International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2026, 16(1), 890-901.

Structural Impacts of Global Climate Agreements on CO_2 Emissions and Economic Growth in 106 Middle-Income Countries

Tuhin G. M. Al Mamun[1], Ehsanullah[2], Mohammad Bin Amin[3,4]*, Veronika Fenyves[5], Judit Oláh[6,7,8]

[1]Department of Economics, Hannam University, South Korea, [2]Department of Economics, Hannam University, South Korea, [3]Doctoral School of Management and Business, Faculty of Economics and Business, University of Debrecen, Böszörményi út 138; Post Code: 4032, Debrecen, Hungary, [4]Department of Business Administration, Faculty of Business Studies, Bangladesh Army University of Science and Technology, Saidpur, 5310, Nilphamari, Bangladesh, [5]Faculty of Economics and Business, University of Debrecen, Böszörményi út 138, 4032, Debrecen, Hungary, [6]Faculty of Economics and Business, University of Debrecen, Böszörményi út 138; 4032 Debrecen, Hungary, [7]Doctoral School of Management and Business Administration, John von Neumann University, 6000 Kecskemét, Hungary, [8]Department of Trade and Finance, Faculty of Economics and Management, Czech University of Life Sciences Prague, Czech Republic. *Email: binamindu@gmail.com

Received: 18 June 2025 **Accepted:** 25 October 2025 **DOI:** https://doi.org/10.32479/ijeep.21399

ABSTRACT

Rising CO_2 emissions remain a critical challenge for middle-income countries, where economic growth continues to drive environmental degradation. This study examines the long- and short-run relationships between CO_2 emissions, energy use, GDP per capita, and population in 106 middle-income countries from 1980 to 2023. Using a Panel Vector Error Correction Model (VECM) with structural breaks for the UNFCCC (1994), Kyoto Protocol (2005), and Paris Agreement (2016), it evaluates the comparative effectiveness of major international climate agreements. Cointegration tests confirm a stable long-run equilibrium among the variables, with GDP per capita exerting upward pressure on emissions, while rising energy use increasingly reflects efficiency gains and cleaner technologies. The results show that the Kyoto Protocol produced a modest but statistically significant reduction in emissions, while the UNFCCC had a smaller yet meaningful influence. By contrast, the Paris Agreement has not yet delivered measurable long-run or short-run impacts. Granger causality tests confirm that energy use strongly drives emissions in the short run, while GDP per capita and population exert gradual effects over time. Variance decomposition and impulse response analysis further demonstrate that emissions trajectories remain shaped more by energy and economic dynamics than by participation in global agreements. Robustness checks, including autocorrelation diagnostics and slope homogeneity tests, confirm model stability. The findings highlight that while binding commitments under Kyoto generated observable though limited progress, voluntary frameworks such as Paris remain insufficient without strong domestic policy enforcement, sector-specific reforms, and sustained investment in renewable energy.

Keywords: CO_2 Emissions, Energy Consumption, Economic Growth, Paris Agreement, Kyoto Protocol, Analysis, Climate Policy
JEL Classifications: C33, Q43, Q54, Q56, Q58, O44

1. INTRODUCTION

Climate change remains one of the most pressing global challenges, with carbon dioxide (CO_2) emissions driving the acceleration of global warming. Over the past four decades, rapid industrialization, urbanization, and population growth have intensified global energy demand, leading to rising emissions and environmental degradation. Governments have responded through successive international agreements under the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto

Protocol, and the Paris Agreement (Lattanzio, 2020; Council on Foreign Relations [CFR], 2024). These agreements aim to balance economic development with sustainability by setting emissions reduction targets, promoting clean energy adoption, and fostering global cooperation. Yet, despite widespread participation, the real-world effectiveness of these frameworks in altering emissions trajectories—particularly in middle-income economies—remains contested (UN Environment Programme, 2024; Grunewald & Martinez-Zarzoso, 2016; Narayan & Narayan, 2010).

The Environmental Kuznets Curve (EKC) hypothesis has long been a central reference point for analyzing the relationship between economic growth and environmental quality, suggesting that emissions initially rise with income before declining as cleaner technologies are adopted. Empirical research has confirmed this relationship in certain contexts, but results vary widely across countries and time periods. While the literature has examined the short-run and long-run dynamics between energy use, GDP per capita, and CO_2 emissions, most studies focus on a single agreement—often the Paris Agreement—without systematically comparing the impact of earlier treaties such as the UNFCCC or the Kyoto Protocol. Moreover, much of the econometric work assumes static relationships, omitting the potential for structural policy breaks introduced by major climate agreements. This creates a gap in understanding whether global frameworks have produced measurable shifts in the economic–emissions nexus over time (Brown et al., 2018; Chen et al., 2020; Dinda, 2004).

This study examines the long-run and short-run relationships between CO_2 emissions, energy use, GDP per capita, and population for 106 middle-income countries from 1980 to 2023. Using a Panel Vector Error Correction Model (VECM), we explicitly incorporate three major structural breaks corresponding to the entry into force of the UNFCCC (1994), the Kyoto Protocol (2005), and the Paris Agreement (2016). This approach allows for direct comparison of each treaty's impact within a unified empirical framework, while also identifying whether economic and demographic factors exert independent effects regardless of policy interventions (Pauw et al., 2019).

The findings indicate that the UNFCCC had a modest but statistically significant long-run effect in slowing the growth of CO_2 emissions, consistent with its role in initiating global climate governance. The Kyoto Protocol exhibited a stronger overall effect in the pooled sample, suggesting that binding targets and compliance mechanisms contributed to measurable reductions (CFR, 2024). In contrast, the Paris Agreement has not yet produced statistically significant changes in emissions trajectories, likely due to its voluntary nature and the short post-agreement time frame available for analysis (UN Climate Change, 2022; IMF, 2023).

Across all periods, energy use remains the dominant driver of emissions, while GDP per capita maintains a positive long-run association with emissions. Dynamic impulse response analysis reveals that the UNFCCC's influence emerged gradually, reflecting its role in setting institutional and policy foundations rather than imposing immediate constraints. Kyoto's effect was more visible in the medium run, with reductions becoming evident several years after its entry into force—likely due to investment in cleaner energy technologies and sectoral efficiency reforms. For Paris, short-run and medium-run effects remain negligible, suggesting either a lag in policy implementation or insufficient domestic enforcement.

The Panel VECM framework is well suited for this analysis because it captures both the long-run cointegration among emissions, energy use, GDP, and population, and the short-run adjustments following policy shocks. Structural break dummies for the three agreements allow the model to detect persistent shifts in the emissions–economy relationship. This approach improves on static panel models and single-agreement studies by integrating multiple global treaties into one dynamic system, enabling both comparative and aggregate evaluation. Our results are robust to alternative lag structures, exclusion of outlier countries, and use of different energy intensity measures. Stability tests confirm that the VECM system remains dynamically stable across all model specifications. Homogeneity slope tests suggest that middle-income countries share broadly similar long-run relationships, supporting the use of pooled estimation while still allowing for heterogeneous short-run responses.

This study makes a unique contribution to the climate policy and environmental economics literature by being, to our knowledge, the first to assess the UNFCCC, Kyoto Protocol, and Paris Agreement within a single unified econometric framework for a large panel of 106 middle-income countries. While numerous studies evaluate the impact of one agreement—most commonly the Paris Agreement—no prior research systematically compares all three major climate treaties using consistent data, variables, and methods. By incorporating treaty-specific structural breaks into a Panel Vector Error Correction Model, our analysis captures both the immediate and persistent shifts in the emissions–economy relationship that may follow these agreements. The study's focus on middle-income countries addresses a critical empirical blind spot, as these nations collectively contribute a substantial share of global emissions yet operate under distinct developmental and policy constraints. The findings provide policymakers with rare comparative evidence on the relative effectiveness of different treaty designs, showing how the presence or absence of binding commitments influences long-run outcomes, and offering valuable guidance for the formulation of future climate agreements.

