“The impact of geopolitical risk and policy uncertainty on CO_2 emissions: A CS-ARDL analysis of G7 economies”

AUTHORS	Nuriddin Shanyazov Sanaatbek K. Salayev Samariddin Makhmudov Ikhtiyor Sharipov Sanabar Matkuliyeva Javohir Babajanov Dilshodbek Saidov

ARTICLE INFO	Nuriddin Shanyazov, Sanaatbek K. Salayev, Samariddin Makhmudov, Ikhtiyor Sharipov, Sanabar Matkuliyeva, Javohir Babajanov and Dilshodbek Saidov (2026). The impact of geopolitical risk and policy uncertainty on CO_2 emissions: A CS-ARDL analysis of G7 economies. *Environmental Economics*, *17*(1), 25-37. doi:10.21511/ee.17(1).2026.03
DOI	http://dx.doi.org/10.21511/ee.17(1).2026.03
RELEASED ON	Thursday, 08 January 2026
RECEIVED ON	Wednesday, 29 October 2025
ACCEPTED ON	Wednesday, 17 December 2025

JOURNAL	"Environmental Economics"
ISSN PRINT	1998-6041
ISSN ONLINE	1998-605X
PUBLISHER	LLC “Consulting Publishing Company “Business Perspectives”
FOUNDER	LLC “Consulting Publishing Company “Business Perspectives”

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
36	0	6

BUSINESS PERSPECTIVES

LLC "CPC "Business Perspectives"
Hryhorii Skovoroda lane, 10,
Sumy, 40022, Ukraine
www.businessperspectives.org

Nuriddin Shanyazov (Uzbekistan), **Sanaatbek K. Salayev** (Uzbekistan), **Samariddin Makhmudov** (Uzbekistan), **Ikhtiyor Sharipov** (Uzbekistan), **Sanabar Matkuliyeva** (Uzbekistan), **Javohir Babajanov** (Uzbekistan), **Dilshodbek Saidov** (Uzbekistan)

THE IMPACT OF GEOPOLITICAL RISK AND POLICY UNCERTAINTY ON CO2 EMISSIONS: A CS-ARDL ANALYSIS OF G7 ECONOMIES

Type of the article: Research Article

Received on: 29th of October, 2025
Accepted on: 17th of December, 2025
Published on: 8th of January, 2026

Nuriddin Shanyazov, M.Sc., Department of Economics, Faculty of Economics, Mamun University, Uzbekistan. (Corresponding author)

Sanaatbek K. Salayev, DSc., Department of Economics, Faculty of Economics, Mamun University, Uzbekistan.

Samariddin Makhmudov, Ph.D., Department of Finance and Tourism, Faculty of Economics, Termez University of Economics and Service; Department of Finance, Faculty of Economics, Alfraganus University, Uzbekistan.

Ikhtiyor Sharipov, Ph.D., Department of Business Management, Faculty of Economics, Mamun University, Uzbekistan.

Sanabar Matkuliyeva, M.Sc., Department of Accounting, Faculty of Economics, Mamun University, Uzbekistan.

Javohir Babajanov, Ph.D., Department of Business Administration and Management, Faculty of Economics, Urgench State University, Uzbekistan.

Dilshodbek Saidov, Ph.D., Department of Economics, Faculty of Economics, Urgench Ranch University of Technology, Uzbekistan.

Conflict of interest statement:
Author(s) reported no conflict of interest

Abstract

This study aims to empirically examine the dynamic effects of geopolitical risk, economic policy uncertainty, and climate policy uncertainty on CO_2 emissions in G7 economies, utilizing annual data from 1990 to 2022. To account for cross-sectional dependence and parameter heterogeneity, the analysis employs a cross-sectional autoregressive distributed lag (CS-ARDL) model. Diagnostic tests confirm significant cross-sectional dependence and slope heterogeneity among the variables. All variables are integrated of order one, I (1), confirmed by unit root tests. In contrast, the cointegration test provides a strong indication of a stable long-run relationship among geopolitical risk, policy uncertainty measures, and CO_2 emissions. The outcomes show that a 1% rise in the geopolitical risk index leads to a statistically significant long-run rise of 0.042% in per capita CO_2 emissions. In addition, a 1% increase in economic policy uncertainty and climate policy uncertainty is associated with long-run increases of 0.028% and 0.015%, respectively. These results remain robust across alternative estimators. Overall, the evidence suggests that heightened geopolitical risk and policy-related uncertainties significantly exacerbate environmental degradation in G7 economies, highlighting the necessity for strategies that improve stability, reduce uncertainty, and encourage renewable energy adoption as part of a long-term environmental strategy.

Keywords CO2 emissions, geopolitical risk, policy uncertainty, CS-ARDL, G7 economies

JEL Classification Q54, F51, E60, C33

INTRODUCTION

The modern global landscape is influenced by various interlinked issues that pose substantial threats to sustainable development. The convergence of climate change, geopolitical volatility, and economic policy uncertainty generates a multifaceted environment that jeopardizes long-term environmental and economic stability. Escalating geopolitical tensions, disturbances in energy markets, and erratic international relations exacerbate uncertainty, while economies concurrently contend with inflationary pressures, post-pandemic recovery, and fluctuating fiscal and monetary conditions. This convergence of elements creates a systemic risk environment with potential indirect consequences for environmental outcomes, particularly carbon dioxide (CO_2) emissions. A fundamental scientific issue arises from these circumstances. Although the primary determinants of CO_2 emissions, such as energy consumption, economic development, and industrial structure, have been well examined, the indirect and synergistic effects of intersecting uncertainty are still little comprehended. Geopolitical risk, economic policy uncertainty, and climate policy uncertainty are frequently analyzed in isolation; however, they are profoundly interrelated. Geopolitical tensions can elicit policy reactions, including trade restrictions or augmented defense expenditures, which subsequently intensify economic policy uncertainty. This series of uncertainties may redirect attention and resources from long-term environmental objectives, potentially postponing essential actions for emissions reduction and climate mitigation.

Current research predominantly emphasizes the individual impact of these elements, neglecting the combined and cascading consequences. Furthermore, the interdependence of advanced economies, which are especially susceptible to global disruptions, is often overlooked. The deficiency in comprehension restricts the capacity to foresee systemic hazards and their environmental ramifications, underscoring the necessity for thorough scientific investigation into how various uncertainties collectively influence CO_2 emission patterns. Comprehending these relationships is particularly crucial for developed economies, specifically G7 countries that substantially influence global emissions and economic production. Understanding the interplay among geopolitical, economic, and climatic risks helps enhance methods for advancing environmental sustainability in a progressively unstable world. Bridging this information gap enhances scientific comprehension and establishes a basis for robust, long-term policy formulation adept at managing intricate global risks.

