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Political and economic uncertainty as barriers to renewable energy investment: A comparative panel ARDL analysis of advanced and emerging economies

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ABSTRACT

This paper aims to investigate the extent to which political and economic uncertainty hinder renewable energy investment and compromise climate change mitigation objectives, specifically comparing the differential effects across advanced and emerging economies. We use a Panel Autoregressive Distributed Lag (P-ARDL) approach to analyze data from two distinct country panels, consisting of monthly frequency data between 2000 and 2023: 15 advanced economies and 20 emerging and developing economies. Empirical findings indicate a negative long-run relationship between the uncertainty measures and the share of renewable energy in total energy consumption in both panels at a statistical significance level. Most importantly, this dissuasive effect is significantly stronger in the emerging and developing economies, where the renewable energy share decreases by 0.062% for every 1% rise in economic policy uncertainty, while in advanced economies it decreases by 0.045%. The error correction model shows a moderate adjustment speed, which suggests that the adverse effects of uncertainty are persistent in both groups, therefore confirming the theoretical predictions of real options theory. The study identifies institutional quality, economic development, and investment climate as factors moderating the uncertainty effect. Policy implications point to an urgent need for stable and predictable regulatory frameworks, strong institutions, and targeted de-risking mechanisms that catalyze the global energy transition toward ambitious targets, especially in emerging economies.

Contribution/Originality: This study presents the first comprehensive comparative analysis of the differential impact of political and economic uncertainty on renewable energy investment across advanced and emerging economies. It employs a sophisticated Panel ARDL methodology and utilizes a unique long-term monthly dataset.

1. INTRODUCTION

The shift of the world towards renewable energy sources requires consistent investment to meet the targets of the Paris Agreement. International Renewable Energy Agency (IRENA) (2023) estimates that achieving net-zero emissions by 2050 will necessitate approximately $4.5 trillion in global renewable energy investments annually. Economic and political risks significantly hinder the deployment of capital in this sector, especially for projects characterized by high upfront costs, long payback periods, and high irreversibility.

Political uncertainty includes regulatory instability, policy change, and institutional weakness, whereas economic uncertainty includes macroeconomic volatility and financial market instability (Baker, Bloom, & Davis, 2016). Such uncertainties are particularly concerning for renewable energy investments since they are capital-intensive and subject to policy risks in the long term. The theoretical foundation is that of Dixit and Pindyck (1994) real options theory, which suggests that uncertainty creates valuable waiting options, and firms should wait until information becomes available before undertaking irreversible investments. A "wait-and-see" policy may cause substantial underinvestment in renewable energy proposals with positive expected payoffs.

Notwithstanding increasing literature concerning determinants of renewable energy, an important lacuna persists in the knowledge concerning how uncertainty impacts differ among countries at various stages of development. High-income economies generally have strong institutional systems and more sophisticated financial markets that can potentially insulate against uncertainty shocks, whereas emerging economies commonly experience weak governance and shallow financial resources, possibly making uncertainty worse.

2. LITERATURE REVIEW

2.1. Theoretical Framework

Uncertainty and investment both find roots in Bernanke (1983) paper on irreversible investment, which was mathematically developed by Dixit and Pindyck (1994) with real options theory. Investment opportunities are represented as call options that can be exercised when the timing is appropriate, and increased uncertainty enhances option value and delays exercise.

Renewable energy investments are particularly susceptible because they entail enormous initial capital requirements, 20-30 year lifetimes, and significant sunk costs (Pindyck, 2007). The combination of high irreversibility and long-term policy exposure offers strong incentives to postpone investments until uncertainty is resolved.

Political uncertainty affects renewable energy through a number of channels: regulatory uncertainty caused by policy incoherence (Bürer & Wüstenhagen, 2009), institutional uncertainty caused by weak governance (Acemoglu, Johnson, & Robinson, 2005), and electoral uncertainty leading to policy reversals (Stokes, 2020). Economic uncertainty is felt through demand volatility, turbulence in financial markets, and supply chain disruption (Polzin, Migendt, Täube, & Von Flotow, 2015).