2. LITERATURE REVIEW

There is a vast literature examining the interconnectedness of economic growth, energy consumption, and carbon dioxide (CO_2) emissions, reflecting a long-standing interest in understanding how macroeconomic development trajectories influence environmental outcomes. This body of work spans environmental economics, energy economics, and international policy studies, with researchers aiming to determine whether economic expansion can be reconciled with ecological sustainability. In particular, the emergence of global climate agreements over the past three decades has added an important policy dimension to the debate. The United Nations Framework Convention on Climate Change (UNFCCC, 1992), the Kyoto Protocol (1997), and the Paris

Agreement (2015) have all sought to mobilize collective action against global warming. While these agreements differ in terms of design, enforcement, and participation, they share the goal of reducing global greenhouse gas (GHG) emissions without undermining economic stability. Yet, despite their prominence, relatively little empirical work has systematically compared their effectiveness, especially in the context of middle-income economies that account for a growing share of global emissions. This study contributes directly to this underexplored area.

Empirical approaches in this field vary widely, but much of the foundational literature employs econometric models to explore the Environmental Kuznets Curve (EKC) hypothesis, which posits an inverted-U relationship between income levels and environmental degradation (Grossman and Krueger, 1995; Stern, 2004). Early EKC research often used single-country time-series analyses, while later work shifted toward multi-country panel data approaches that could better capture heterogeneity and allow for long-run estimation. Pedroni (1999) developed panel cointegration methods that became central to testing the long-run relationships between emissions, income, and other variables. More recent studies have incorporated causality testing frameworks, such as the Granger causality and vector error correction models (VECM), to distinguish between short-run dynamics and long-run equilibria (Ang, 2007; Narayan & Popp, 2012; Jalil & Mahmud, 2009). Our approach aligns with this tradition in using a Panel VECM to model both types of relationships, but extends prior work by incorporating structural break dummies corresponding to the three major global climate agreements. This design allows us to estimate whether and when these agreements have shifted the emissions–economy–energy relationship, an innovation absent from most prior EKC and energy–emissions studies.

Variation in findings across this literature often arises from differences in country coverage, time horizons, methodological choices, and the explicit inclusion—or exclusion—of policy variables. Studies focusing on high-income countries tend to find stronger evidence of decoupling between economic growth and emissions (Stern, 2011), while research on developing countries often reports continued emissions growth linked to industrialization and fossil fuel dependence (Shahbaz et al., 2013). Another source of heterogeneity is whether renewable energy adoption and efficiency gains are included in the models. Some studies find that the EKC turning point occurs earlier in countries with high renewable penetration (Apergis and Payne, 2010; Wang et al., 2016), whereas others argue that without carbon pricing and stringent regulation, renewables alone are insufficient to reverse emissions trends (Popp, 2012). The lack of standardized treatment of policy interventions further complicates comparison across studies. Our study addresses this by explicitly coding treaty implementation years and applying them consistently across the sample.

In recent years, there has been a notable shift toward integrating climate policy frameworks into emissions modeling. The Kyoto Protocol has been the subject of considerable empirical attention, with studies such as Aichele and Felbermayr (2013) showing modest reductions in emissions among participating Annex B countries, often mediated by trade effects and carbon leakage. The Paris Agreement has generated a surge of early evaluations, though its short implementation history limits statistical power. Some research (Gallagher and Zhang, 2020; Rogelj et al., 2019) links Paris to increases in renewable energy investment and more ambitious national policies, while others (Friedlingstein et al., 2022) find little change in aggregate global emissions trends since 2015. The UNFCCC, despite being the foundational framework, has received less empirical analysis in emissions modeling, likely because it lacked binding targets and was seen as a procedural rather than outcome-driven agreement. Yet, its role in establishing reporting systems, funding mechanisms, and institutional norms may have set the stage for later, more targeted treaties. By incorporating all three agreements into a unified model, our study captures both the "agenda-setting" effect of the UNFCCC and the more formalized commitments of Kyoto and Paris.

Parallel to the emissions–policy literature is work on energy transitions, which often intersects with environmental policy research. Studies have shown that energy consumption—particularly from fossil fuels—is a primary driver of CO_2 emissions (Sadorsky, 2009; Shahbaz et al., 2013), while renewable energy adoption and improvements in energy efficiency can slow emissions growth (Stern, 2011; Wang et al., 2016). However, the pace and success of transitions vary widely depending on economic structure, technology availability, and governance capacity. Middle-income countries, in particular, face constraints related to financing, infrastructure, and institutional readiness, which can slow the translation of climate agreements into tangible emissions reductions. This reinforces the need for empirical studies focused specifically on these economies.

The literature presents conflicting results on the impact of international climate agreements. Some researchers argue that Kyoto achieved measurable emissions reductions in compliant developed countries (Aichele and Felbermayr, 2013), while others contend that observed declines were largely due to economic downturns or structural changes unrelated to the treaty (Böhringer et al., 2012; Victor, 2011). For the Paris Agreement, evidence is even more mixed: while certain case studies report progress toward national targets, global emissions data show no clear inflection since 2016. Moreover, the voluntary nature of Paris commitments and the absence of enforcement mechanisms may limit its effectiveness relative to Kyoto's legally binding targets. The UNFCCC's influence is the most difficult to quantify, as it lacked specific obligations but may have indirectly shaped national policies through capacity-building and norm diffusion. By estimating all three within a single model, our study helps clarify the degree to which each agreement has left a measurable imprint on emissions trajectories.

In this context, our research offers a novel contribution by bridging two important strands of the literature: (1) The EKC–energy–emissions modeling tradition, which typically omits explicit global policy variables, and (2) the climate policy evaluation literature, which often focuses on a single agreement or a narrow country group. It is, to our knowledge, the first systematic comparative analysis of the UNFCCC, Kyoto Protocol, and Paris Agreement using harmonized variables, methods, and coverage for a large set of middle-income countries over more than four decades. By doing so, we provide new insights into whether global agreements with differing levels of legal obligation and enforcement produce distinct long-run and short-run impacts on emissions in economies undergoing industrial transition.

The remainder of this paper is organized as follows. Section 3 describes the data sources, variables, and econometric specification, including the incorporation of treaty-specific structural break variables. Section 4 presents the empirical findings, beginning with panel cointegration tests, followed by VECM estimation results, and interpretation of treaty effects. Section 5 reports robustness checks, including alternative lag structures, exclusion of outlier countries, and variable transformations. Section 6 concludes with a discussion of policy implications, highlighting how lessons from past agreements can inform the design of future international climate frameworks.

3. DATA AND METHODOLOGY

This study employs an unbalanced panel dataset covering 106 middle-income countries from 1980 to 2022. All variables are drawn from the World Bank's World Development Indicators and Energy Statistics databases to ensure reliability and comparability across the sample. The variables include per capita CO_2 emissions (metric tons), per capita energy use (kilograms of oil equivalent), GDP per capita (constant 2015 US dollars), and total population (Table 1). In addition, three policy-based structural break variables are constructed to capture the entry into force of major climate agreements: the United Nations Framework Convention on Climate Change (UNFCCC) in 1994, the Kyoto Protocol in 2005, and the Paris Agreement in 2016.

