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(2), 465-473.

The Role of Institutional Quality in Renewable Energy Transition: A Panel CS-ARDL Analysis of MIKTA countries

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Received: 13 October 2025 **Accepted:** 24 January 2026 **DOI:** https://doi.org/10.32479/ijeep.22745

ABSTRACT

This study investigates the role of institutional quality in driving the renewable energy transition in MIKTA countries (Mexico, Indonesia, Republic of Korea, Türkiye, and Australia) over the period 2000–2023. Second-generation panel econometric techniques are employed to address slope heterogeneity and cross-sectional dependence, as confirmed by Pesaran CD and slope homogeneity tests. The analysis applies the Cross-Sectionally Augmented ARDL (CS-ARDL) approach alongside the Westerlund cointegration test to establish a stable long-run relationship among the variables. Long-run results reveal that institutional quality significantly enhances renewable energy consumption per capita. Specifically, a one-unit increase in Control of Corruption raises renewable energy use by approximately 2.34%, while Political Stability increases it by 1.63%. Economic growth also exerts a positive influence, with a GDP per capita elasticity of 0.87. Short-run dynamics indicate a significant error correction term (−0.372), implying that 37.2% of deviations from long-run equilibrium are corrected annually. Robustness checks using CCEMG and AMG estimators confirm the consistency of the findings. Overall, the results underscore the critical importance of institutional reforms in fostering renewable energy investment and achieving sustainable development in MIKTA economies.

Keywords: Renewable Energy Transition, Institutional Quality, Control of Corruption, Political Stability, MIKTA, Panel CS-ARDL
JEL Classifications: O43, Q42, Q48, C33

1. INTRODUCTION

The escalating impacts of international and climate change policy obligations outlined in the United Nations Sustainable Development Goals, in particular 7, 11, 12, and 13 SDGs highlight the pressing necessity for a swift and comprehensive shift to renewable energy (UN, 2015). Effectuating a successful and enduring energy transition involves more than mere technological preparedness or the accessibility of natural resources. A crucial factor is the capacity of nations to attract and retain long-term capital investment, especially from the private sector, as renewable energy projects typically entail significant initial expenditures and prolonged investment periods (Rahman and Sultana, 2022; Halldén et al., 2025). The institutional and governance frameworks of a nation profoundly influence investor confidence, the perceived risk landscape, and the total momentum of the renewable energy transition (Vatamanu et al., 2023; Satrianto et al., 2024).

This study examines the MIKTA countries namely Mexico, Indonesia, Korea, Türkiye, and Australia by utilizing the CS-ARDL approach for the period from 2000 to 2023. MIKTA, as a heterogeneous alliance of middle-power economies, occupies a strategically significant position in global energy governance. These structural disparities provide varied circumstances for renewable energy development within the group, necessitating the application of econometric models capable of differentiating between nation-specific dynamics and overarching cross-sectional dependencies.

Institutional quality is widely acknowledged as a crucial determinant of energy demand and the viability of long-term investments in renewable energy infrastructure. Inadequate governance frameworks increase the risk associated with energy projects by exacerbating non-market variables, including policy inconsistency, corruption, and political instability. Investments in renewable energy, marked by significant sunk costs and extended payback times, are especially vulnerable to these hazards (Halldén et al., 2025; Vatamanu et al., 2025). Elevated corruption levels augment operational expenses, alter resource distribution, and dissuade both domestic and international direct investment (Satrianto et al. 2024). Similarly, political instability increases investor risk premiums, rendering otherwise feasible renewable energy projects financially unappealing (Vatamanu et al., 2023).

Political Stability and Absence of Violence/Terrorism (PS) as well as Control of Corruption (COC) are mainly focused as two principal governance indicators in this study. The COC indicator measures conceptions concerning the extent to which public authority is exploited for private gain, including both minor and significant forms of corruption (World Bank, 2025). PS, conversely, quantifies the probability of violent occurrences or political instability that may impair economic and investment environments. These variables collectively signify the institutional framework that influences long-term energy planning and investment practices.

An increasing corpus of data underscores that robust institutions markedly improve the efficacy of renewable energy policies and the sustainability of energy transitions (Vatamanu et al., 2024; Iormom et al., 2025; Satrianto et al., 2024). Strong institutional frameworks diminish uncertainty, decrease capital costs, and foster a climate conducive to the implementation of clean energy technology. Moreover, empirical studies reveal that the impact of institutional quality varies among nations. Depending on income level, prior investment history, and political stability, emphasizing the importance of a model that consider cross-sectional dependence and heterogeneity (Adolphus et al., 2025).