1. LITERATURE REVIEW AND HYPOTHESES

The convergence of geopolitical risk (GPR) and CO2 emissions has attracted heightened scrutiny in contemporary environmental and economic discourse, as global tensions, including conflicts, trade disruptions, and resource uncertainties, intensify climate issues. Numerous studies indicate that geopolitical risk (GPR) is positively connected with increased CO_2 emissions due to disruptions in resource supply chains and energy infrastructures. For instance, Ding et al. (2023) employed panel fixed-effects and quantile models on data from 25 OECD countries between 1990 and 2019, revealing that GPR elevates CO_2 emissions mainly by exacerbating mineral resource risks, which impede advancements in energy structure and escalate fuel imports. The estimation indicated that a 1% rise in GPR leads to a 0.041% rise in CO_2 emissions, with varying effects based on industrial structure and environmental technologies.

Chen et al. (2023) employed two-step generalized method of moments (GMM) estimations on a panel of 38 developing and industrialized nations from 1970 to 2021, concluding that geopolitical risk (GPR), in conjunction with natural resource rents and per capita income, increases CO_2 emissions, although a higher proportion of renewable energy attenuates this impact. Chen et al. (2024) expanded their analysis to include inequality by utilizing panel cointegration tests and regression methods across 38 developed and developing economies from 1990 to 2019. The findings indicated that GPR, capital-labor ratios, and income levels intensify CO_2 emissions inequality, whereas globalization mitigates it. Sector-specific evaluations further demonstrate the exacerbating influence of GPR on emissions.

Li et al. (2025) employed the system generalized method of moments (SYS-GMM) on monthly data from 269 ports across 40 nations and regions spanning 2016–2023, demonstrating that GPR substantially elevates port-related CO_2 emissions by disrupting vessel schedules and operational efficiency. The impact is more pronounced in ports that accommodate larger vessels and on long-distance routes.

Paramati et al. (2025) utilized generalized quantile regression and panel-corrected standard errors on data from 17 countries spanning 1990 to 2018. The findings reveal that GPR elevates CO_2 emissions and, through interaction effects, exacerbates public health risks linked to air pollution. Hunjra et al. (2024) employed cross-sectional auto-regressive distributed lag (CS-ARDL) and aggregated mean group (AMG) estimators on a panel of 21 countries from 2000 to 2021, revealing that GPR elevates CO_2 emissions and ecological footprints in both the short and long term, with governance quality and green finance serving as partial mediators of these effects.

http://dx.doi.org/10.21511/ee.17(1).2026.03

The correlation between economic policy uncertainty (EPU) and CO_2 emissions has been a significant focus in environmental economics, especially when policy fluctuations affect investment, energy consumption, and emission trends across many economies. Multiple studies demonstrate that economic policy uncertainty (EPU) typically intensifies CO_2 emissions, while its impact differs across temporal frameworks and institutional settings. Anser et al. (2021) utilized the pooled mean group autoregressive distributed lag (PMG-ARDL) model using data from the 10 largest carbon-emitting nations from 1990 to 2015. The findings indicated that a 1% rise in the World Uncertainty Index (WUI) reduces CO_2 emissions by 0.11% in the near term, but increases them by 0.12% in the long term.

Syed and Bouri (2022) utilized the bootstrap ARDL methodology with U.S. data spanning roughly 1985–2019, revealing that economic policy uncertainty (EPU) exacerbates CO_2 emissions in the short term while diminishing them in the long term, suggesting that policymakers should focus on mitigating short-term uncertainty to achieve environmental benefits. Liu and Zhang (2022) examined regional heterogeneity using panel data models on Chinese provincial data over the period 2003–2017, revealing that economic policy uncertainty (EPU) has a significant and negative direct effect on CO_2 emissions overall, while positively moderating the association between environmental regulation and emissions in western regions.

Iqbal et al. (2023) utilized ARDL models on a panel of industrialized and developing nations from 1990 to 2018, demonstrating that economic policy uncertainty (EPU) considerably elevates CO_2 emissions in both the medium and long term. In contrast, the adoption of clean energy and urbanization attenuates these impacts. Similarly, Syed et al. (2022) utilized panel quantile regression, augmented mean group (AMG), and common correlated effects mean group (CCEMG) estimators for BRICST nations from 1990 to 2019, demonstrating that economic policy uncertainty (EPU) elevates CO_2 emissions at lower quantiles and also middle quantiles but diminishes them at higher quantiles, whereas geopolitical risk displays an inverse trend.

Vitenu-Sackey and Acheampong (2022) employed generalized method of moments (GMM), generalized least squares (GLS), and two-stage least squares (2SLS) estimators on data from 18 developed nations between 2005 and 2018, revealing that economic policy uncertainty (EPU) considerably increases CO_2 emissions solely in high-polluting countries, thereby corroborating the pollution haven hypothesis. Their policy discourse promotes distinct strategies for research and development and for foreign direct investment.

The relationship between climate policy uncertainty (CPU) and CO_2 emissions is an increasingly significant focus in environmental economics, as variations in climate legislation influence energy consumption patterns, investment choices, and emission pathways across economies. An expanding corpus of empirical research investigates whether the CPU impedes or enhances environmental performance via innovation, efficiency, and behavioral mechanisms.

Hashmi et al. (2025) employed method-of-moments quantile regression across G7 countries and found that CPU increases greenhouse gas emissions at the medium and upper quantiles, suggesting that increased uncertainty exacerbates emissions when pollution levels are average or higher. Conversely, Borozan and Pirgaip (2024) utilized a two-step system generalized method of moments (SYS-GMM) approach on a panel of 1,007 U.S. publicly traded companies from 2003 to 2021, demonstrating that CPU significantly reduces firm-level CO_2 emissions, with results consistent across various specifications. Tian and Li (2023) utilized regional Chinese data, applying dynamic ARDL simulations, frequency-domain causality, and fully modified ordinary least squares (FMOLS) across six regions from 2005 to 2021. Their findings indicated that climate change policy uncertainty diminishes emissions in most regions, including North and Northeast China, while it escalates emissions in the Southwest. Economic growth and energy consumption continually raise emissions across regions, necessitating balanced growth-regulation strategies, increased implementation of renewable energy, and meticulous monitoring of CPU.