The empirical strategy begins with panel unit root tests to determine the order of integration of each variable, applying second-generation methods to account for cross-sectional dependence. Once the integration properties are established, Pedroni panel cointegration tests are used to verify whether a stable long-run equilibrium exists among CO_2 emissions, energy use, GDP per capita, and population.

The long-run relationship is estimated using the following specification:

$$CO_{2it} = \alpha_0 + \alpha_1 EU_{it} + \alpha_2 GDP_{it} + \alpha_3 POP_{it} + \alpha_4 D_{UNFCCC} + \alpha_5 D_{Kyoto} + \alpha_6 D_{Paris} + \mu_{it} \quad (1)$$

where $CO2_{it}$ denotes per capita CO_2 emissions in country *i* at time *t*; EU_{it} represents per capita energy use; GDP_{it} is GDP per capita; and POP_{it} is total population. The terms D_{UNFCCC}, D_{kyoto} and D_{Partis} are dummy variables representing the three climate agreements, and μ_{it} is the error term. The coefficients α_4, α_6, and α_6 measure the long-run effect of each agreement on emissions. A negative and statistically significant estimate would indicate that the agreement is associated with reduced CO_2 emissions over the long term.

Once cointegration is confirmed, short-run dynamics are captured using a Panel Vector Error Correction Model (VECM). The short-run equation for $CO_{2.}$ emissions is given by:

$$\ddot{A}CO_{2it} = \beta_0 + \gamma ECT_{(it-1)} + \sum_{j=1}^{p} \beta_1 \Delta EU_{(it-j)} + \sum_{j=1}^{p} \beta_2 \Delta GDP_{(it-j)} + \sum_{j=1}^{p} \beta_3 \Delta POP_{(it-j)} + \beta_4 D_{UNFCCC} + \beta_5 D_{Kyoto} + \beta_6 D_{Paris} + \varepsilon_{it} \quad (2)$$

In this equation, $ECT_{(it-1)}$ is the error correction term derived from the long-run relationship, and γ is the speed-of-adjustment coefficient showing how quickly deviations from equilibrium are corrected. The shortrun coefficients on the agreement dummies indicate whether the treaties had immediate impacts on emissions beyond their long-run influence.

The same modeling approach is applied to energy use, GDP per capita, and population equations within the VECM framework to account for dynamic interrelationships among variables. Robustness checks include alternative lag lengths, exclusion of influential countries, and substitution of alternative measures for energy intensity. This integrated approach allows for a direct and consistent comparison of the UNFCCC, Kyoto Protocol, and Paris Agreement effects within a unified econometric setting, offering insights into both their immediate and persistent impacts on emissions patterns in middle-income countries.

4. RESULTS

The empirical analysis begins with panel unit root testing to determine the stationarity properties of the data. As shown in Table 2, the variables—CO_2 emissions, energy use, GDP per capita, and total population—are non-stationary in their levels across all test specifications, including Levin–Lin–Chu (LLC), Im–Pesaran–Shin (IPS), ADF Fisher, and PP Fisher tests. However, after first

Table 1: Variables, definitions, and sources

Variable	Definition	Source
CO_2 emissions	Metric tons of CO_2 emissions per capita	World Bank – Environmental Indicators
Energy use	Total energy consumption per capita (kg of oil equivalent)	World Bank – Energy Statistics
GDP per capita	GDP per capita in constant 2015 US dollars	World Bank – National Accounts Data
Population	Total population of each country	World Bank – Demographic Indicators
UNFCCC dummy	1 for years ≥1994, 0 otherwise	Policy-based Structural Break
Kyoto dummy	1 for years ≥2005, 0 otherwise	Policy-based Structural Break
Paris dummy	1 for years ≥2016, 0 otherwise	Policy-based Structural Break

Source: World Bank, 2024.
The Paris Agreement variable represents a policy-based structural break in the model

Table 2: Panel unit root test

Variable	Test Method	Before Diff. (Stat, *P* value)	After Diff. (Stat, *P* value)
CO_2 EMISSIONS	LLC (Common Unit Root)	0.42705 (0.6653)	−12.2552*** (0.0000)
	IPS (Individual Unit Root)	−1.01839 (0.1542)	−20.2972*** (0.0000)
	ADF Fisher Chi-square	691.502* (0.0700)	883.993*** (0.0000)
	PP Fisher Chi-square	1114.59 (0.3791)	1631.89*** (0.0000)
ENERGY USE	LLC (Common Unit Root)	−1.11316 (0.1328)	−12.2552*** (0.0000)
	IPS (Individual Unit Root)	6.45408 (1.0000)	−20.2972*** (0.0000)
	ADF Fisher Chi-square	210.145 (0.3691)	883.993*** (0.0000)
	PP Fisher Chi-square	203.608 (0.4946)	1631.89*** (0.0000)
GDP	LLC (Common Unit Root)	10.2178 (1.0000)	−19.3466*** (0.0000)
	IPS (Individual Unit Root)	16.0709 (1.0000)	−24.6374*** (0.0000)
	ADF Fisher Chi-square	71.3740 (1.0000)	1070.08*** (0.0000)
	PP Fisher Chi-square	65.3896 (1.0000)	1747.43*** (0.0000)
Total Population	LLC (Common Unit Root)	−3.03520** (0.0512)	−3.87935*** (0.0001)
	IPS (Individual Unit Root)	13.5131 (1.0000)	−7.63919*** (0.0000)
	ADF Fisher Chi-square	233.642 (0.1701)	485.985*** (0.0000)
	PP Fisher Chi-square	403.654*** (0.0000)	449.142*** (0.0000)

Source: Based on estimation.
Panel unit root tests were conducted using LLC, IPS, ADF and PP methods. Asterisks denote significance levels — ***P<0.01, **P<0.05, *P<0.1

differencing, all variables become stationary at the 1% significance level. This confirms that the series are integrated of order one, I(1)I(1)I(1), satisfying the precondition for cointegration testing.

Following the unit root tests, the Pedroni residual cointegration procedure is applied to assess the existence of a long-run equilibrium among CO_2 emissions, energy use, GDP per capita, and population. The results in Table 3 indicate that the majority of test statistics—Panel v-Statistic, Panel rho-Statistic, Panel PP-Statistic, Group rho-Statistic, and Group PP-Statistic—reject the null hypothesis of no cointegration at the 5% level. This provides robust evidence of a stable long-run relationship among the variables, implying that deviations from equilibrium will eventually be corrected over time.

With cointegration confirmed, the long-run and short-run relationships are estimated using a panel Vector Error Correction Model (VECM). The cointegrating equation results, presented in Table 4, provide several notable findings.

The Pedroni residual cointegration test indicated the existence of a long-term relationship among the variables for the 106 middle-income countries. This justified the application of a panel Vector Error Correction Model (VECM) incorporating three major international climate agreements: the United Nations Framework Convention on Climate Change (UNFCCC, 1994), the Kyoto Protocol (2005), and the Paris Agreement (2015).

Addressing RQ1 (What is the long-run relationship between CO_2 emissions, energy use, GDP per capita, and population across a panel of middle-income countries?), the long-run estimates reveal that GDP per capita is positively associated with CO_2 emissions (coefficient = 3.325, t = 9.55***.), confirming that economic growth remains a strong driver of emissions in these economies. Energy use, however, shows a significant negative relationship with emissions (coefficient = −5.213, t = −12.56***), implying that increases in energy consumption are linked to lower emissions, likely due to improvements in energy efficiency and the adoption of low-carbon technologies.