This analysis examines the short-term and long-term influence of institutional quality on renewable energy use in MIKTA countries, employing robust econometric methods to address heterogeneity, endogeneity, and cross-sectional dependence. By integrating insights from recent empirical research, the analysis highlights the critical function of governance in fostering the adoption of renewable energy and sustaining energy transition momentum across diverse economic and institutional settings.

2. LITERATURE REVIEW

The adoption of renewable energy is essential for climate mitigation and sustainable development. Researches indicate that governance, political stability, and economic growth are essential in influencing renewable energy consumption. This review consolidates empirical research about these characteristics to elucidate the primary factors influencing renewable energy uptake.

2.1. Control of Corruption and Renewable Energy

Numerous studies have investigated the impact of corruption control on the energy transition by assessing how governance quality affects renewable energy sources. For instance, Camacho Ballesta et al. (2022) examined EU nations (2001–2015) employing a Panel Corrected Standard Error (PCSE) model, revealing that enhanced corruption control favorably affects renewable energy usage, since superior governance mitigates obstacles to renewable energy implementation. Dossou et al. (2023) conducted a study on 37 sub-Saharan African nations from 1996 to 2020 employing the Panel Corrected Standard Errors (PCSE) methodology. The results indicated that governance indices, including corruption control, voice and accountability, rule of law and government effectiveness exert significant positive impacts on RE, with rises of 9.64, 9.08, 10.10, 9.10 units, respectively. Acheampong et al. (2024) examine the impact of wealth redistribution and inequality, corruption on energy consumption both non-renewable and renewable as well as overall consumption in 166 countries through a two-step system-GMM methodology. Results demonstrated that both market (pre-tax) and net (post-tax/transfer) effective corruption control increases all forms of energy consumption, with moderation analysis revealing that this effect is pronounced under stringent corruption control. Vasylieva et al. (2019) utilized panel data models for Ukraine and EU countries from 2000 to 2016, demonstrating that a 1% increase in terms of the Control of Corruption Index resulted in a 0.88% reduction in greenhouse gas emissions, indirectly promoting more renewable energy utilization. Nabaweesi et al. (2023) employed CS-ARDL and second-generation panel models for East African Community nations (1996–2019), concluding that inadequate governance, particularly corruption, significantly impedes the execution of modern renewable energy sources. Belaïd et al. (2021) utilized panel quantile regression for MENA countries (1984–2014), demonstrating that governance quality, particularly corruption control, is fundamental to the renewable energy advancement. Mahmood et al. (2024) studied the impact of the rule of law and institutional quality on renewable energy consumption (REC) in Saudi Arabia from 1996 to 2022. Their findings demonstrated substantial favorable correlations, both short- and long-term, with the rule of law, corruption control, and voice and accountability, all facilitating the renewable energy transition (RET). The research emphasizes that legal and regulatory improvements can significantly expedite renewable energy technologies. Recently, Xu (2025) analyzed the influence of corruption control on energy consumption trends in ASEAN nations from 1998 to 2022. The CS-ARDL model, employing FMOLS and GMM for robustness, indicates that enhanced corruption control fosters renewable energy utilization, elevates per capita total energy consumption, and diminishes dependence on non-renewable energy sources. The results underscore the significance of robust governance and anti-corruption initiatives in facilitating the transition to sustainable energy systems across the ASEAN area.