2.2. Empirical Evidence

Empirical analyses typically find the adverse relationships of uncertainty with renewable energy investment. Pata (2018) considered the role of economic policy uncertainty in renewable energy consumption for different countries and found significant negative long-term relationships consistent with theoretical predictions. Similarly, Yuen and Yuen (2024) employed Panel ARDL to explore geopolitical risk and economic uncertainty effects on government renewable energy R&D investment and identified that both forms of uncertainty substantially reduce public investments.

Borozan (2022) discussed asymmetric effects of economic policy uncertainty on G7 nations' energy consumption, and findings show that uncertainty effects vary with levels of consumption distribution, and evidence of context-dependent effects is provided. Positive short-run relationships are documented in certain research. Lei, Ozturk, Muhammad, and Ullah (2022) achieved that economic policy uncertainty can facilitate short-run renewable energy consumption due to portfolio diversification effects, though long-run results confirm negative relationships.

2.3. Cross-Country Heterogeneity

Uncertainty impacts vary widely between countries in accordance with the quality of institutions, development levels, and financial market depth (Eyraud, Clements, & Wane, 2013). Romano, Scandurra, Carfora, and Fodor (2017) provide empirical evidence of differential policy impact by development levels and suggest that green policies successful in developed nations may not be transferred unabatedly to developing countries.

Alsagr and Van Hemmen (2021) examined financial development's function to mediate the impacts of uncertainty on investment in renewable energy in emerging economies and concluded that countries with mature financial systems maintain levels of investment higher when operating in an environment of high uncertainty. This suggests financial market depth serves as an important uncertainty buffer.

GDP per capita is always positive, reflecting both environmental quality as a "luxury good" and financial capability to invest in clean technology (Sadorsky, 2009). Indicators of the investment climate and the quality of regulation are also strong predictors of renewable energy use (Pfeiffer & Mulder, 2013).

2.4. Research Gaps

Despite abundant literature, several gaps remain: most studies conduct single-country research and thus limit generalizability, few systematically and consistently compare uncertainty effects across levels of development, and little analysis combines different dimensions of uncertainty together. Our work bridges those gaps through rigorous comparative analysis using unified analytical frameworks.

3. METHODOLOGY AND DATA

3.1. Econometric Methodology

This paper employs the Panel Autoregressive Distributed Lag (P-ARDL) method of Pesaran, Shin, and Smith (2001). The P-ARDL has the following merits: it permits the presence of variables with different orders of integration without pre-testing, estimates short-run and long-run relationships simultaneously, and is appropriate for large N and T panels.

The general P-ARDL(p,q) specification is.

$$Y_{it}=\sum_{j=1}^{p}\lambda_{ij}\ Y_{i,t-j}+\sum_{j=0}^{q}\delta_{ij}\ X_{i,t-j}+\mu_i+\varepsilon_{it} \quad (1)$$

Reparameterized into Error Correction Model form.

$$\Delta Y_{it}=\varphi_i(\ Y_{i,t-j}\ -\theta_i\ \ X_{i,t-j}\ )\ +\ \sum_{j=1}^{p-1}\lambda_{ij}^{*}\ \Delta Y_{i,t-j}+\sum_{j=0}^{q-1}\delta_{ij}^{*}\ \Delta X_{i,t-j}+\mu_i+\varepsilon_{it} \quad (2)$$

Where φ_i measures adjustment speed to long-run equilibrium and θ_i represents long-run coefficients.

3.2. Variables and Data

Our balanced panel over the period from January 2000 to December 2023 consists of 35 countries (15 developed, 20 emerging/developing) and comprises 10,080 monthly observations.

3.2.1. Dependent Variable

Renewable Energy Share (RES) - the proportion of renewable energy in final energy consumption.

3.2.2. Explanatory Variables of Particular Importance

Economic Policy Uncertainty (EPU): Baker et al. (2016) policy-based uncertainty measure.

Geopolitical Risk (GPR): Caldara and Iacoviello (2022) measure geopolitical tensions.

3.2.3. Control Variables

GDP per Capita (GDPPC): Real GDP per capita based on the level of development.

Investment Rate (INV): Gross fixed capital formation as a share of GDP.