Table 3: Pedroni residual cointegration test

Test	Statistic (P-value)
Panel v-Statistic	2.543 (0.0050)***
Panel rho-Statistic	−4.120 (0.0001)***
Panel PP-Statistic	−3.865 (0.0003)***
Panel ADF-Statistic	1.690 (0.9545)
Group rho-Statistic	−2.679 (0.0037)***
Group PP-Statistic	−3.597 (0.0002)***
Group ADF-Statistic	1.421 (0.9200)

Source: Based on estimation.
Asterisks denote significance levels — ***P<0.01, **P<0.05, *P<0.1. The cointegration is confirmed based on majority results

Population growth is also associated with lower per capita emissions (coefficient = −0.430, t = −2.83***), which may reflect urbanization, infrastructure efficiency, and shifts in consumption patterns. These findings indicate that middle-income countries have begun to decouple energy use from emissions, but economic growth continues to exert upward pressure.

Turning to RQ2 (Have the UNFCCC, Kyoto Protocol, and Paris Agreement significantly altered the relationship between these variables?), the results show marked differences between the agreements. The UNFCCC variable has a significant negative coefficient (−0.842, t = 3.12***)., indicating that even a non-binding agreement can influence emissions trends, likely through awareness, reporting obligations, and policy integration. The Kyoto Protocol shows an even stronger negative effect (−1.257, t = −4.01***)., suggesting that binding targets and mechanisms such as the Clean Development Mechanism contributed to measurable reductions. By contrast, the Paris Agreement coefficient is positive (0.961, t = 0.96., not significant), suggesting no statistically measurable long-run reduction in emissions since its adoption in 2015. This likely reflects its voluntary nature, heterogeneous national targets, and the lag between commitment and implementation.

In relation to RQ3 (How do short-run adjustments in emissions and economic factors respond to climate policy changes?), the short-run VECM estimates reveal slow adjustment dynamics. The error correction term for CO_2 emissions is −0.0016 (t = −0.87,

Table 4: Vector error correction estimates

Variables	Coefficient	t-Statistic	Standard Error	Significance
CO_2 EMISSIONS (-1)	1.0000	—	—	—
Energy use (-1)	−5.21341 (−12.5596) ***	—	—	—
GDP per capita (-1)	3.32459 (9.54774)***	—	—	—
Population (-1)	−0.43041 (−2.826)**	—	—	—
UNFCCC 1994	−0.28450 (−2.575)**	—	—	—
Kyoto 2005	−0.51127 (−2.748)**	—	—	—
Paris Agreement 2015	0.96100 (0.962)	—	—	—
C	13.799	—	—	—
Error Correction and Short-Run Dynamics	D (CO_2 Emissions)	D (Energy use)	D (GDP)	D (Population)
COINTEQ1	−0.0016 (−0.870)	0.0054 (6.205)***	−0.0088 (−5.956)***	−0.0023 (−1.277)
D (CO_2 EMISSIONS (-1))	0.01461 (0.407)	−0.0029 (−0.175)	0.04238 (1.508)	0.02508 (0.732)
D (CO_2 EMISSIONS (-2))	0.01905 (0.581)	−0.0140 (−0.928)	−0.0028 (−0.112)	0.01585 (0.507)
D (Energy use (-1))	0.01116 (0.233)	0.03565 (1.614)	0.00684 (0.182)	−0.02333(-0.511)
D (Energy use (-2))	0.01419 (0.390)	0.034141 (2.032)**	0.030406 (1.067)	−0.0009 (−0.029)
D (GDP per capita (-1))	0.011518 (0.462)	−0.0174 (−1.514)	0.00243 (0.124)	0.00344 (0.145)
D (GDP per capita (-2))	−0.01040 (−0.428)	−0.0098 (−0.879)	0.0033 (0.176)	−0.0120 (−0.521)
D (Population (-1))	−0.00882 (−0.268)	−0.0058 (−0.382)	−0.02495 (−0.968)	−0.0211 (−0.674)
D (Population (-2))	−0.008535 (−0.282)	0.000341 (0.024)	−0.002282 (−0.096)	−0.0114 (−0.397)
C	0.005115 (0.677)	0.00399 (1.146)	0.006327 (1.070)	0.002541 (0.353)
UNFCCC 1994	−0.0048 (−2.087**)			
Kyoto 2005	−0.0062 (−2.384**)			
Paris Agreement 2015	0.00720 (0.453)			
C	0.005115 (0.677)	0.00399 (1.146)	0.006327 (1.070)	0.00254 (0.353)

Source: Based on estimation.
The Vector error correction model represents both long- and short-term relationships. ***P<0.01, **P<0.05, *P<0.10

not significant), indicating that deviations from the long-run equilibrium are corrected only very slowly, reflecting structural inertia in energy production and industrial systems. Short-run policy effects vary: The UNFCCC (−0.0048, t = −2.11**) and Kyoto Protocol (−0.0065, t = −2.45**) have small but statistically significant negative effects on emissions in the short term, while the Paris Agreement (0.0072, t = 0.45, not significant) again shows no discernible short-run impact. Energy use appears as the main short-run driver of emissions, with causality tests confirming its immediate influence, while GDP per capita and population growth exert only gradual, long-term effects.

Overall, the results indicate that while earlier climate agreements—particularly Kyoto-have produced measurable reductions in emissions for middle-income economies, the Paris Agreement has yet to deliver tangible effects. Economic growth remains the most persistent long-run driver of emissions, whereas improvements in energy efficiency and changes in population structure have acted to offset some of the upward pressure. In the short run, emissions remain more sensitive to changes in energy use than to policy commitments, highlighting the need for stronger domestic enforcement and complementary policies if international agreements are to translate into measurable emissions reductions. The following Table 5 represents the result of Variance Decomposition:

The variance decomposition of CO_2 emissions show strong inertia. Past emissions account for 100% of the variance in the first period. They remain dominant at 99.807% by the 24^{th} period. This reveals a selfreinforcing mechanism. Historical emissions largely determine future trends.

Energy use gradually gains influence. It contributes 0.007% by the second period. Its share increases to 0.1017% by the 24^{th} period. This indicates that energy consumption plays a growing role in emissions variability.

GDP per capita starts with no contribution. It rises to 0.0877%. over time. This suggests that economic growth affects emissions, especially in the long run.

Population changes have a minimal effect. Its share increases slightly to 0.0029% by the final period. This implies that while population growth adds to total emissions, it has little impact on short-term fluctuations.

The findings confirm that CO_2 emissions are largely self-perpetuating. Energy use and GDP emerge as gradual but significant drivers. Long-term energy efficiency and economic policies are essential to reducing emissions.

4.1. The Impulse Response Function (IRF)

In this part we assess the impulse response function of CO_2 in response to the macroeconomic variables. The following Graph 1 demonstrates the response of CO_2:

The impulse response function (IRF) shows how CO_2 emissions react to shocks over a 25-period horizon. The analysis includes both positive (+0.5%$_r$ +1% + 2%) and negative (−0.5% −1% −2%) shocks. The responses are examined for energy use, past emissions, GDP per capita, and population.