2.2. Political Stability and Absence of Violence/Terrorism and Renewable Energy

An increasing volume of research has investigated the influence of political stability and the lack of violence or terrorism on the energy transition, focusing on how a secure and predictable political climate affects renewable energy investment, implementation, and the transition from fossil fuel-based energy sources. Bilan et al. (2019) analyzed the correlation between political issues, economic growth and renewable energy development, and in EU candidate nations from 1995 to 2015. The study employed advanced econometric methodologies, namely Fully Modified Ordinary Least Squares (FMOLS), the Vector Error Correction Model (VECM), and Dynamic Ordinary Least Squares (DOLS) and concluded that political stability is required for fostering investments in renewable energy sector. The paper emphasized that the initiatives of renewable energy typically have extended payback periods, rendering strong political and institutional frameworks crucial for attracting and maintaining investment. Wang et al. (2024) explored in what way political instability affects innovation in the renewable energy sector (REI) utilizing dataset for 60 countries between 2002 and 2020. Findings indicated that political instability adversely impacts renewable energy investment, particularly in wind and solar technologies, with variations influenced by government corruption, democratic governance, and military expenditure. Shao and Wang (2025) investigate the influence of political stability on renewable energy technology innovation (RETI) using a panel data for 65 nations over the period 2002-2022. The research indicated that political stability substantially enhances RETI by fostering financial, industrial, and R&D stability, with more pronounced advantages in nations encountering more economic risks. Reduced economic risk bolsters RETI and can partially compensate for political stability, underscoring the need of stable political and economic conditions for promoting renewable energy innovation. Belaïd et al. (2021) explored the drivers influencing renewable energy implementation in nine MENA nations from 1984 to 2014, emphasizing political stability, governance quality, and financial development. Using a panel quantile regression approach, the results indicated that political stability exerts a varied although predominantly beneficial influence on renewable energy investment. The research emphasized that political stability, efficient governance, and financial advancement are crucial factors in terms of renewable energy implementation in the MENA region. Mahjabeen et al. (2020) employed ARDL, FMOLS, and DOLS methodologies for D-8 nations (1990–2016), demonstrating that institutional stability is essential for economic growth and the adoption of renewable energy. Similarly, Uzar (2020) analyzed the correlation between renewable energy usage and institutional quality in 38 countries from 1990 to 2015, while adjusting for economic development and CO_2 emissions. The findings demonstrate that enhanced institutional quality positively influences the long-term adoption of renewable energy. Kousar et al. (2020) employed dynamic common correlated effects on South Asian nations (1988–2018), revealing that governance, encompassing political stability, enhances the beneficial influence of renewable energy on environmental quality. Huang and Wen (2025) examined the influence of political instability on renewable energy development utilizing panel data from 108 countries from 2003 to 2020. Their findings demonstrated that political instability considerably obstructs the advancement of renewable energy, mainly in the initial and developmental phases. The study demonstrated nonlinear effects and emphasized that instability compromises the efficacy of policy and market operations. The authors proposed stage-specific regulatory frameworks, methods for policy continuity, and tactics for mitigating political risk to facilitate renewable energy development.

2.3. Economic Growth and Renewable Energy

A growing body of work examines the relationship between economic growth and renewable energy by evaluating how income growth, structural transformation, and energy demand dynamics affect the acceptance and advancement of renewable energy sources. Fotourehchi (2017) examined the long-term causation between renewable energy usage and economic growth in a cohort of 42 developing nations from 1990 to 2012. The use of the Canning and Pedroni (2008) long-run causality test indicated a positive long-run causation from renewable energy consumption to real GDP. The findings suggest that conservation rules limiting renewable energy may impede growth in these countries, while dialogues highlight the necessity for governments to embrace clean energy advancement for energy security and environmental sustainability. Ntanos et al. (2018) employed ARDL and cluster analysis on 25 European countries from 2007 to 2016, discovering a strong long-term association, particularly among nations with greater GDP. Eren et al. (2019) investigated the impact of economic growth and financial development on renewable energy consumption in the case of India from 1971 to 2015. Cointegration and DOLS studies indicated that both economic growth and financial development exert a beneficial influence on renewable energy use. Granger causality experiments revealed a bidirectional association between economic growth and renewable energy usage, with long-term consequences influenced by financial development. Li and Leung (2021) examined the relationship between renewable energy and economic growth in seven European nations from 1985 to 2018 utilizing panel data. The findings indicated a long-term causal relationship from GDP and fossil fuel costs to renewable energy consumption, accompanied by short-term effects from fossil fuel prices. The study emphasized the crucial influence of economic growth and non-renewable energy prices on facilitating the transition to renewable energy. Aliyev et al. (2024) conducted a comparative study investigating the causal association between renewable energy use and GDP per capita in Iceland and Azerbaijan, employing data that lacks a defined temporal scope in the abstract, although it suggests a contemporary analysis. The authors employed the Toda-Yamamoto causality test within a vector autoregressive (VAR) model framework. The findings indicated a significant causal relationship between renewable energy consumption and economic growth in both nations, emphasizing Iceland's leadership in green energy production and Azerbaijan's initiatives to transition from oil dependency to sustainable alternatives, marking this as a critical domain for contemporary scientific research in green economics. Piyinchu (2025) employed an ARDL model to analyze Cameroon (1990–2024), indicating that renewable energy usage adversely influences GDP per capita in the long term while positively affecting it in the short term, implying that policy should prioritize short-term growth. Chen et al. (2020) investigated the correlation between economic growth and renewable energy usage with in case of 103 countries between 1995 and 2015 utilizing a threshold model. In emerging and non-OECD nations, renewable energy stimulates growth only after exceeding a specific consumption threshold; below this threshold, it may impede growth. Tudor and Sova (2021) utilized static and dynamic panel fixed-effects models across 94 countries (1995–2019), demonstrating that GDP per capita fosters renewable energy usage solely above a $5,000 threshold, with impacts differing by socioeconomic group. Su et al. (2022) employed threshold panel regression across 116 nations, revealing non-linear effects: urbanization, aging, and trade openness enhance renewable energy, whereas industrialization suppresses it, although this suppression diminishes beyond specific thresholds. Polcyn et al. (2021) examined European nations from 2000 to 2018 using fixed-effects and GMM models, revealing that GDP per capita positively affect renewable energy use, whereas labor force and capital formation exert negative influences. These studies collectively emphasize that the relationship between GDP and renewable energy is generally positive but can be intricate, differing by area, income level, and other structural factors.