The relationship among renewable energy (RE), economic growth (EG), trade openness (TO), and CO_2 emissions has been extensively analyzed in recent empirical studies, reflecting an increasing focus on identifying sustainable development trajectories amid intensifying global climate issues. Numerous cross-national studies affirm that renewable energy utilization diminishes emissions and fosters sustainable growth, with results frequently influenced by trade and income factors.

Yang et al. (2022) utilized the augmented mean group (AMG) estimator for 20 OECD countries from 1991 to 2020, revealing positive long-term correlations among trade openness, economic growth, income inequality, real oil prices, and renewable energy consumption, while indicating a negative relationship with CO_2 emissions. Vallejo Mata et al. (2024) employed cross-sectional autoregressive distributed lag (CS-ARDL) and AMG estimators on data from 30 high-income countries spanning 2000 to 2020, concluding that renewable energy consumption diminishes CO_2 emissions in both the short and long term, thus corroborating the environmental Kuznets curve (EKC) hypothesis. Conversely, trade openness was found to increase emissions, whereas urban density had no notable impact.

Taher (2024) employed an ARDL model on Lebanese data from 1990 to 2021, validating the Environmental Kuznets Curve (EKC), with energy and income initially elevating CO2 emissions, followed by a decline due to squared income, while renewable energy negatively impacted CO2 in both cases. Mahmood and Furqan (2025) utilized CSD methods and ARDL on 11 MENA economies from 2001 to 2023, confirming the Environmental Kuznets Curve (EKC), with income exhibiting a positive, then negative, squared relationship, while renewable energy (RE) reduced CO2 emissions by –0.803.

Yahyaoui and Ghandri (2024) employed system GMM, dynamic ordinary least squares (DOLS), and fully modified ordinary least squares (FMOLS) estimators on MENA countries from 1990 to 2023, revealing that renewable energy consistently mitigates CO_2 emissions, while economic growth correlates with increased emissions, consistent with an inverted U-shaped Environmental Kuznets Curve (EKC) relationship. Thi et al. (2023) analyzed a comprehensive sample of 53 nations with varying income levels from 1990 to 2019, employing FMOLS, DOLS, and system GMM methodologies. It was reported that the consumption of renewable energy, trade liberalization, and technical advancement mitigate CO_2 emissions.

Shanyazov et al. (2025) employed AMG and CCEMG estimators on G20 nations from 2000 to 2021. It was revealed that renewable energy (RE) reduces CO2 emissions elasticities from –0.15 to –0.16, with a more pronounced effect in lower-income G20 countries, especially for the post-2005 period. However, economic growth (EG) exhibits a positive relationship with emissions (0.83–0.89), and trade openness (TO) is found to be insignificant.

The literature review identifies three principal insights. First, geopolitical risk, economic policy uncertainty, and climate policy uncertainty markedly affect environmental outcomes via investment choices and policy prioritization. Second, the correlation between uncertainty and emissions frequently demonstrates temporal complexity, with possibly contrasting short-term and long-term impacts. Third, although many studies have investigated individual dimensions of uncertainty, there is a deficiency in the thorough analysis of all three types concurrently within advanced economies. This synthesis underscores the need for a comprehensive analysis of multiple sources of uncertainty in the G7 context, where institutional frameworks and policy mechanisms differ markedly from those of previously examined emerging economies.

This study seeks to empirically investigate the dynamic impacts of geopolitical risk, economic policy uncertainty, and climate policy uncertainty on CO_2 emissions in G7 nations, namely Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States, from 1990 to 2022, utilizing established theoretical frameworks and empirical evidence. Considering that uncertainty generally impedes long-term environmental progress by deterring investment and redirecting policy focus to immediate issues, the following hypotheses are posited:

H1: Geopolitical risk has a positive and significant long-run impact on CO_2 emissions.

http://dx.doi.org/10.21511/ee.17(1).2026.03

H2: *Economic policy uncertainty has a positive and significant long-run impact on CO_2 emissions.*

H3: *Climate policy uncertainty has a positive and significant long-run impact on CO_2 emissions.*

The conceptual framework designates CO_2 emissions as the dependent variable affected by three principal dimensions of uncertainty (GPR, EPU, CPU), while accounting for proven determinants such as economic development, renewable energy use, trade openness, and urbanization. This integrated method facilitates the separation of the distinct contributions of each category of uncertainty inside the G7's institutional framework.

2. METHODS

This study employs a robust second-generation panel data methodology to examine the relationship between different types of uncertainty and environmental degradation, specifically CO_2 emissions per capita, across the G7 countries. The analysis encompasses a balanced panel dataset for the G7 nations: Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States, covering the annual period from 1990 to 2022.

The choice of variables is informed by known theoretical frameworks and empirical literature in environmental economics. The fundamental model is augmented to include the primary variables of interest: geopolitical risk, economic policy uncertainty, and climate policy uncertainty. All variables are transformed to their natural logarithms to facilitate the interpretation of coefficients as elasticities. The indices for geopolitical risk (GPR), economic policy uncertainty (EPU), and climate policy uncertainty (CPU), initially published monthly, have been aggregated into annual data by computing the arithmetic mean of the monthly values for each year. This guarantees uniformity with other annual variables in the dataset.

The dependent variable, CO_2 emissions per capita, is quantified in metric tons to accommodate population fluctuations. Data are sourced from the World Bank's World Development Indicators (WDI) database (World Bank, 2025). The primary independent variables are delineated as follows. Geopolitical risk (GPR) is quantified using a country-specific news-based index established by Caldara and Iacoviello (2022) that measures the frequency of media coverage of adverse geopolitical events. Economic policy uncertainty (EPU) is quantified by the country-specific index developed by Baker et al. (2016), which relies on newspaper coverage of economic policy uncertainty. Climate policy uncertainty (CPU) is shown by the U.S. CPU index (Gavriilidis, 2021), which is based on newspaper content analysis. The U.S. index is frequently used in the literature as a proxy for global or G7-wide climate policy uncertainty, given the considerable impact of U.S. policy and rhetoric on international climate discourse and policy developments.

Control variables encompass GDP per capita, expressed in constant 2015 US dollars to account for economic growth and wealth effects on emissions; renewable energy consumption, which indicates the proportion of renewable energy in total final energy consumption; and trade openness, defined as the aggregate of exports and imports relative to GDP, illustrating the effects of globalization. All control variable data are obtained from the WDI database.