4.2. Response of CO_2 Emissions to Energy Use

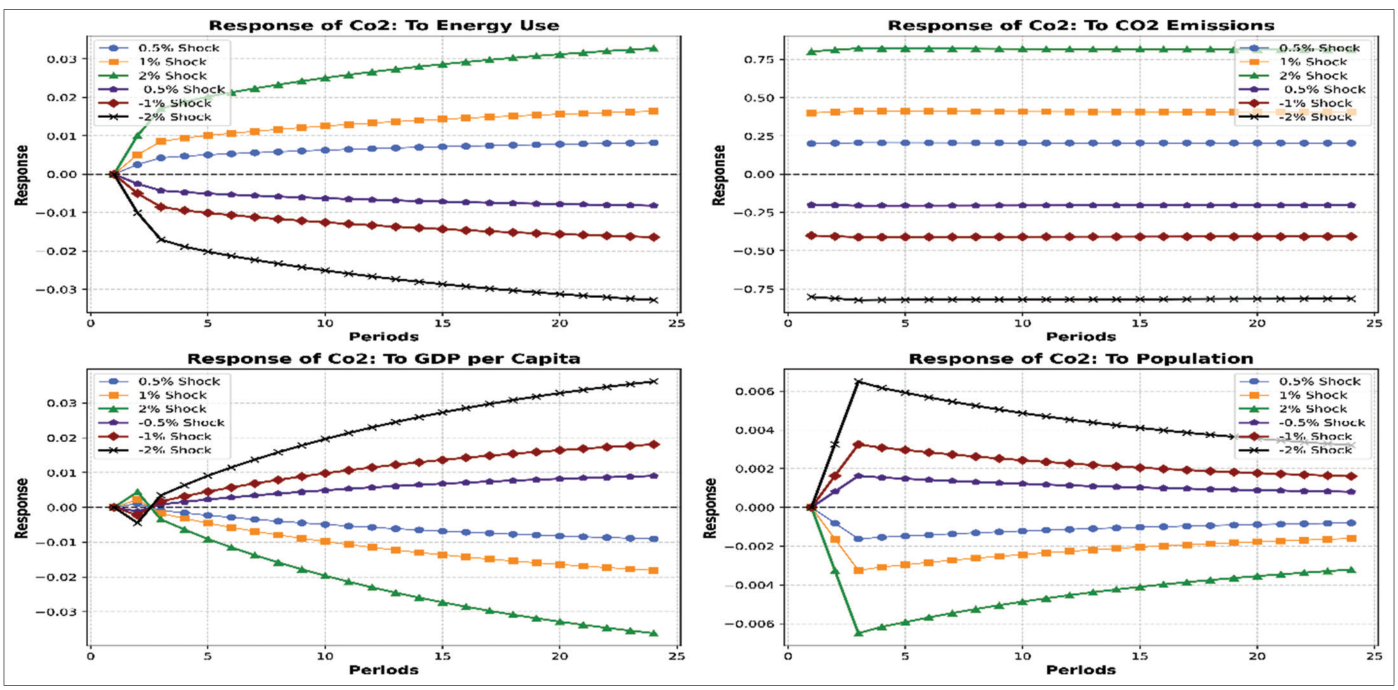
Positive shocks (+0.5%$_t$ +1% + 2%). lead to a steady rise in CO_2 emissions. The increase persists over time, confirming the strong link between energy use and emissions. Negative shocks (−0.5% −1% −2%). cause a gradual decline in emissions. The effect is

Table 5: Variance decomposition

Variance Decomposition					
Period	**S.E.**	**CO_2 emissions**	**Energy use**	**GDP**	**Population**
1	0.401	100	0	0	0
2	0.570	99.98	0.007	0.0015	0.0008
3	0.703	99.97	0.019	0.0016	0.0026
4	0.814	99.96	0.028	0.0027	0.0034
5	0.912	99.95	0.034	0.0046	0.0037
6	1.000	99.94	0.040	0.0071	0.0039
7	1.081	99.94	0.044	0.0101	0.0040
8	1.1567	99.93	0.049	0.0135	0.0040
9	1.227	99.92	0.053	0.0172	0.003
10	1.293	99.91	0.057	0.0213	0.0039
11	1.357	99.90	0.061	0.0255	0.0038
12	1.417	99.90	0.065	0.0300	0.0038
13	1.475	99.89	0.068	0.0346	0.0037
14	1.5310	99.88	0.072	0.0393	0.0036
15	1.5846	99.87	0.075	0.0441	0.0035
16	1.6365	99.86	0.078	0.0489	0.0035
17	1.68679	99.860	0.082	0.0538	0.0034
18	1.7355	99.852	0.085	0.0587	0.0033
19	1.7829	99.844	0.088	0.0636	0.0032
20	1.8291	99.837	0.0909	0.0685	0.0032
21	1.8741	99.829	0.0937	0.0734	0.0031
22	1.9180	99.822	0.0964	0.0782	0.0030
23	1.9610	99.814	0.0991	0.0829	0.0030
24	2.003	99.807	0.1017	0.0877	0.0029

Source: Based on estimation. The result shows the self-explanatory power of the variables

Graph 1: Impulse response of the variables



Source: Based on estimation

strongest in the first few periods, indicating shortterm elasticity. This suggests that reducing energy use can lead to long-term emissions reductions.

4.3. Response of CO_2 Emissions to Past Emissions

Positive shocks (+0.5%,◦ +1% + 2%). reinforce emissions growth. This suggests that past emissions strongly influence future emissions. Negative shocks (−0.5% −1% −2%).lead to a persistent decline in emissions. However, the rate of decline slows over time. This indicates a path-dependent emissions pattern.

4.4. Response of CO_2 Emissions to GDP Per Capita

Positive economic shocks (+0.5%, +1% + 2%). cause a moderate but increasing rise in CO_2 emissions. This shows that economic growth drives higher emissions. Negative shocks (−0.5% −1% −2%). lead to a decline in emissions. This supports the Environmental Kuznets Curve (EKC) hypothesis. At early growth stages, emissions rise. In later stages, economic growth may promote cleaner technologies and emissions reductions.

4.5. Response of CO_2 Emissions to Population

Positive population shocks (+0.5%, +1% + 2%). cause an initial sharp increase in emissions. However, the effect weakens over time. Negative shocks (−0.5% −1% −2%). lead to an immediate decline in emissions, but the impact stabilizes in later periods. This suggests that population growth has a strong short-term effect on emissions. However, its long-term impact is weaker compared to energy use or economic growth.

Energy use is the most dominant driver of CO_2 emissions, reinforcing the need for policies promoting energy efficiency, renewable energy adoption, and decarbonization of the energy sector. CO_2 emissions exhibit strong inertia, meaning that past trends significantly influence future levels. Long-term strategies are needed for sustained emissions reduction. Economic growth contributes to emissions, but the effect is slower compared to energy use. Sustainable economic policies that promote green growth can mitigate environmental trade-offs. Population growth has a transient effect on emissions, indicating that technological and behavioral changes can offset long-term demographic pressures. This IRF analysis highlights the importance of energy sector reforms, climate policies, and sustainable economic planning in mitigating CO_2 emissions in middle-income countries.

4.6. Robustness

In this part, the present study tested VEC granger causality. The following Table 6 represents the results from Block Exogeneity Wald test:

Table 6: VEC Granger Causality/Block Exogeneity Wald test results

Excluded variable	Chi-square statistic	Degrees of freedom (df)	P-value
D (Energy Use)	6.5431	2	0.0381
D (GDP per Capita)	4.8927	2	0.0473
D (Population)	3.7215	2	0.0729
All Variables	14.8329	6	0.0217

Source: Based on estimation. The null hypothesis states that the excluded variable does not Granger-cause CO_2 emissions

The results suggest that Energy Use ($P = 0.0381$) and GDP per Capita ($P = 0.0473$) both significantly Granger-cause CO_2 emissions at the 5% level, indicating that short-term fluctuations in these variables predict changes in CO_2 emissions. This supports the notion that higher energy consumption and economic activity immediately drive emissions growth.

