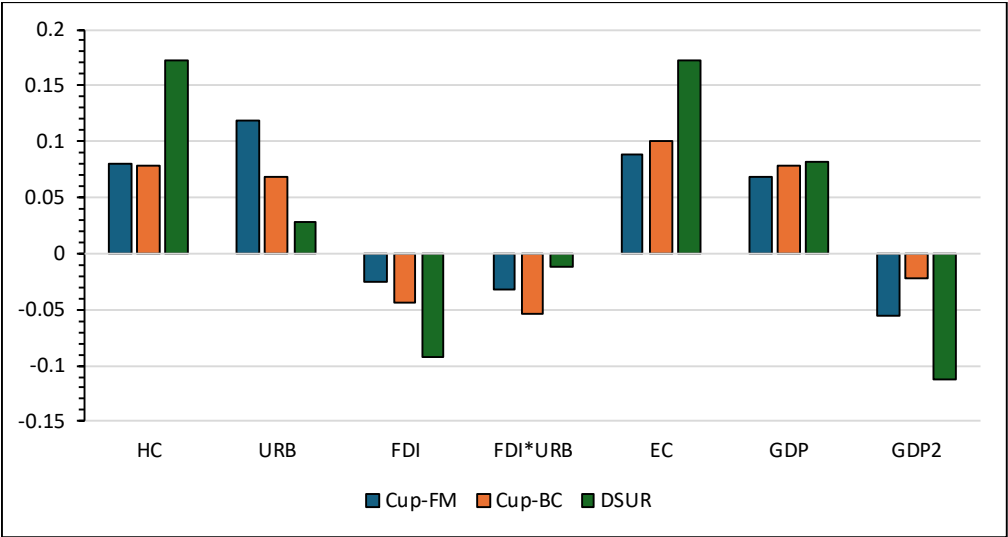


Figure 7. CUP-FM, CUP-BC, and DSUR results: Mediating effects of FDI and urbanization. Source: Author’s calculation.

Table 6. CUP-FM, CUP-BC, and DSUR results; mediating effect of FDI & Human capital.

Variables	CUP-FM			CUP-BC			DSUR		
	Coeff.	Std. error	t-stat	Coeff.	Std. error	t-stat	Coeff.	Std. error	t-stat
HC	0.103 ^c	0.033	3.050	0.147 ^b	0.038	3.851	0.119 ^a	0.015	7.988
URB	0.091 ^c	0.037	2.412	0.119 ^a	0.022	5.955	0.168 ^a	0.025	6.540
FDI	-0.094 ^b	0.025	-3.696	-0.081 ^b	0.038	-2.130	-0.132 ^a	0.017	-7.708
FDI*HC	-0.080 ^a	0.028	-4.987	-0.103 ^a	0.044	-6.346	-0.115 ^a	0.033	-5.876
EC	0.157 ^a	0.021	7.253	0.150 ^a	0.021	7.188	0.109 ^a	0.019	5.654
GDP	0.169 ^a	0.027	6.152	0.150 ^a	0.033	5.007	0.135 ^a	0.021	6.379
GDP ²	-0.078 ^c	0.036	-2.149	-0.102 ^a	0.021	-4.872	-0.132 ^a	0.028	-4.674
C	11.237 ^a	0.240	46.795	10.842 ^a	0.240	45.150	16.941 ^a	0.240	70.549
R ²	0.888			0.899			0.905		
Adj R ²	0.950			0.938			0.944		

Note: c, b, and a significance level of 10%, 5%, and 1%.

Table 6 demonstrates the negative effect of the FDI*HC interaction term on CO₂ emissions in E-7 countries. It is a synergistic effect of combining foreign investment with a skilled and educated

workforce. FDI often brings innovative technologies and practices to the host country. These technologies can be efficiently implemented and utilized by a well-educated and skilled workforce (high human capital), leading to more sustainable and less carbon-intensive industrial processes. Enhanced human capital maximizes the benefits of FDI by adopting new technologies and methods more effectively, resulting in improved energy efficiency and reduced CO₂ emissions [62]. FDI and human capital foster an environment conducive to innovation. It has resulted in the development and adoption of greener technologies and sustainable practices within industries, thereby reducing CO₂ emissions. Workforces with advanced human capital are likely to be more so. When such a workforce collaborates with foreign firms, they advocate and implement environmentally friendly practices that reduce the carbon footprint of their operations. Thus, the interaction between FDI and human capital mitigates CO₂ emissions by enhancing technological adoption, operational efficiency, and environmental sustainability in the economic activities of the E-7 countries [8]. Figure 8 presents the findings in Table 6.