Based on the insights from the analysed theoretical frameworks and empirical investigations, the following hypotheses are established to comprehensively examine the primary factors influencing per capita renewable energy use. These hypotheses seek to clarify the influence of institutional, economic, and political aspects on the adoption and utilization of renewable energy in context of MIKTA countries, establishing a framework for empirical validation and policy ramifications.

- H_1: Corruption Control positively influences renewable energy consumption.
- H_2: Political stability significantly enhances renewable energy adoption and investment.
- H_3: Economic growth positively affects renewable energy consumption, although the relationship may vary by income level and structural conditions.

3. DATA AND METHODOLOGY

3.1. Data Sources, Sample, and Transformation

This study utilizes annual panel data for MIKTA countries (Mexico, Indonesia, Republic of Korea, Turkiye, and Australia) spanning from 2000 to 2023 (Table 1). The natural logarithm of per capita energy consumption from renewables (lnREN) is used as the dependent variable. The principal independent institutional variables are Control of Corruption (COC) and Political Stability and Absence of Violence/Terrorism (PS), both evaluated as WGI percentile ranks (0–100) (World Bank, 2025). The control variable includes GDP per capita (lnGDP). In line with conventional econometric practices for energy demand models, Renewables Consumption per capita and GDP per capita are logarithmically transformed to facilitate elasticity interpretation.

3.2. Econometric Model Specification

The econometric estimation process adheres to the following steps: Initially, Pesaran CD test which is cross-sectional dependence tests are performed to ascertain the existence of common causes among countries. Secondly, Pesaran and Yamagata (2008) Delta tests for slope homogeneity corroborate parameter heterogeneity among selected countries. Third, CIPS unit root test ascertains the order of integration for all chosen variables, guaranteeing that no variable is I (2). The presence of long-term relations among the variables is checked via Westerlund (2007) cointegration test. The ideal lag lengths are ascertained using the Schwarz Bayesian Criterion (SBC) and the Akaike Information Criterion (AIC), with a maximum lag of 3 due to the moderate temporal dimension. The CS-ARDL model is implemented by utilizing the Mean Group estimator to provide long-run coefficients and short-run dynamics, with robustness checks conducted using Common Correlated Effects Mean Group (CCEMG) and Augmented Mean Group (AMG) estimators to ensure result consistency. The research calculates the long-term equilibrium relationship utilizing the subsequent equation:

$$\text{In } REV_{i,t} = \beta_0 + \beta_1 COC_{i,t} + \beta_2 PS_{i,t} + \beta_3 \text{ In } GDP_{i,t} + \varepsilon_{i,t} \quad (1)$$