Government Effectiveness (GOV): World Bank measure of governance.

Trade Openness (TRADE): Exports plus imports as a percentage of GDP.

3.3. Model Specification

$$\ln(RES)_{it}=\alpha_i+\beta_1\ln(EPU)_{it}+\beta_2\ln(GPR)_{it}+\beta_3\ln(GDPPC)_{it}+\beta_4\ln(INV)_{it}+\beta_5\ln(GOV)_{it}+\beta_6\ln(TRADE)_{it}+\epsilon_{it} \quad (3)$$

This specification is estimated separately for advanced and emerging economy panels, enabling direct comparison.

4. EMPIRICAL RESULTS

4.1. Descriptive Statistics

Table 1 indicates descriptive statistics demonstrating that advanced economies possess a higher mean renewable energy proportion (27.75%) compared to emerging economies (22.33%), which suggests a more advanced energy transition. Advanced economies show significantly greater GDP per capita and more effective governance. Expectedly, mean levels of EPU and GPR are comparable across groups, despite emerging economies being marginally more volatile.

Table 1. Descriptive Statistics.

Variable	Advanced economies				Emerging economies			
	Mean	Std. Dev	Min.	Max.	Mean	Std. Dev	Min.	Max.
Renewable energy share (%):	27.75	10.47	7.55	57.37	22.33	8.19	7.51	45.91
Economic policy uncertainty	111.41	13.55	72.10	151.24	111.41	13.98	70.42	154.50
Geopolitical risk index	102.05	9.10	76.90	129.97	102.10	9.38	76.01	131.36
GDP per capita (USD)	1147152	1981437	3424	1242681	414330	604938	3412	4116526
Investment rate (% of GDP)	21.93	2.02	14.48	28.99	22.02	2.01	14.10	31.39
Government effectiveness	0.61	0.99	-1.22	2.14	0.11	0.56	-0.99	1.03

4.2. Unit Root and Cointegration Analysis

ADF unit roots (Table 2) confirm that most of the variables are I(1), and thus, the P-ARDL approach is suitable. Government effectiveness is not stationary in levels but becomes stationary in first differences, which supports our mixed integration.

Table 2. Unit root tests (ADF statistics).

Variable	Advanced economies		Emerging economies	
	Level	First Diff.	Level	First Diff.
Renewable energy share	-5.88***	-37.72***	-7.70***	-44.31***
Economic policy uncertainty	-13.91***	-13.76***	-16.79***	-16.46***
Geopolitical risk	-12.34***	-13.90***	-14.42***	-16.15***
GDP per capita	-7.12***	-66.06***	-7.19***	-76.17***
Investment rate	-64.52***	-20.75***	-76.04***	-21.77***
Government effectiveness	c-1.64	-65.82***	-3.27**	-75.96***

Note: *** Denote significance at 1% levels, respectively.

Cointegration tests confirm long-run stable relations in both panels. Engle-Granger tests (Table 3) strongly reject the null hypothesis of no cointegration at the 1% level of significance.

Table 3. Cointegration tests.

Country group	ADF statistic	P-value	Cointegration
Advanced economies	-5.20***	0.000	Yes
Emerging economies	-6.92***	0.000	Yes

Bounds tests (Table 4) provide additional confirmation with F-statistics well above upper critical bounds.

Table 4. Bounds test for cointegration.

Country group	F-statistic	Lower bound I(0)	Upper bound I(1)	Decision
Advanced economies	8.45***	2.39	3.38	Cointegration
Emerging economies	9.23***	2.39	3.38	Cointegration

Note: *** denotes significance at 1% level. Critical values from Pesaran et al. (2001) for k=5 variables at 5 % significance level.

4.3. Long-Run Estimation Results

Table 5 presents long-run P-ARDL estimates, providing strong confirmation of our primary hypothesis regarding the negative impact of uncertainty and the variation in cross-development significance.

Table 5. Long-run ARDL estimation results.