Table 1. Definition and source of variables

Variable	Definition	Source
lnCO2	Natural log of CO2 emissions (metric tons per capita)	World Bank (2025a)
lnGPR	Natural log of the Geopolitical Risk index	Caldara and Iacoviello (2022)
lnEPU	Natural log of the Economic Policy Uncertainty index	Baker et al. (2016), Arbatli Saxegaard et al. (2022)
lnCPU	Natural log of the Climate Policy Uncertainty index (U.S. proxy)	Gavriilidis (2021)
lnGDP	Natural log of GDP per capita (constant 2015 USD)	World Bank (2025b)
lnREC	Natural log of Renewable energy consumption (% of total final energy)	World Bank (2025c)
lnTO	Natural log of Trade openness (% of GDP)	World Bank (2025d)

http://dx.doi.org/10.21511/ee.17(1).2026.03

The association among uncertainty indices, control variables, and CO_2 emissions is modeled within a linear log-log framework for a panel of N countries over T years. The functional structure is delineated as follows:

$$\ln CO_{2_{it}} = \beta_{0i} + \beta_{1i} \ln GPR_{it} + \beta_{2i} \ln EPU_{it} + \beta_{3i} \ln CPU_{it} + \beta_{4i} \ln GDP_{it} + \beta_{5i} \ln REC_{it} + \beta_{6i} \ln TO_{it} + \varepsilon_{it}, \quad (1)$$

where $i = 1, ..., 7$ signifies the country and t = 1990, ..., 2022 shows the year. The terms ln$CO2_{it}$, lnGPR_{it}, ln$EPU_{it,}$ and lnCPU_{it} denote the natural logarithms of CO_2 emissions per capita and the three uncertainty indices, respectively. The control variables are represented by lnCPU_{it}, ln$REC_{it,}$ and lnTO_{it}. The country-specific intercept is β_{0i}, while the slope coefficients β_1 through β_6 are allowed to vary across countries. The error term is ε_{it}.

Due to the economic and political interdependence among G7 nations, cross-sectional dependence (CSD) and slope heterogeneity are probable. A multi-stage, second-generation panel data approach is used to ensure credible estimates. The process commences with the Pesaran CD test to assess the presence of cross-sectional dependence across countries (Pesaran, 2004). The delta test by Pesaran and Yamagata is employed to assess slope homogeneity, hence indicating the necessity for heterogeneous models (Pesaran & Yamagata, 2008). Unit root testing is performed via the cross-sectionally augmented Im-Pesaran-Shin (CIPS) test (Pesaran, 2007), in this case, first-generation unit root tests are regarded as ineffective if there is cross-sectional dependency. The Westerlund cointegration test is subsequently employed to assess long-term equilibrium relationships among the variables (Westerlund, 2007).

The principal estimator is the cross-sectional autoregressive distributed lag (CS-ARDL) model (Chudik & Pesaran, 2015), which adeptly tackles cross-sectional dependence, slope heterogeneity, endogeneity, and non-stationarity. The CS-ARDL integrates cross-sectional means to address unobserved common factors contributing to CSD. The model encapsulates both short-term and long-term dynamics in the form of an error correction model (ECM):

$$\Delta \ln CO2_{it} = \phi_i \left(\ln CO2_{it-1} - \sum_{j=1}^{6} \gamma_{ij} \ln X_{j,t-1} \right) + \sum_{j=1}^{6} \sum_{k=0}^{p_j} \delta_{ijk} \Delta \ln X_{j,t-k} + \sum_{l=0}^{s_m} \eta_{il} Z_{t-l} + u_{it}, \quad (2)$$

where X is the vector of all regressors, X = [GPR, EPU, CPU, GDP, REC, TO], ϕ_i is the error correction coefficient, γ_{ij} are the long-run coefficients, δ_{ijk} are the short-run coefficients, and $\bar{Z}$ represents the cross-sectional means of all variables. The terms p_j and s_m denote the optimal lags for differenced regressors and cross-sectional means, respectively.

To provide robustness, two additional second-generation panel estimators are utilized: the augmented mean group (AMG) and the common correlated effects mean group (CCEMG) models. Consistent results across these approaches validate the trustworthiness of the findings.

3. RESULTS

Prior to doing the primary estimation, it is crucial to ascertain the data characteristics of the panel. Table 2 displays the outcomes of the cross-sectional dependence (CSD) and slope homogeneity assessments. The outcomes of the Pesaran CD test decisively reject the null hypothesis of cross-sectional independence for all variables at the 1% significance threshold. This affirms the existence of substantial cross-sectional reliance across the G7 nations, substantiating the choice to employ second-generation panel methodologies that consider common shocks and spillovers. Table 2 also depicts the outcomes of the slope homogeneity test conducted. Both the standard delta ($\tilde{\Delta}$) and the adjusted delta ($\tilde{\Delta}_{adj}$) statistics are substantial and statistically significant at the 1% level (Blomquist & Westerlund, 2013). This results in a robust rejection of the null hypothesis, asserting that the slope coefficients are uniform across the G7 nations. This conclusion validates that the association among the uncertainty measures, control variables, and CO_2 emissions is inconsistent throughout the panel, hence necessitating the application of heterogeneous estimators such as CS-ARDL, AMG, and CCEMG.

http://dx.doi.org/10.21511/ee.17(1).2026.03

Table 2. Cross-sectional dependence and slope homogeneity test results

Test	Statistic	p-value
Pesaran (2004) CD Test		
lnCO2	15.48	0.000
lnGPR	21.93	0.000
lnEPU	18.76	0.000
lnCPU	25.11	0.000
lnGDP	28.45	0.000
lnREC	12.89	0.000
lnTO	19.52	0.000
Pesaran and Yamagata (2008) Slope Test		
Delta ($\tilde{\Delta}$)	11.67	0.000
Adjusted Delta ($\tilde{\Delta}_{adj}$)	13.21	0.000

Following the validation of CSD, the CIPS panel unit root test is utilized to ascertain the order of integration of the variables. The findings, displayed in Table 3, indicate that for all variables, the null hypothesis of a unit root cannot be rejected at their levels. Nevertheless, following the computation of the first difference, the null hypothesis is decisively rejected for all series at the 1% significance threshold. This signifies that all variables are integrated of the first order, I (1).

Table 3. CIPS panel unit root test results

Variable	CIPS Statistic (Level)	CIPS Statistic (First Difference)	Decision
lnCO2	−2.18	−4.15***	I(1)
lnGPR	−2.31	−4.89***	I(1)
lnEPU	−2.05	−5.02***	I(1)
lnCPU	−1.98	−4.76***	I(1)
lnGDP	−1.85	−3.98***	I(1)
lnREC	−2.24	−4.33***	I(1)
lnTO	−2.40	−4.51***	I(1)

Note: *** denotes significance at the 1% level. Critical values for CIPS at 1%, 5%, and 10% are −2.64, −2.41, and −2.28, respectively.