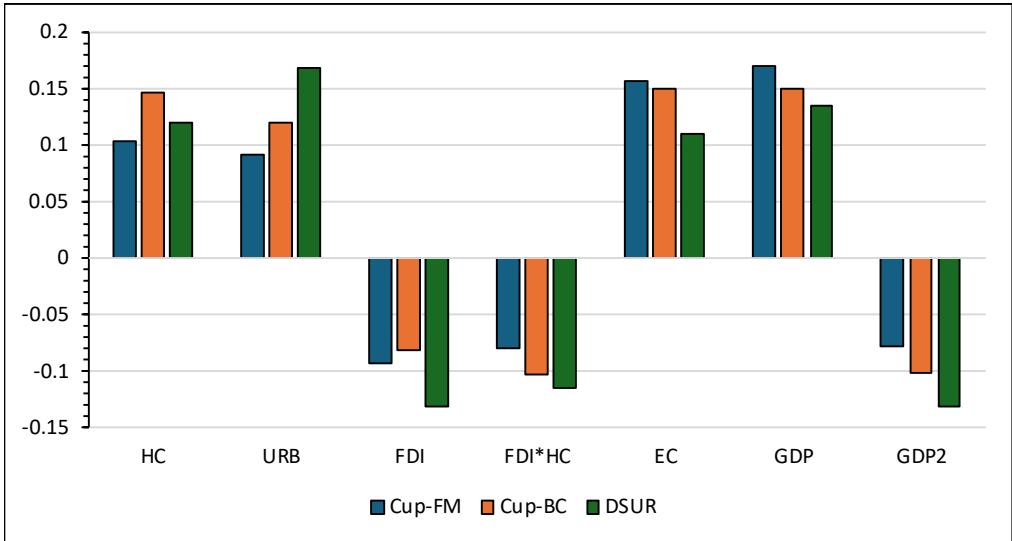


Figure 8. CUP-FM, CUP-BC, and DSUR results: Mediating effect of FDI & Human capital. Source: Author’s calculation.

5. Conclusion and Policy Propositions

This study examines the impact of human capital, urbanization, FDI, energy usage, and GDP on CO₂ emissions, explicitly identifying FDI’s mediating role of FDI with urbanization and human capital in E-7 countries between 2000 and 2022. This study employed Cup-FM, Cup-BC, and DSUR methods. The results show that human capital, urbanization, energy use, and GDP positively impact CO₂ emissions, whereas FDI and GDP² negatively affect CO₂ emissions. FDI mitigates urbanization and the positive impacts of human capital on CO₂ emissions in E-7 economies. The outcomes verify the robustness of the model by having similar coefficient values for all the estimations. Policymakers should encourage FDI, especially green FDI, by establishing policies that facilitate foreign investment in urban areas. An increase in green FDI can improve environmental protection. Encouraging green FDI poses several challenges. Encouraging green FDI means appropriate public policies (regulatory quality and taxation) and good governance (transparency), which can create a favorable political and economic environment for its implementation. For example, the governments of these countries can set climate standards and promote green FDI by requiring investors to comply. Through these policies, emerging countries should relax the circulation of goods and services between member countries, which would facilitate the implementation and use of hybrid cars, electric cars, and

appliances, as well as the development of environmentally friendly roads, railways, and bridge systems.

These countries should implement sustainable urbanization by planning, investing in public transportation, creating walkable neighborhoods, building green infrastructure, and fostering economic diversity. Low-carbon apartments or green environments should be constructed to make them accessible to the general population. Furthermore, cities can promote sustainable transportation, energy efficiency, and waste reduction. FDI can reduce the positive association between human capital and CO₂ emissions by easing awareness-raising programs in emerging countries. Government decision-makers should promote remote work and telecommuting to reduce CO₂ emissions. These countries should build intelligent cities, skyscrapers, and short distances between workplaces and residences. By reducing energy use, these countries can reduce their CO₂ emissions as well. Efficient urbanization planning is a prerequisite for managing the growth of existing cities and facilitating the construction of new cities. The effectiveness of sustainable policies should be based on countries' development levels, as it can be difficult for policymakers to balance economic growth and environmental sustainability. Future research should consider incorporating political and institutional factors, such as political stability, which can contribute to environmental degradation. Political stability influences FDI growth by highlighting a country's safety.

Authors' contributions: Conceptualization, JiaZheng Yu; Data curation, Abdul Majeed; Formal analysis, Abdul Majeed; Methodology, Abdul Majeed; Resources, JiaZheng Yu; Software, Abdul Majeed; Validation, JiaZheng Yu; Visualization, Yiran Liu; Writing – original draft, JiaZheng Yu; Writing – review & editing, Abdul Majeed and Yiran Liu.

Funding: Not Applicable.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data availability: The datasets used and/or analyzed in the current study are available from the corresponding author upon reasonable request.

Competing interests: The authors declare no competing interests.

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