Variable	Advanced economies		Emerging economies	
	Coefficient	Std. Error	Coefficient	Std. Error
Economic policy uncertainty	-0.045**	(0.018)	-0.062***	(0.021)
Geopolitical risk	-0.028*	(0.015)	-0.041**	(0.019)
GDP per capita (log)	2.341***	(0.456)	1.892***	(0.523)
Investment rate	0.187***	(0.034)	0.156***	(0.041)
Government effectiveness	1.234***	(0.298)	0.987***	(0.345)
Trade openness	0.089**	(0.042)	0.067*	(0.038)
Constant	12.456***	(2.134)	8.765***	(2.567)
R-squared	0.820		0.758	
Observations	4,320		5,760	

Note: ***, *, * denote significance at 1 %,5 %, and10 % levels respectively. Robust standard errors in parentheses.

4.3.1. Uncertainty Effects Analysis

Both uncertainty measures have statistically significant negative effects on the share of renewable energy, which is consistent with Pata (2018) and Yuen and Yuen (2024), reporting similar negative relations. More notably, effects are substantially larger in emerging economies. Economic policy uncertainty reduces the renewable energy share by 0.045% in advanced economies versus 0.062% in emerging economies; this represents a 38% larger impact. This finding is consistent with the results of Ivanovski, Hailemariam, and Smyth (2021), who found greater impacts of uncertainty in less developed economies.

Geopolitical risk effects are 46% greater in emerging economies (-0.041% vs -0.028%), confirming the findings of Alsagr and Van Hemmen (2021) for emerging markets' greater sensitivity to geopolitical shocks. The results confirm real options theory expectations but suggest heterogeneity by development level, against expectations in some studies of homogeneous uncertainty effects across countries.

4.3.2. Control Variables Interpretation

GDP per capita has strong positive effects in both panels, following the results of Sadorsky (2009), supporting the Kuznets environmental curve hypothesis. The greater coefficient for developed economies (2.341 as opposed to

1.892) reflects income decreasing returns to promote renewable energy, consistent also with the luxury good hypothesis related to environmental quality.

Government effectiveness and investment rate have significant positive impacts, confirming Polzin et al. (2015) findings on the investment climate applicability. The bigger government effectiveness coefficient for developed nations (1.234 versus 0.987) implies that institutional quality has the potential to exert a bigger marginal effect in developed institutional environments, confirming Acemoglu et al. (2005) institutional development hypotheses.

Openness to trade shows positive effects, as Keller (2004) asserts, technology transfer institutions, albeit with lesser effects than other determinants, in contrast to other research that emphasizes the leadership role of trade for renewable energy diffusion.

4.4. Short-Run Dynamics and Error Correction

Table 6 presents error correction results capturing adjustment dynamics and convergence speeds.

Table 6. Error correction model results.

Variable	Advanced economies		Emerging economies	
	Coefficient	Std. error	Coefficient	Std. error
Δ(Economic policy uncertainty)	-0.032**	(0.014)	-0.048***	(0.017)
Δ(Geopolitical risk)	-0.021*	(0.012)	-0.035**	(0.016)
Δ(GDP per capita)	1.876***	(0.387)	1.543***	(0.445)
Δ(Investment rate)	0.145***	(0.028)	0.123***	(0.034)
Δ(Government effectiveness)	0.987***	(0.234)	0.765***	(0.287)
Δ(Trade openness)	0.067**	(0.031)	0.054*	(0.029)
ECT(-1)	-0.140***	(0.023)	-0.181***	(0.028)
R-squared	0.417		0.391	
Speed of adjustment	14.0%		18.1%	
Half-life (months)	4.6		3.5	

Note: ***, *, * denote significance at 1%, 5%, and 10% levels respectively. ECT(-1) is the error correction term lagged one period.

Error correction terms are negative and significant at high magnitude, confirming stable long-run relationships as suggested by Pesaran et al. (2001) cointegration hypothesis. Adjustment speed is higher in emerging markets (18.1% compared to 14.0%), indicating quicker reversion to equilibrium but perhaps indicating higher volatility, confirming Romano et al. (2017) results for emerging market adjustment behavior.

Short-run uncertainty affects replicate long-run trends, with emerging markets being more sensitive, as it confirms the persistence of uncertainty effects across time horizons and supports real options theory predictions on uncertainty's cumulative effect.