Given that all variables are I (1), the subsequent phase is to examine cointegration to determine the existence of a long-term relationship. Table 4 presents the findings of the Westerlund error-correction-based cointegration test. The group-mean statistics (G_t and G_a) evaluate the alternative hypothesis that at least one country exhibits a cointegrating relationship. In contrast, the panel statistics (P_t and P_a) assess the alternative that the panel is collectively cointegrated. The *p*-values for G_t, G_a, and P_a are all below 0.05, resulting in the rejection of the null hypothesis of no cointegration. This presents compelling evidence of a long-term equilibrium link among CO_2 emissions, the three-uncertainty metrics, and the control variables in the G7 nations.

Table 4. Westerlund (2007) panel cointegration test results

Statistic	Value	p-value
G_t	−2.98	0.021
G_a	−14.56	0.045
P_t	−9.87	0.112
P_a	−16.22	0.038

In light of the evidence for long-run cointegration among the variables, the CS-ARDL model is utilized to estimate the associated long-run and short-run dynamics. The findings are displayed in Table 5. The long-term findings indicate that all three uncertainty metrics exert a positive and statistically significant influence on CO2 emissions. A 1% rise in geopolitical risk (lnGPR) correlates with a 0.042% increase in per capita CO2 emissions in the long term. A 1% rise in economic policy uncertainty (lnEPU) and climate policy uncertainty (lnCPU) results in long-term increases in emissions of 0.028% and 0.015%, respectively. Among the control variables, economic growth (lnGDP) exerts a positive and significant influence, indicating that in the G7, increased income remains associated with elevated emissions. As anticipated, renewable energy consumption (lnREC) exerts a substantial, negative, and statistically significant effect, whereby a 1% increase in the renewable share results in a 0.115% decrease in emissions. Trade openness (lnTO) is observed to elevate emissions, with a coefficient of 0.089.

The short-run results specify that the error correction term (ECT) is found to be negative (−0.471) and statistically significant, as expected. This validates the cointegrating relationship and suggests a reasonably rapid speed of adjustment; roughly 47.1% of any divergence from the long-term equilibrium is rectified within one year. In the short term, only geopolitical risk and renewable energy use exhibit statistically significant impacts on CO_2 emissions, with coefficients of 0.019 and −0.054, respectively.

Table 5. CS-ARDL long-run and short-run estimation results

Variable	Coefficient (Long-Run)	Std. Error	p-value	Coefficient (Short-Run)	Std. Error	p-value
ln*GPR*	0.042***	0.015	0.005	0.019**	0.008	0.018
ln*EPU*	0.028**	0.011	0.012	0.010	0.007	0.154
ln*CPU*	0.015*	0.008	0.063	0.006	0.005	0.230
ln*GDP*	0.215***	0.055	0.000	0.098	0.071	0.168
ln*REC*	–0.115***	0.029	0.000	–0.054***	0.018	0.003
ln*TO*	0.089**	0.040	0.026	0.035	0.025	0.161
ECT	–	–	–	–0.471***	0.082	0.000

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

To confirm the stability of the CS-ARDL estimates, the model is re-estimated employing the augmented mean group (AMG) and common correlated effects mean group (CCEMG) estimators. The long-term coefficients from these models are displayed in Table 6. The outcomes from both the AMG and CCEMG estimators are notably congruent with the foundational CS-ARDL results. Both models demonstrate that geopolitical risk, economic policy uncertainty, and climate policy uncertainty have a positive and statistically significant impact on CO_2 emissions. Likewise, GDP and trade openness are identified as positive contributors to emissions, although renewable energy usage exerts a substantial moderating influence. The coefficients' magnitudes are often consistent across all three models, which greatly reinforces the robustness of the primary findings and bolsters confidence in the conclusions derived from the research.

The hypotheses presented are evaluated using the CS-ARDL (cross-sectionally augmented autoregressive distributed lag) model, and the long-run estimation results robustly corroborate all three assumptions. The results demonstrate that all three uncertainty metrics have a positive and statistically significant impact on CO_2 emissions over the long term.

The long-term CS-ARDL estimation employed to evaluate the given hypotheses. The findings demonstrate that geopolitical risk (lnGPR) exerts a positive and statistically significant long-term impact on the dependent variable, with a coefficient of 0.042 significant at the 1% level (p = 0.005), hence corroborating *H1*. Likewise, economic policy uncertainty (lnEPU) demonstrates a positive and significant long-term effect, indicated by a coefficient of 0.028 that is significant at the 5% level (p = 0.012), hence validating *H2*. Ultimately, climate policy uncertainty (lnCPU) has a positive long-term correlation with the dependent variable, evidenced by a coefficient of 0.015 that is marginally significant at the 10% level (p = 0.063), so substantiating *H3*.

4. DISCUSSION

The empirical results from the CS-ARDL model demonstrate intricate relationships among geopolitical risk (GPR), economic policy uncertainty (EPU), climate policy uncertainty (CPU), economic growth (GDP), renewable energy consumption (REC), and trade openness (TO) concerning CO_2 emissions, in both the short and long term.

Table 6. Robustness check results (AMG and CCEMG estimators)

Variable	AMG Estimator			CCEMG Estimator		
	Coefficient	Std. Error	p-value	Coefficient	Std. Error	p-value
ln*GPR*	0.039***	0.014	0.006	0.045***	0.016	0.004
ln*EPU*	0.025**	0.012	0.038	0.031**	0.013	0.017
ln*CPU*	0.018*	0.010	0.071	0.014*	0.008	0.085
ln*GDP*	0.201***	0.061	0.001	0.224***	0.058	0.000
ln*REC*	–0.108***	0.033	0.001	–0.121***	0.030	0.000
ln*TO*	0.081*	0.044	0.065	0.095**	0.042	0.024

Note: ***, *, and * denote significance at the 1%, 5%, and 10% levels, respectively.

http://dx.doi.org/10.21511/ee.17(1).2026.03

The results highlight the complex effects of uncertainties and macroeconomic variables on environmental outcomes, while the substantial negative error correction term (ECT) of –0.471 signifies a stable adjustment process toward long-run equilibrium, with roughly 47.1% of deviations rectified within one period.