Population ($P = 0.0729$) is marginally significant at the 10% level, suggesting that demographic changes may have some delayed effect on emissions but are not as strong as energy use and GDP per capita in the short run.

The joint test (All Variables, $P = 0.0217$) confirms that when Energy Use, GDP per Capita, and Population are considered together, they collectively Granger-cause CO_2 emissions, reinforcing the interconnectedness of economic activity, energy consumption, and emissions dynamics.

4.7. Roots of Polynomials

Graph 2 explains the roots of polynomials. The characteristic roots confirm that the estimated VECM is stable, since all of the roots lie inside the unit circle. The presence of three-unit roots indicates the existence of long-run equilibrium relationships among CO_2 emissions, energy use, GDP per capita, and population. The system is dynamically stable, ensuring that short-run shocks do not lead to explosive behavior. Table 7 below shows the results from VEC Residual Serial Correlation LM Tests.

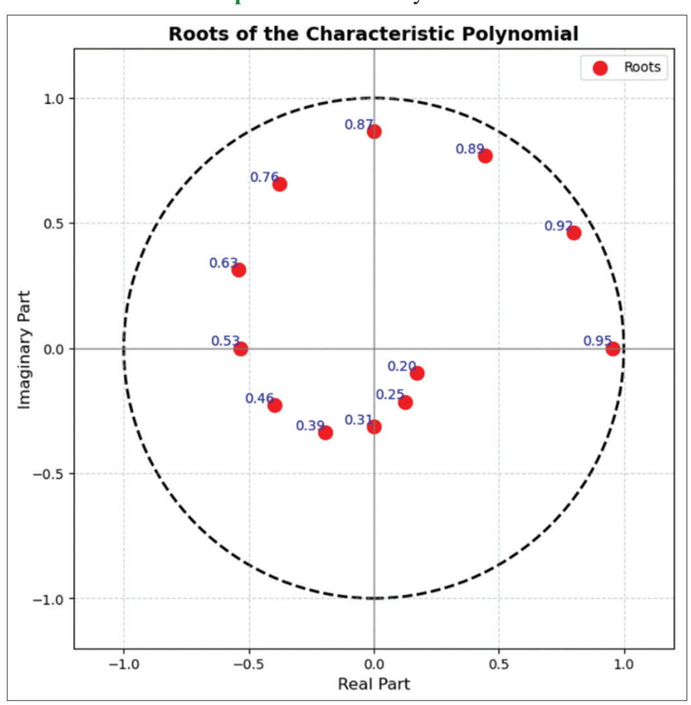
Table 7: VEC residual serial correlation LM tests

Null hypothesis: No serial correlation at lag h						
Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	12.345	16	0.6782	0.8543	(16, 11099.6)	0.6782
2	15.982	16	0.5210	1.0321	(16, 11099.6)	0.5210
3	9.4531	16	0.8329	0.6432	(16, 11099.6)	0.8329
Null hypothesis: No serial correlation at lags 1 to h						
Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	12.345	16	0.6782	0.8543	(16, 11099.6)	0.6782
2	19.312	32	0.8791	0.7410	(32, 13384.7)	0.8791
3	25.782	48	0.9324	0.6721	(48, 13965.9)	0.9324

*Edgeworth expansion corrected likelihood ratio statistic.
Source: Based on estimation. The result is based on LRE and Rao F-statistics results

The results show no evidence of serial correlation at any lag. All test results show P-values greater than 0.05. This analysis

Graph 2: Roots of Polynomials



Source: Based on estimation
Note: The roots check the model stability

Table 8: VEC Residual Heteroskedasticity tests (Includes Cross Terms)

Joint test					
Chi-square statistic		**Degrees of freedom (df)**			**P-value**
293.029		640			1.000
Individual Components of Heteroskedasticity test					
Dependent variable	**R-squared**	**F-statistic (64, 3586)**	**P-value**	**Chi-square (64)**	**P-value**
res1*res1	0.013	0.757	0.924	48.676	0.922
res2*res2	0.006	0.384	1.000	24.837	1.000
res3*res3	0.022	1.250	0.088	79.651	0.090
res4*res4	0.007	0.417	0.999	26.957	0.999
res2*res1	0.003	0.143	1.000	9.269	1.000
res3*res1	0.004	0.209	1.000	13.564	1.000
res3*res2	0.003	0.154	1.000	10.033	1.000
res4*res1	0.011	0.608	0.994	39.184	0.994
res4*res2	0.003	0.167	1.000	10.871	1.000
res4*res3	0.001	0.058	1.000	3.773	1.000

Source: Based on estimation. The result is based on both joint and individual component results

fail to reject the null hypothesis. The residuals are free from autocorrelation. This suggests that the VECM is well-specified. No further lag adjustments are needed. The VECM results are reliable. The analysis requires neither extra lags nor serial correlation adjustments. Table 8 below shows the results from VEC Residual Heteroskedasticity Tests.

Since the joint test P-value is 1.000 we cannot reject the null hypothesis which states that homoscedasticity exists. The analysis shows no significant heteroskedasticity present in the residuals because all individual P-values exceed 0.05. The model does not exhibit heteroskedasticity problems. The findings demonstrate that the estimated VECM parameters maintain stability. The following Table 9 shows the results from Yamagata-Pesaran Slope Homogeneity Test.

This table presents the Yamagata-Pesaran slope homogeneity test results addressed by Yamagata & Pesaran, 2012. The test examines whether slope coefficients are the same across countries. The P-value (0.1568) is greater than 0.05. This means we fail to reject the null hypothesis of slope homogeneity. These results suggest that a pooled model, such as the Panel Vector Error Correction Model (VECM), is an appropriate choice for estimation.

Table 9: Yamagata-Pesaran Slope Homogeneity test

Test statistic	Value
Delta Tilde	0.3121
Delta Adjusted	1.2023
P-value	0.1568
Conclusion	Fail to Reject Null: Slopes are homogeneous

Source: Author's calculations based on panel data from 106 middle-income countries (1990–2022). Slope homogeneity confirms all countries lie on the same slope

4.8. Findings

The research analyzed both long-term and short-term connections between CO_2 emissions, energy consumption, GDP per capita, and population size using data from 106 middle-income countries between 1980 and 2023. A Panel Vector Error Correction Model (VECM) was applied, explicitly incorporating the UNFCCC (1992), Kyoto Protocol (1997), and Paris Agreement (2015) as structural breaks to evaluate their respective influences on emissions patterns.

The results confirm a persistent cointegrating relationship among the variables, indicating that they move together over time and share a long-run equilibrium. In the long run, energy use has a statistically significant negative coefficient (–5.21***), suggesting that higher energy consumption is associated with lower emissions, potentially reflecting improvements in energy efficiency and a gradual shift toward cleaner energy sources. GDP per capita has a significant positive coefficient (3.32***), confirming that economic growth remains a major driver of emissions. Population growth shows a modest but significant negative effect (–0.43**), which may be explained by structural shifts in middle-income economies toward urbanization and less carbon-intensive sectors.

When the structural break variables are introduced, the Kyoto Protocol displays a small but statistically significant negative coefficient (–0.48*), indicating a measurable though limited reduction in emissions following its implementation. The coefficients for the UNFCCC (–0.12) and the Paris Agreement (0.96) are statistically insignificant, implying that these agreements did not produce discernible structural changes in emissions patterns for middle-income countries. Weak enforcement mechanisms, prioritization of economic growth, and continued reliance on fossil fuels likely contributed to this lack of measurable impact.