The CS-ARDL model is utilized in its error correction specification. The Mean Group CS-ARDL equation is formulated for a generic collection of variables X, facilitating the estimation of long-run coefficients (θ_i) and the Error Correction Term (φ_i) for each country, which are subsequently averaged to yield the Mean Group estimates:

$$\Delta \ln REN_{i,t} = \phi_i \left(\ln REN_{i,t-1} - X_{i,t-1}\theta_i \right) + \sum_{k=1}^{p-1} \lambda_{i,k} \Delta \ln REN_{i,t-k} + \sum_{j=1}^{K}\sum_{k=0}^{q-1} \gamma_{i,j,k} \Delta X_{i,j,t-k} + \sum_{l=0}^{p_T} \delta_{i,l} \overline{Z_{t-l}} + u_{i,t} \quad (2)$$

where φ_i denotes the loading coefficient (ECT), $X_{i,t-1}$ signifies the vector of all regressors in levels, $\overline{Z_{t-l}}$ indicates the cross-sectional means for both dependent and independent variables employed to capture the unobserved common factors (CSD), and $u_{i,t}$ represents the idiosyncratic error term. The long-run coefficient $\hat{\theta}$ is obtained from the Mean Group average of the individual nation estimates.

Table 1: Variable definition and data sources

Variable	Definition	Unit	Source
LNREN	Per capita energy consumption from renewables (Measured in kilowatt-hours of primary energy per person)	Log (Index)	Energy Institute (2025)
COC	Control of Corruption (WGI Percentile Rank)	Percentile Rank (0–100)	Worldwide Governance Indicators (WGI)
PS	Political Stability and Absence of Violence/Terrorism (WGI Percentile Rank)	Percentile Rank (0–100)	Worldwide Governance Indicators (WGI)
lnGDP	Gross Domestic Product per capita (constant 2015 US$)	Log (constant 2015 US$)	World Development Indicators (WDI)

4. RESULTS AND DISCUSSION

4.1. Preliminary Analysis

The descriptive statistics highlight the diversity within the MIKTA group (Table 2).

The significant disparity between the minimum and maximum values for Control of Corruption (COC) and Political Stability (PS) underscores the considerable institutional heterogeneity within the panel, spanning from the highly stable and transparent Australia (Max COC: 96.552) to areas demonstrating greater institutional fragility, such as Indonesia (Min COC: 8.466). The maximum of lnREN is over twice the minimum, demonstrating the disparate rates of renewable energy consumption within the bloc, hence underscoring the need for a Mean Group strategy to facilitate country-specific solutions.

The findings indicate robust, positive initial correlations between renewable energy use and both institutional quality metrics (COC: 0.812; PS: 0.768) (Table 3). This indicates that countries with superior governance and reduced political risk are inclined to consume a greater amount of renewable energy per capita. The most significant association is noted between ln REN and lnGDP (0.899), affirming the crucial influence of economic scale on energy demand and the potential for green investment.

The CSD test is conducted to validate the interconnectedness of MIKTA economies, hence substantiating the selection of second-generation estimators (Table 4). The null hypothesis (H_0) posits no cross-sectional dependency among the residuals.

The findings decisively refute the null hypothesis of no cross-sectional dependency for all variables, with P-values approaching zero. This affirms that unobserved common factors among MIKTA countries (Chudik and Pesaran, 2015). Thus, estimation methods that utilize cross-sectional averages (such as CS-ARDL) are essential for generating dependable parameter estimations.

Table 2: Descriptive statistics

Variable	Mean	Std. Dev.	Min	Max
lnREN	6.819	1.102	5.294	9.094
COC	50.150	25.110	8.466	96.552
PS	41.524	26.981	2.646	93.122
lnGDP	9.771	0.945	7.510	11.028

Table 3: Correlation matrix

Variable	lnREN	COC	PS	lnGDP
lnREN	1.000	0.812	0.768	0.899
COC	0.812	1.000	0.901	0.887
PS	0.768	0.901	1.000	0.825
ln GDP	0.899	0.887	0.825	1.000

Table 4: Cross-sectional dependence (CSD) test results

Pesaran CD	Statistic	P-value	Conclusion (Null: No CSD)
lnREN	6.815	0.000	Reject H_0
COC	5.109	0.000	Reject H_0
PS	4.905	0.000	Reject H_0
lnGDP	7.021	0.000	Reject H_0

The test of slope homogeneity measures whether the long-term coefficients are uniform across all countries in the panel (Table 5). The null hypothesis (H_0) stands for that the slope coefficients are uniform (β_i = for all i).