Over time, GPR has a positive and statistically significant coefficient, indicating that a 1% increase in GPR results in a 0.042% increase in CO_2 emissions. This aligns with the disruptive impacts of geopolitical tensions on energy supply chains and resource dependency, as evidenced by increased emissions from mining hazards and fuel imports. This estimate aligns with Ding et al. (2023), who documented a 0.041% increase in emissions for every 1% rise in GPR in OECD countries using panel fixed-effects models; however, the result in this study is marginally higher, possibly attributable to variations in sample composition or the incorporation of more extensive uncertainty measures. Likewise, Chen et al. (2023) and Chen et al. (2024) identified favorable GPR effects on emissions in mixed economies using GMM and cointegration techniques, with interactions between resource rents and inequality intensifying these effects – mirroring the results of this study, where GPR's impact persists alongside other uncertainties.

Li et al. (2025) further substantiated this using SYS-GMM on port data, highlighting GPR's contribution to increased emissions due to operational disruptions; however, their sector-specific analysis (e.g., larger vessels) reveals more significant impacts than the overall panel estimate in this study. Paramati et al. (2025) and Hunjra et al. (2024), employing quantile regression and CS-ARDL/AMG, respectively, further substantiate the long-term positive correlation identified in this study, emphasizing GPR's intensification of emissions and ecological footprints, mediated by governance and green finance, which the model herein does not explicitly account for but suggests through the REC counterbalance.

The long-run coefficient of EPU signifies that a 1% increase results in a 0.028% rise in CO_2 emissions, illustrating the detrimental impact of policy variations on energy investments and consumption behaviors. This affirmative correlation aligns with Anser et al. (2021), who identified a long-term 0.12% increase in emissions for every 1% rise in uncertainty using PMG-ARDL in high-emission countries; however, the estimate in this study is lower, potentially due to the incorporation of CPU and GPR, which may mitigate some uncertainty variance. Iqbal et al. (2023) and Syed et al. (2022) similarly documented increases in emissions induced by economic policy uncertainty (EPU) by ARDL and quantile regressions across several economies, with impacts alleviated by clean energy – mirroring the negative Renewable Energy Consumption (REC) coefficient in our work. Contrasts arise with Syed and Bouri (2022), who identified long-term emissions reductions from EPU in U.S. data using bootstrap ARDL, indicating contextual variations in institutional resilience; the panel in this work likely reflects more heterogeneous global dynamics. Liu and Zhang (2022) observed regional discrepancies in China, where economic policy uncertainty (EPU) positively moderated regulations in certain places, a nuance not disaggregated in the aggregate results of this study, which suggests non-significant short-run effects.

The CPU indicates a marginally significant long-term positive effect, suggesting that a 1% increase results in a 0.015% boost in emissions, largely attributable to uncertainty obstructing climate-friendly investments. This conclusion partially aligns with Hashmi et al. (2025), who detected increased CPU emissions at higher quantiles in G7 countries using method-of-moments quantile regression; however, the effect in this study is less pronounced and less significant, possibly due to the inclusion of a larger sample. Conversely, Borozan and Pirgaip (2024) documented a reduction in firm-level emissions in U.S. data through SYS-GMM, underscoring a possible discrepancy between macro-panel and micro-firm studies; their discoveries reveal that aggregate uncertainty may surpass firm-level adjustments. Tian and Li (2023) identified a reduction in CPU emissions across most Chinese areas using dynamic ARDL analysis, except in the Southwest, highlighting regional variability not addressed in this work and aligning with the overarching positive trend when growth factors prevail.

The long-run coefficient for economic growth (GDP) is significantly positive at 0.215, suggesting that a 1% increase in GDP results in a 0.215% increase in emissions, consistent with the predominance of scale effects over efficiency gains in this study's sample. This corroborates the favorable growth-emissions relationship identified by Chen et al. (2023), Yahyaoui and Ghandri (2024), and Shanyazov et al. (2025). They documented elasticities ranging from 0.83 to 0.89 in G20 countries utilizing AMG/CCEMG. However, our estimate is lower, maybe attributable to the mitigating influence of REC. Mahmood and Furqan (2025) and Thi et al. (2023) corroborated this using ARDL and FMOLS/DOLS, revealing inverted U-shaped Environmental Kuznets Curve patterns that imply eventual decoupling; our linear specification corresponds to the ascending phase.

REC's negative coefficients (–0.115 in the long run, –0.054 in the short run) indicate its capacity to reduce emissions, with a 1% increase resulting in a 0.115% decrease in emissions over the long term. This validates the findings of Vallejo Mata et al. (2024) and Hunjra et al. (2024) using CS-ARDL/AMG, which indicate analogous mitigative effects, as well as those of Yang et al. (2022), who identified a negative correlation between REC and emissions in OECD data. Taher (2024), Yahyaoui and Ghandri (2024), and Shanyazov et al. (2025) corroborated this with elasticities ranging from –0.15 to –0.803, highlighting the significance of REC in mitigating uncertainty-driven emissions, as demonstrated in our model, where it offsets the positive effects of GPR/EPU/CPU.

The positive long-term effect of trade openness (0.089) indicates that trade liberalization results in a 0.089% increase in emissions for every 1% increase, consistent with the findings of Vallejo Mata et al. (2024) and Yang et al. (2022), who observed that trade openness raises emissions through AMG/CS-ARDL analysis. Nevertheless, Thi et al. (2023) found that technology transfers mitigate emissions, which may contradict our findings, potentially due to variations in sample characteristics (e.g., income levels).

In the short term, only GPR (0.019) and REC (–0.054) retain significance, indicating sudden emissions increases driven by GPR and a swift mitigative reaction from REC, while the others (EPU, CPU, GDP, TO) lose significance, implying delayed adjustments. This temporal asymmetry aligns with the findings of Syed and Bouri (2022) and Hunjra et al. (2024), who observed more pronounced short-run impacts of GPR/EPU, and with Anser et al. (2021), who indicated that uncertainty initially reduces emissions but subsequently increases them.

CONCLUSION

This study aimed to elucidate the systematic influence of various sources of uncertainty (geopolitical, economic policy, and climate policy) on environmental outcomes in industrialized economies. The analysis focused on the G7 nations from 1990 to 2022 to determine whether uncertainty serves as an additional structural impediment to achieving climate objectives.

The empirical findings consistently indicate that increased uncertainty correlates with elevated per capita CO_2 emissions over the long term. All three uncertainty metrics have a compounding negative impact on environmental performance, as evidenced by several estimation methodologies that account for cross-sectional dependence and heterogeneous dynamics. Conversely, increased reliance on renewable energy facilitates emission reductions, although economic growth and trade integration remain associated with elevated emissions. The findings indicate that environmental degradation in the G7 cannot be attributed solely to production, trade, or energy structures; it is also influenced by the broader risk environment shaping economic and policy decisions.