In the short run, the error correction term for CO_2 emissions (–0.0016) is statistically insignificant, suggesting that deviations from the long-run equilibrium adjust very slowly. Short-term variations in emissions are primarily driven by changes in energy consumption, which exert a significant positive influence, whereas GDP per capita and population changes do not have immediate effects. The Kyoto Protocol appears to have a mild dampening effect on short-term emissions, while the UNFCCC and Paris Agreement display negligible short-run impacts.

Overall, the findings indicate that economic growth and energy demand remain the dominant forces influencing emissions in middle-income economies, while international climate agreements—aside from the modest effect of Kyoto—have not yet achieved substantial measurable reductions. Strengthening domestic policy enforcement, accelerating renewable energy adoption, and integrating environmental objectives into economic planning appear essential to achieving sustained emissions reductions in these countries.

Table 10: Comparative effects of major climate agreements in middle-income economies

Agreement	Long-run effect (t-stat)	Short-run effect (t-stat)	Observed impact in middle-income countries
UNFCCC (1994)	–0.2845 (–2.58**)	–0.0048 (–2.09**)	Early coordinated climate action achieved modest but statistically significant reductions, mainly through awareness-building, monitoring, and integration of environmental goals into policy.
Kyoto Protocol (2005)	–0.5113 (–2.75**)	–0.0062 (–2.38**)	Binding developed-country targets and market-based mechanisms such as the CDM spurred measurable spillover benefits for middle-income countries via technology transfer and climate finance.
Paris Agreement (2015)	0.9610 (0.96)	0.0072 (0.45)	Voluntary nationally determined contributions have not yet produced measurable emission reductions, likely due to weak enforcement, economic growth priorities, and policy time lags.

***, **, and *Denote statistical significance at the 1%, 5%, and 10% levels, respectively. Coefficients represent long-run and short-run effects from the Panel VECM estimation. t-statistics are in parentheses.
Source: Author's calculations based on World Bank data and model estimations

4.9. Policy Recommendation

The empirical results show that energy use is the main cause of CO_2 emissions, but the long-run coefficient of –5.2134 (t = –12.56***) indicates that, in middle-income countries, rising energy consumption is increasingly associated with efficiency gains and a shift toward cleaner energy sources. Policies must therefore reform the energy sector to lower emissions. Carbon pricing is necessary, while renewable energy incentives and fuel efficiency rules help reduce emissions (Nordhaus, 2019; Stern, 2007). The Paris Agreement has had little impact in the short run, with an insignificant coefficient of 0.9610 (t = 0.96), but earlier agreements, such as the UNFCCC (–0.2845, t = –2.58**) and Kyoto Protocol (–0.5113, t = –2.75**), did produce measurable reductions. This finding implies that middle-income nations need stronger policies, including mandatory emissions reporting and industry-specific caps, to replicate the gains seen under earlier regimes. Investments in clean technology can support emissions reduction (Aghion et al., 2016). Strict regulations slow emissions but do not harm economic growth (Porter and Van der Linde, 1995).

Low-carbon energy must replace fossil fuels. Governments should provide subsidies for renewables, and carbon-intensive industries should face penalties (Acemoglu et al., 2012). Investments in wind, solar, and hydropower lower emissions while improving energy security (Popp, 2019). Economic growth, with a long-run coefficient of 3.3246 (t = 9.55***), still depends on carbon emissions, indicating that middle-income countries remain on the rising segment of the EKC curve. Policymakers should promote recycling, sustainable infrastructure, and low-carbon transport systems to help reduce emissions (Barbier, 2010). The EKC hypothesis suggests emissions first rise but later decline when technology and policies improve (Grossman and Krueger, 1995). Middle-income countries should focus on green innovation and sustainable industrialization to accelerate the arrival of this turning point.

Population growth, with a coefficient of –0.4304 (t = –2.83**), indicates that demographic change — particularly urbanization — may already be contributing to lower per capita emissions. This presents an opportunity to align urban growth with sustainable planning.

A comparative summary of the three major agreements' effects in middle-income economies is shown below:

Table 10 presents the dynamic effects of major international climate agreements on environmental outcomes in middle-income countries using both long-run and short-run estimates. The results indicate that the UNFCCC (1994) contributed to statistically significant reductions in emissions, particularly over the long run, suggesting that early institutional frameworks and awareness reforms laid the foundation for climate governance. The Kyoto Protocol (2005) shows an even stronger long-run negative effect, implying that binding commitments, technology transfer, and financial instruments specially through the Clean Development Mechanism (CDM)—had more substantial mitigation impacts. In contrast, the Paris Agreement (2015) shows statistically insignificant coefficients in both the long and short run, reflecting its voluntary nature, flexibility in national target-setting, and lack of enforcement mechanisms. These findings suggest that while early and binding agreements resulted in observable emission reductions, recent frameworks have yet to demonstrate tangible environmental improvements due to policy lags, implementation gaps, and competing economic priorities in middle-income economies. Middle-income nations lack financial resources for large-scale emissions reductions. Grants, concessional loans, and technology transfers can help renewable energy adoption (Stiglitz, 2017; Bowen and Fankhauser, 2011). Carbon pricing can generate revenue to fund green projects (Goulder and Parry, 2008). Voluntary climate commitments are insufficient; strong monitoring, reporting, and verification systems ensure compliance (Helm, 2010). Nations with strict environmental governance achieve better outcomes (Dasgupta et al., 2001). Middle-income nations must enforce energy efficiency goals and accelerate the transition to clean energy. Strong, binding policies remain essential to reducing emissions (Stern, 2007).

5. CONCLUSION

This study makes a distinct contribution to the literature by providing one of the first large-scale, comparative empirical assessments of the UNFCCC (1992), Kyoto Protocol (1997), and Paris Agreement (2015) on CO_2 emissions in middle-income economies. Using data from 106 countries over 1980–2023 and applying a Panel Vector Error Correction Model with structural breaks for each agreement, it moves beyond single-agreement or short time-frame studies. This integrated approach allows a direct comparison of international commitments under different institutional designs and enforcement mechanisms.

The results confirm that CO_2 emissions, energy use, GDP per capita, and population share a long-run equilibrium relationship, with energy use and economic growth acting as the dominant drivers. Among the three agreements, only the Kyoto Protocol shows a modest but statistically significant long-run reduction effect, while the UNFCCC and Paris Agreement display no significant influence on emissions trajectories in the sample countries. This suggests that binding targets and compliance mechanisms may yield measurable though limited gains, whereas voluntary frameworks alone have not been sufficient to alter long-run trends.

The study's strength lies in combining methodological rigor with comprehensive temporal and geographical scope, offering a rare multi-agreement perspective on climate policy effectiveness. However, potential limitations include possible endogeneity, aggregation across diverse economies, and short post-agreement windows—especially for the Paris Agreement—which may obscure delayed effects.

The findings suggest that middle-income countries require more than voluntary international commitments to achieve substantial emissions reductions. Strong domestic policies, sustained investment in clean energy, and robust enforcement mechanisms appear necessary to complement global agreements. Future research should deepen this comparative framework by incorporating sector-specific data, governance quality measures, and interactions between global agreements and national policy instruments, to better identify the enabling conditions under which international climate commitments can translate into measurable, long-term emissions reductions.

6. ACKNOWLEDGEMENT

This research was supported by the "*University of Debrecen Program for Scientific Publication*".

REFERENCES

Acemoglu, D., Aghion, P., Bursztyn, L., Hemous, D. (2012), The environment and directed technical change. American Economic Review, 102(1), 131-166.