At the 1% significance level, both test statistics decisively reject the null hypothesis of slope homogeneity (H_0). This result corroborates the application of the Mean Group estimation method inside the CS-ARDL framework, affirming that the influence of GDP per capita and institutional quality on renewable energy consumption varies across the MIKTA panel.

After the presence of cross-sectional dependence is confirmed, the Cross-Sectionally Augmented IPS (CIPS) unit root test is employed as a second-generation test to ascertain the order of integration for all variables (Pesaran, 2007) (Table 6).

The findings suggest a heterogeneous order of integration. Control of Corruption (COC) and Political Stability (PS) are stationary at levels, I (0). Renewable consumption (ln REN) and GDP per capita (lnGDP) exhibit non-stationarity at their levels but achieve stationarity upon initial differencing, signifying they are I (1) variables. Given that no variable is integrated of order two I (2), the CS-ARDL method is suitable for predicting both long-run and short-run connections (Pesaran et al., 1999).

The Westerlund (2007) cointegration test, which is resilient to cross-sectional dependence and heterogeneity, is utilized to evaluate the null hypothesis of the absence of cointegration among the variables (Table 7). A rejection of the null hypothesis substantiates the existence of a long-term and stable equilibrium connection.

At the 1% significance level, all four test statistics decisively reject the null hypothesis of no cointegration. This significant

Table 5: Slope homogeneity test results

Test	Statistic	P-value	Conclusion (Null: Homogeneity)
Pesaran and Yamagata (Δ_{Adj})	4.118	0.000	Reject H_0
Swamy's test (Δ)	5.345	0.000	Reject H_0

Table 6: Second-generation CIPS unit root test results

Variable	I(0)	P-value	I(1)	P-value	Integr. Order
ln REN	−1.981	0.125	−4.502	0.000	I(1)
COC	−3.120	0.001	−5.776	0.000	I(0)
PS	−3.004	0.002	−5.611	0.000	I(0)
lnGDP	−1.705	0.211	−4.318	0.000	I(1)

Table 7: Westerlund (2007) Panel Cointegration test results

Statistic	Value	Z-value	P-value	Conclusion (H_0: No Cointegration)
Gt	−2.761	−3.518	0.000	Reject H_0
Pt	−3.109	−3.985	0.000	Reject H_0
Ga	−1.912	−3.204	0.001	Reject H_0
Pa	−2.155	−3.490	0.000	Reject H_0

discovery verifies the presence of a long-term consistent co-movement among energy consumption per capita from renewables, indicators of economic growth and institutional quality in MIKTA nations. The research can thus advance to estimate these long-term characteristics utilizing CS-ARDL.

4.2. Cross-Sectionally Augmented ARDL (CS-ARDL) Estimation

The CS-ARDL (MG) estimates yield the long-term elasticities and the rate of adjustment (ECT). The Mean Group long-run coefficients denote the average long-term effect of the independent factors on per capita renewable consumption within the MIKTA panel (Table 8).

The long-term coefficient for Control of Corruption (COC) is found to be statistically significant and positive (0.0234, P = 0.000), suggesting that enhanced corruption control substantially fosters the uptake and consumption of renewable energy over time. An increase of 1 unit in the COC percentile rank corresponds to an estimated 2.34% gain in long-term per capita renewable energy consumption. This outcome robustly corroborates the current literature, wherein Camacho Ballesta et al. (2022) and Dossou et al. (2023) established that enhanced governance, especially in terms of corruption control, positively influences renewable energy utilization by alleviating implementation barriers and fostering a more stable investment environment. The data corroborates the notion that less corruption decreases transaction costs and uncertainty linked to substantial, long-term infrastructure projects such as renewable energy programs, consistent with the conclusion that insufficient governance markedly hinders adoption.

The long-term coefficient for Political Stability (PS) is positive and statistically significant (0.0163, P = 0.000), indicating that A consistent political environment is crucial for the sustained growth of renewable energy. A 1-unit improvement in the PS percentile rank results in an estimated 1.63% gain in long-term per capita renewable energy usage. This outcome aligns with Bilan et al. (2019), who underscored the necessity of robust political and institutional frameworks for attracting and sustaining renewable energy investments, particularly due to the prolonged payback periods associated with these initiatives. Moreover, the discovery corroborates the studies by Shao and Wang (2025) and Belaïd et al. (2021), which demonstrated that political stability significantly promotes innovation and investment in renewable energy technology, whereas instability negatively affects technology adoption, underscoring the essential importance of institutional continuity.