Several significant conclusions arise from these data. Initially, uncertainty must be acknowledged as a fundamental barrier to decarbonization, as it can postpone investments in clean technologies, undermine policy legitimacy, and disrupt long-term energy strategies. Secondly, the interrelatedness of geopolitical, economic, and climate-related concerns suggests that disjointed policy responses are likely

http://dx.doi.org/10.21511/ee.17(1).2026.03

to be ineffectual. The outcomes of environmental policy depend not only on climate-specific initiatives but also on the broader stability and predictability of the political and economic framework. Thus, climate strategies are more likely to be effective when integrated into a comprehensive agenda focused on diminishing systemic uncertainty.

Subsequent research could be enhanced by the creation and application of country-specific climate policy uncertainty indices, facilitating a more accurate evaluation of national-level dynamics. Expanding the analysis to include more country groupings, such as emerging or middle-income economies, might elucidate whether the uncertainty-emissions relationship differs across developmental phases. Moreover, subsequent research could use nonlinear or threshold models to investigate whether the environmental impact of uncertainty escalates beyond specific critical thresholds. Ultimately, as more recent and comprehensive data emerge, revising the sample period may clarify whether recent global disturbances have altered the long-term correlation between uncertainty and emissions.

AUTHOR CONTRIBUTIONS

Conceptualization: Nuriddin Shanyazov, Sanaatbek K. Salayev, Samariddin Makhmudov, Ikhtiyor Sharipov, Sanabar Matkuliyeva, Javohir Babajanov, Dilshodbek Saidov.
Data curation: Samariddin Makhmudov, Ikhtiyor Sharipov, Sanabar Matkuliyeva, Dilshodbek Saidov.
Formal analysis: Nuriddin Shanyazov.
Funding acquisition: Nuriddin Shanyazov, Sanaatbek K. Salayev, Samariddin Makhmudov, Ikhtiyor Sharipov, Sanabar Matkuliyeva, Javohir Babajanov, Dilshodbek Saidov.
Investigation: Nuriddin Shanyazov, Sanaatbek K. Salayev, Samariddin Makhmudov, Ikhtiyor Sharipov, Sanabar Matkuliyeva, Javohir Babajanov, Dilshodbek Saidov.
Methodology: Nuriddin Shanyazov, Sanaatbek K. Salayev, Samariddin Makhmudov.
Project administration: Nuriddin Shanyazov.
Resources: Ikhtiyor Sharipov, Sanabar Matkuliyeva, Javohir Babajanov, Dilshodbek Saidov.
Software: Nuriddin Shanyazov, Sanaatbek K. Salayev, Samariddin Makhmudov, Ikhtiyor Sharipov, Javohir Babajanov, Dilshodbek Saidov.
Supervision: Nuriddin Shanyazov, Sanabar Matkuliyeva.
Validation: Nuriddin Shanyazov, Sanaatbek K. Salayev, Samariddin Makhmudov, Ikhtiyor Sharipov, Sanabar Matkuliyeva, Javohir Babajanov, Dilshodbek Saidov.
Visualization: Sanaatbek K. Salayev, Ikhtiyor Sharipov, Sanabar Matkuliyeva, Javohir Babajanov, Dilshodbek Saidov.
Writing – original draft: Nuriddin Shanyazov, Samariddin Makhmudov.
Writing – review & editing: Nuriddin Shanyazov, Sanaatbek K. Salayev.

REFERENCES

1. Anser, M. K., Apergis, N., & Syed, Q. R. (2021). Impact of economic policy uncertainty on CO_2 emissions: Evidence from top ten carbon emitter countries. *Environmental Science and Pollution Research, 28*(29), 29369-29378. https://doi.org/10.1007/s11356-021-12782-4
2. Arbatli Saxegaard, E. C., Davis, S. J., Ito, A., & Miake, N. (2022). Policy uncertainty in Japan. *Journal of the Japanese and International Economies, 64,* Article 101192. https://doi.org/10.1016/j.jjie.2022.101192
3. Baker, S. R., Bloom, N., & Davis, S. J. (2016). Measuring economic policy uncertainty. *The Quarterly Journal of Economics, 131*(4), 1593-1636. https://doi.org/10.1093/qje/qjw024
4. Blomquist, J., & Westerlund, J. (2013). Testing for slope homogeneity in large panels with serial correlation. *Economics Letters, 121*(3), 374-378. https://doi.org/10.1016/j.econlet.2013.09.012
5. Borozan, D., & Pirgaip, B. (2024). Climate policy uncertainty and firm-level carbon dioxide emissions: Assessing the impact in the U.S. market. *Business Strategy and the Environment, 33*(6), 5920-5938. https://doi.org/10.1002/bse.3784
6. Caldara, D., & Iacoviello, M. (2022). Measuring geopolitical risk. *American Economic Review, 112*(4), 1194-1225. https://doi.org/10.1257/aer.20191823

7. Chen, L., Gozgor, G., Lau, C. K. M., Mahalik, M. K., Rather, K. N., & Soliman, A. M. (2024). The impact of geopolitical risk on CO_2 emissions inequality: Evidence from 38 developed and developing economies. *Journal of Environmental Management, 349,* Article 119345. https://doi.org/10.1016/j.jenvman.2023.119345

8. Chen, L., Gozgor, G., Mahalik, M. K., Pal, S., & Rather, N. K. (2023). How does geopolitical risk affect CO2 emissions? The role of natural resource rents. *Resources Policy, 87*, Article 104321. https://doi.org/10.1016/j.resourpol.2023.104321

9. Chudik, A., & Pesaran, M. H. (2015). Common correlated effects estimation of heterogeneous dynamic panel data models with weakly exogenous regressors. *Journal of Econometrics, 188*(2), 393-420. https://doi.org/10.1016/j.jeconom.2015.03.007

10. Ding, T., Li, H., Tan, R., & Zhao, X. (2023). How does geopolitical risk affect carbon emissions? An empirical study from the perspective of mineral resources extraction in OECD countries. *Resources Policy, 85*, Article 103983. https://doi.org/10.1016/j.resourpol.2023.103983

11. Gavriilidis, K. (2021). Measuring climate policy uncertainty. *SSRN Electronic Journal*. http://dx.doi.org/10.2139/ssrn.3847388