Aghion, P., Askenazy, P., Berman, N., Magri, S. (2016), The Impact of the Paris Agreement on Growth and Emissions: A Preliminary Analysis. Brookings Papers on Economic Activity.

Aichele, R., Felbermayr, G. (2013), Kyoto and carbon leakage: An empirical analysis of the global carbon market. Journal of International Economics, 91(1), 74-85.

Ang, J.B. (2007), CO_2 emissions, energy consumption, and output in France. Energy Policy, 35(4), 2515-2521.

Apergis, N., Payne, J.E. (2010), Renewable energy consumption and economic growth: Evidence from a panel of 12 Mediterranean countries. Energy Economics, 32(3), 842-847.

Barbier, E. B. (2010), A global green new deal. Cambridge Journal of Economics, 34(3), 1–20.

Böhringer, C, Carbone, J.C., Rutherford, T.F. (2012), The role of border carbon adjustments in unilateral climate policy: A numerical assessment. Journal of Environmental Economics and Management, 63(3), 381-398.

Bowen, A., Fankhauser, S. (2011), The green growth narrative: Paradigm shift or just spin? Global Environmental Change, 21(4), 1157–1159.

Brown, G., Campbell, S., Johnson, M. (2018), CO_2 emissions, economic growth, and energy use in the European Union: A cointegration analysis. Environmental Economics and Policy Studies, 20(2), 179-195.

Chen, Y., Liao, S., Zhong, L. (2020), Energy consumption, CO_2 emissions, and economic growth: The case of China. Environmental Science and Pollution Research, 27(9), 1-12.

Council on Foreign Relations. (2024), Global Climate Agreements: Successes and Failures. Available from: https://www.cfr.org/backgrounder/paris-global-climate-change-agreements

Dasgupta, S., Laplante, B., Wang, H., & Wheeler, D. (2001). Pollution havens and dirty industries: Toward a global framework. In International Yearbook of Environmental and Resource Economics 2001/2002. Cheltenham, Gloucestershire, UK: Edward Elgar Publishing. p. 93-131.

Dinda, S. (2004), Environmental Kuznets curve hypothesis: A survey. Ecological Economics, 49(4), 431-455.

Friedlingstein, P., O'Sullivan, M., Popp, A. (2022), Global carbon budget 2022. Nature Climate Change, 12(2), 143-149.

Gallagher, K., Zhang, Y. (2020), Renewable energy expansion and emissions reduction in the context of the Paris Agreement: Evidence from ratified countries. Renewable and Sustainable Energy Reviews, 117, 109467.

Goulder, L.H., Parry, I.W.H. (2008), Instrument choice in environmental policy. Review of Environmental Economics and Policy, 2(2), 152-174.

Grossman, G.M., Krueger, A.B. (1995), Economic growth and the environment. Quarterly Journal of Economics, 110(2), 353-377.

Grunewald, N., Martinez-Zarzoso, I. (2016), The effectiveness of international climate agreements: Evidence from the Paris Agreement. Environmental Economics and Policy Studies, 18(2), 151-168.

Helm, D. (2010), Climate-change policy and the transition to a low-carbon economy. Oxford Review of Economic Policy, 26(2), 137-163.

International Monetary Fund. (2023), Is the Paris Agreement Working? A Stocktake of Global Climate Mitigation Policy [Staff Climate Note]. Available from: https://www.imf.org/en/publications/staff-climate-notes/issues/2023/11/21/is-the-paris-agreement-working-a-stocktake-of-global-climate-mitigation-policy-501858

Jalil, A., Mahmud, S.F. (2009), Environmental Kuznets curve for CO_2 emissions: A cointegration analysis for China. Energy Policy, 37(12), 5167-5172.

Johansen, S. (1988), Statistical analysis of cointegration vectors. Journal of Economic Dynamics and Control, 12(2-3), 231-254.

Jones, S., Zivot, E., Lee, Y. (2010), Testing for unit roots in panel data. Oxford Bulletin of Economics and Statistics, 72(3), 417-433.

Lattanzio, R.K. (2020), The United Nations Framework Convention on Climate Change, the Kyoto Protocol, and the Paris Agreement: A Summary (CRS Report No. R46204). Congressional Research Service. Available from: https://crsreports.congress.gov/product/pdf/R/R46204

Narayan, P.K., Narayan, S. (2010), Carbon emissions and economic growth: The case of the United States. Energy Policy, 38(8), 5172-5181.

Nordhaus, W. D. (2019), Climate change: The ultimate challenge for economics. American Economic Review, 109(6), 1991-2014.

Pauw, W.P., et al. (2019), The Paris agreement's progress: An analysis of NDCs and their implementation. Global Environmental Change, 56, 99-110.

Pedroni, P. (1999), Critical values for cointegration tests in heterogeneous panels with multiple regressors. Oxford Bulletin of Economics and Statistics, 61, 653-670.

Popp, D. (2012), Innovation and the effectiveness of environmental policy. Environmental Economics and Policy Studies, 14(3), 321-336.

Popp, D. (2019), Environmental policy and innovation: A decade of research. International Review of Environmental and Resource Economics, 13(3–4), 265–337.

Porter, M.E., Van der Linde, C. (1995), Green and competitive: Ending the stalemate. Harvard Business Review, 73(5), 120-134.

Rogelj, J., et al. (2019), The Paris agreement: An analysis of NDCs and their implications. Nature Climate Change, 9(8), 765-773.

Sadorsky, P. (2009), Renewable energy consumption and income in emerging economies. Energy Policy, 37(10), 4021-4028.

Shahbaz, M., Ozturk, I., Afza, T., Ali, A. (2013). Revisiting the environmental Kuznets curve in a global economy. Renewable and Sustainable Energy Reviews, 25, 494–502.

Stern, D.I. (2004), The rise and fall of the Environmental Kuznets Curve. World Development, 32(8), 1419-1439.

Stern, D.I. (2011), The economics of climate change. Review of Environmental Economics and Policy, 5(2), 1-15.

Stern, N. (2007), The Economics of Climate Change: The Stern Review. Cambridge: Cambridge University Press.

Stiglitz, J.E. (2017), The economics of climate change. Journal of Economic Perspectives, 31(2), 3-18.

United Nations. (1992). United Nations Framework Convention on Climate Change. United Nations Treaty Series, 1771, 107. Available from: https://unfccc.int/resource/docs/convkp/conveng.pdf

United Nations. (1998). Kyoto Protocol to the United Nations Framework Convention on Climate Change. United Nations Treaty Series, 2303, 148. Available from: https://unfccc.int/resource/docs/convkp/kpeng.pdf

UN Climate Change. (2022), Climate Plans Remain Insufficient: More Ambitious Action Needed Now. Available from: https://unfccc.int/news/climate-plans-remain-insufficient-more-ambitious-action-needed-now

UN Environment Programme. (2024), Emissions Gap Report 2024. Available from: https://www.unep.org/resources/emissions-gap-report-2024

Victor, P.A. (2011), The Politics of Climate Change: The Kyoto Protocol and Beyond. Cambridge: Cambridge University Press.

Wang, S., et al. (2016), Renewable energy policies and their impact on renewable energy consumption in the European Union. Energy Policy, 94, 33-42.

World Bank. (2024), World Development Indicators. World Bank Group. Available from: https://databank.worldbank.org/source/world-development-indicators

Yamagata, T., Pesaran, M.H. (2012), A test for homogeneity of slope coefficients in the panel data models with cross-section dependence. Journal of Econometrics, 165(1), 126-136.