The coefficient for lnGDP per capita is positive, highly significant, and notably the greatest (0.8715, P = 0.000), indicating that economic growth is the primary long-term determinant of renewable energy consumption implementation. A 1% rise in GDP per capita correlates with an approximate 0.8715% increase in renewable energy. The robust long-term relationship is corroborated by the literature (Ntanos et al., 2018; Polcyn et al., 2021), which typically finds a significant positive relationship between elevated GDP and enhanced renewable energy utilization, frequently attributed to increased financial resources for investment and the capacity to adopt cleaner, albeit initially costlier, energy technologies. Although several studies present complexities about income thresholds and non-linear effects (Tudor and Sova, 2021; Su et al., 2022), the model's overarching long-term outcome unequivocally identifies economic development as the primary factor.

Table 8: CS-ARDL long-run estimated coefficients

Variable	Coefficient	Standard error	t-statistic	P-value
Control of Corruption (COC)	0.0234	0.0051	4.588	0.000***
Political Stability (PS)	0.0163	0.0044	3.705	0.000***
lnGDP per capita (lnGDP)	0.8715	0.1284	6.787	0.000***

***P<0.01; **P<0.05; *P<0.1

According to the results of short-run, it captures the immediate response of renewable energy consumption to changes in the independent variables, alongside the dynamic adjustment towards the long-run equilibrium (Table 9).

The paramount short-run metric is the Error Correction Term (ECT), which is statistically significant and negative (–0.3724, t = –7.040, P < 0.001). This shows a steady long-term cointegrating link and corroborates the previous cointegration test findings. The size suggests that around 37.24% of the divergence in renewable energy consumption from its long-term equilibrium is rectified annually. The inferred half-life of roughly 1.5 years—computed as ln (0.5)/ln (1–0.3724)—indicates relatively rapid adjustment processes, aligning with investment and policy reactions rather than gradual structural alterations.

Short-run coefficients indicate significant differences between structural long-run determinants and immediate cyclical effects:

The variation in ln GDP (Δln GDP) is statistically significant (0.4721, P < 0.001), demonstrating a robust short-term responsiveness of energy consumption to economic factors. The short-run elasticity (0.47) constitutes approximately 54% of the long-run elasticity (0.87), aligning with business-cycle dynamics in which expansions promptly elevate energy consumption, while complete correction transpires gradually as new infrastructure is developed.

Short-term variations in corruption control (ΔCOC) are negligible (0.0073, P = 0.147), whereas short-term variations in political stability (ΔPS) exhibit a slight positive impact (0.0088, P = 0.034). This imbalance reinforces the perspective that institutional quality functions primarily as a long-term structural determinant rather

Table 9: CS-ARDL short-run and error correction term (ECT) results

Variable	Coefficient	Standard error	t-Statistic	P-value
Error correction term (ECT)	−0.3724	0.0529	−7.040	0.000***
Δ Control of Corruption	0.0073	0.0050	1.460	0.147
Δ Political Stability	0.0088	0.0041	2.146	0.034**
Δ ln GDP per capita	0.4721	0.1035	4.561	0.000***

***P<0.01; **P<0.05; *P<0.1

Table 10: Robustness checks (CCEMG and AMG estimators)

Long-run variable	CS-ARDL (LR)	CCEMG (LR)	AMG (LR)
Control of corruption (COC)	0.0234***	0.0259***	0.0227***
Political stability (PS)	0.0163***	0.0181***	0.0152***
ln GDP per capita (ln GDP)	0.8715***	0.8931***	0.8698***

***P<0.01; **P<0.05; *P<0.1

than a catalyst for short-term fluctuations. Governance reforms impact renewable energy via progressive mechanisms, including investor confidence, regulatory enhancements, and reputational repercussions, which require years to manifest.

To guarantee the reliability and consistency of the CS-ARDL long-run estimates, two alternative second-generation panel estimators which are the Common Correlated Effects Mean Group (CCEMG) and the Augmented Mean Group (AMG) are utilized (Chudik and Pesaran, 2015). Both CCEMG and AMG exhibit resilience to cross-sectional dependency and heterogeneity (Table 10).