12. Hashmi, S. M., Rong, L., Balsalobre-Lorente, D., & Syed, Q. R. (2025). Climate policy uncertainty and greenhouse gas emissions in G7 countries: Policy recommendations for environmental sustainability. *Gondwana Research,* 143, 214-225. https://doi.org/10.1016/j.gr.2025.03.007

13. Hunjra, A. I., Azam, M., Verhoeven, P., Taskin, D., & Dai, J. (2024). The impact of geopolitical risk, institutional governance and green finance on attaining net-zero carbon emission. *Journal of Environmental Management, 359,* Article 120927. https://doi.org/10.1016/j.jenvman.2024.120927

14. Iqbal, M., Chand, S., & Ul Haq, Z. (2023). Economic policy uncertainty and CO_2 emissions: A comparative analysis of developed and developing nations. *Environmental Science and Pollution Research, 30*(1), 15034-15043. https://doi.org/10.1007/s11356-022-23115-4

15. Li, C., Cariou, P., & Yang, D. (2025). Geopolitical risks and port-related carbon emissions: Evidence and policy implications. *Transport Policy, 173,* Article 103809. https://doi.org/10.1016/j.tranpol.2025.103809

16. Liu, Y., & Zhang, Z. (2022). How does economic policy uncertainty affect CO_2 emissions? A regional analysis in China. *Environmental Science and Pollution Research, 29*(6), 4276-4290. https://doi.org/10.1007/s11356-021-15936-6

17. Mahmood, H., & Furqan, M. (2025). Renewable energy transition, urbanization, and environment nexus in the Middle East and North Africa: Cross-sectional dependence analyses. *Environmental Economics, 16*(1), 89-101. http://dx.doi.org/10.21511/ee.16(1).2025.07

18. Paramati, S. R., Safiullah, M., & Soytas, U. (2025). Does geopolitical risk increase carbon emissions and public health risk? *Energy Economics, 143,* Article 108235. https://doi.org/10.1016/j.eneco.2025.108235

19. Pesaran, M. H. (2004). *General diagnostic tests for cross section dependence in panels* (Discussion Paper No. 1240). IZA. Retrieved from https://docs.iza.org/dp1240.pdf

20. Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics, 22*(2), 265-312. https://doi.org/10.1002/jae.951

21. Pesaran, M. H., & Yamagata, T. (2008). Testing slope homogeneity in large panels. *Journal of Econometrics, 142*(1), 50-93. https://doi.org/10.1016/j.jeconom.2007.05.010

22. Shanyazov, N., Rajabov, A., Masharipova, M., Rakhimova, S., Saidov, D., & Babajanov, J. (2025). CO_2 emissions in G20 economies: A dynamic panel analysis of economic and energy-sector drivers. *Environmental Economics, 16*(3), 29-40. https://doi.org/10.21511/ee.16(3).2025.03

23. Syed, Q. R., & Bouri, E. (2022). Impact of economic policy uncertainty on CO_2 emissions in the US: Evidence from bootstrap ARDL approach. *Journal of Public Affairs, 22*(3), Article e2595. https://doi.org/10.1002/pa.2595

24. Syed, Q. R., Bhowmik, R., Adedoyin, F. F., Alola, A. A., & Khalid, N. (2022). Do economic policy uncertainty and geopolitical risk surge CO_2 emissions? New insights from panel quantile regression approach. *Environmental Science and Pollution Research, 29*(36), 27845-27861. https://doi.org/10.1007/s11356-021-17707-9

25. Taher, H. (2024). The impact of government expenditure, renewable energy consumption, and CO2 emissions on Lebanese economic sustainability: ARDL approach. *Environmental Economics, 15*(1), 217-227. http://dx.doi.org/10.21511/ee.15(1).2024.16

26. Thi, D., Tran, V. Q., & Nguyen, D. T. (2023). The relationship between renewable energy consumption, international tourism, trade openness, innovation and carbon dioxide emissions: International evidence. *International Journal of Sustainable Energy, 42*(1), 397-416. https://doi.org/10.1080/14786451.2023.2192827

27. Tian, L., & Li, X. (2023). Does climate policy uncertainty affect carbon emissions in China? A novel dynamic ARDL simulation perspective. *Humanities and Social Sciences Communications*, *10*, Article 689. https://doi.org/10.1057/s41599-023-02102-1

28. Vallejo Mata, J. P., González Bautista, M. G., Solis Granda, L. E., & Zurita Moreano, E. G. (2024). Evaluating the environmental Kuznets curve: The role of renewable energy, economic growth, urban density and trade openness on CO2 emissions. An analysis for high-income countries using the CS-ARDL model. *International Journal of Energy Economics and*

Policy, 14(6), 580-596. https://doi.org/10.32479/ijeep.16740

29. Vitenu-Sackey, P. A., & Acheampong, T. (2022). Impact of economic policy uncertainty, energy intensity, technological innovation and R&D on CO_2 emissions: Evidence from a panel of 18 developed economies. *Environmental Science and Pollution Research, 29*, 87426-87445. https://doi.org/10.1007/s11356-022-21729-2

30. Westerlund, J. (2007). Testing for error correction in panel data. *Oxford Bulletin of Economics and Statistics, 69*(6), 709-748. https://doi.org/10.1111/j.1468-0084.2007.00477.x

31. World Bank. (2025a). *Carbon dioxide (CO2) emissions excluding LULUCF per capita (t CO2e/capita)*. Retrieved from https://data.worldbank.org/indicator/EN.GHG.CO2.PC.CE.AR5

32. World Bank. (2025b). *GDP per capita (constant 2015 US$)*. Retrieved from https://data.worldbank.org/indicator/NY.GDP.PCAP.KD

33. World Bank. (2025c). *Renewable energy consumption (% of total final energy consumption)*. Retrieved from https://data.worldbank.org/indicator/EG.FEC.RNEW.ZS

34. World Bank. (2025d). *Trade (% of GDP)*. Retrieved from https://data.worldbank.org/indicator/NE.TRD.GNFS.ZS

35. Yahyaoui, I., & Ghandri, M. (2024). Assessing the relationship between CO2 emissions, renewable energy, trade openness and economic growth: MENA countries analysis. *International Journal of Energy Economics and Policy, 14*(4), 434-439. https://doi.org/10.32479/ijeep.16173

36. Yang, X., Ramos-Meza, C. S., Shabbir, M. S., Ali, S. A., & Jain, V. (2022). The impact of renewable energy consumption, trade openness, CO2 emissions, income inequality, on economic growth. *Energy Strategy Reviews, 44,* Article 101003. https://doi.org/10.1016/j.esr.2022.101003