The outcomes derived from all three estimators exhibit significant consistency. The coefficients for Control of Corruption, Political Stability, and lnGDP per capita are consistently positive and statistically significant in all models. This consistency offers compelling evidence that the fundamental long-run elasticities obtained from the CS-ARDL model are both robust and dependable (Chudik and Pesaran, 2015). The confirmed favourable correlation between institutional quality and the uptake of renewable energy is statistically robust.

5. CONCLUSION

This study examined the factors influencing per capita renewable energy consumption in MIKTA countries utilizing advanced second-generation panel data methodologies from 2000 to 2023. The initial diagnostic tests affirmed the existence of both slope heterogeneity and cross-sectional dependence, hence substantiating the methodological selection of the CS-ARDL approach. The principal conclusion establishes a robust, affirmative, and statistically significant long-term correlation between institutional quality and per capita renewable energy consumption. Higher percentile ranks in Control of Corruption and Political Stability correlate with increased renewable energy use. This underscores that institutional resilience functions as a significant, non-market catalyst for the energy transition. Furthermore, this finding corresponds with previous theoretical frameworks indicating that institutional quality diminishes information asymmetries and transaction costs in renewable energy markets, therefore promoting more efficient capital allocation.

Economically, GDP per capita is established as a significant positive factor to the long-term level of renewable consumption. The dynamic study demonstrated a swift adjustment process, with the Error Correction Term signifying that deviations from the long-term equilibrium are rectified effectively each year. The projected adjustment rate indicates that roughly 37.24% of any disturbance to the system is mitigated within one year, reflecting rather agile energy policy frameworks within the MIKTA bloc. The institutional variables are significant determinants of long-run equilibrium; however, their short-run impact is less pronounced than that of economic growth, indicating that institutional quality is chiefly a structural, long-term factor in energy sector sustainability.

The empirical evidence obtained from the CS-ARDL model provides essential policy guidance for MIKTA nations, especially those with developing institutional frameworks (Mexico, Indonesia, Turkiye). Policy initiatives must emphasize enhancements in institutional quality particularly Control of Corruption and Political Stability as these are essential mechanisms for securing the substantial private investment necessary for the energy transition. Nations striving to attain their net-zero objectives must prioritize the mitigation of corruption risk and the assurance of regulatory compliance as essential conditions. Establishing clear and transparent regulatory frameworks and management structures for renewable energy policies, including fixed tariffs and tax incentives, is crucial to instill investor confidence in the stability and equity of these programs. Specifically, the establishment of autonomous regulatory agencies with adequate technical expertise can function as reliable commitment mechanisms, protecting renewable energy policies from transient political meddling. Political stability necessitates the mitigation of the risk associated with arbitrary policy reversal. Governments ought to establish frameworks that offer public insurance or state guarantees to mitigate political risks for capital-intensive renewable initiatives. This dedication to stability will directly diminish the risk premium, thereby reducing the cost of capital and rendering green projects economically viable. International cooperation arrangements, such multilateral development bank guarantees and bilateral investment treaties with targeted renewable energy clauses, can enhance domestic risk mitigation techniques, especially for nations with emerging institutional frameworks.

Policy should effectively leverage the observed impacts of economic growth. As GDP increases, regulatory authorities must guarantee that adequate investment is directed towards renewable infrastructure, possibly shifting financial strategies from project finance to corporate finance, where institutional investors are more proficient in capital allocation. Additionally, Policymakers could also contemplate the use of dynamic feed-in tariffs or competitive auction systems that adapt to economic conditions, ensuring that the deployment of renewable energy correlates with economic capacity while preserving fiscal sustainability.

This study provides substantial evidence; nonetheless, it depends on WGI percentile ratings, which are derived from perceptions. Future study may employ objective, comprehensive institutional metrics or investigate sector-specific governance indicators (e.g., regulatory quality in energy policy) to enhance these findings. Additionally, investigating the non-linear or asymmetric impacts of institutional decline compared to institutional enhancement on renewable energy consumption through non-linear ARDL (NARDL) methodologies may yield further refined policy insights. Furthermore, expanding this research to include spatial econometric methods may uncover possible spillover effects of enhancements in institutional quality across adjacent regions, thus guiding coordinated regional energy transition initiatives. Panel threshold regression models can uncover crucial institutional quality thresholds that, once surpassed, dramatically accelerate renewable energy adoption, offering precise benchmarking targets for policymakers.

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