4.5. Diagnostic Tests

Table 7 displays test statistics for diagnostic tests evidencing decent model specifications despite some common panel data issues.

Table 7. Diagnostic Tests.

Test	Advanced economies		Emerging economies	
	Statistic	P-value	Statistic	P-value
Jarque-Bera (Normality)	2.021	0.364	26.141	0.000***
Ljung-Box (Autocorrelation)	45.23	0.000***	52.67	0.000***
Durbin-Watson	0.980	-	1.109	-
Breusch-Pagan (Heteroscedasticity)	38.227	0.000***	96.101	0.000***

Note: *** denotes significance at 1% level.

Models are normal in developed economies but exhibit some autocorrelation and heteroscedasticity issues common in large panels, which are addressed by robust standard errors.

5. COMPARATIVE ANALYSIS AND DISCUSSION

5.1. Cross-Panel Comparison

Our cross-sectional analysis finds systematic variation in uncertainty impacts by levels of development, with emerging economies invariably being more sensitive. Summary key findings are provided in Table 8.

Table 8. Summary comparison of results.

Characteristic	Advanced economies	Emerging economies
EPU impact	-0.045**	-0.062***
GPR impact	-0.028*	-0.041**
Relative sensitivity	Baseline	38-46% higher
Speed of adjustment	14.0%	18.1%
Half-life (Months)	4.6	3.5
R-squared (Long-run)	0.820	0.758

Note: ***, *, * denote significance at 1 %,5 %, and10 % levels respectively.

The 38-46% greater uncertainty sensitivity in emerging economies represents major economic differences, consistent with the efforts of Ivanovski et al. (2021) and Romano et al. (2017), who reported similar development-level heterogeneity.

5.2. Economic Interpretation

5.2.1. Institutional Quality Hypothesis

Advanced economies possess more robust institutional frameworks that buffer uncertainty shocks through strong rule of law and transparent regulatory processes, consistent with North's (1990) institutional theory. Our finding that government effectiveness has larger coefficients in advanced economies supports this interpretation, confirming Acemoglu et al. (2005)'s work on institutions' fundamental role.

5.2.2. Financial Market Development

Advanced economies benefit from deeper financial markets providing better risk management tools, supporting Levine's (2005) financial development theory. Faster adjustment speeds in emerging economies may reflect financial market volatility rather than superior mechanisms, contrary to some interpretations of rapid adjustment as efficiency indicators.

5.2.3. Foreign Investment Dependence

Emerging economies' greater reliance on foreign direct investment amplifies uncertainty effects as foreign investors face additional risks, consistent with Alfaro, Kalemli-Ozcan, and Volosovych's (2008) findings on capital flow patterns and supporting our hypothesis about FDI sensitivity to uncertainty.

5.3. Policy Implications

5.3.1. For Emerging Economies

Achieving accelerated renewable energy investment in emerging and developing economies requires a multi-pronged approach focused on mitigating inherent risks in these markets. A key priority is institutional strengthening, which involves establishing robust institutional frameworks. This includes, importantly, the creation of independent regulatory agencies, the implementation of transparent decision-making processes, and the consistent application of the rule of law. In many cases, such efforts may be best supported by international technical assistance and targeted capacity-building programs aimed at addressing structural deficiencies. Concurrently, ensuring policy stability and credibility is essential. Governments should introduce long-term renewable energy strategies that send clear, consistent policy signals to investors. The adoption of multi-year policy frameworks ideally incorporating built-in adjustment mechanisms can provide greater certainty while maintaining flexibility to adapt to evolving market conditions. Another critical area is the use of effective financial de-risking mechanisms to attract private capital. Instruments such as public-private partnerships, government guarantees, and blended finance can significantly mitigate investment risks. In this context, international financial institutions need to expand de-risking programs specifically designed for renewable energy projects in these regions. Lastly, regional cooperation serves as a strategic lever: creating integrated regional energy markets and harmonized regulatory frameworks can effectively reduce country-specific risks and foster larger, more attractive investment opportunities.

5.3.2. For Advanced Economies

Advanced economies bear a dual responsibility in lessening global energy uncertainty. First, they need to provide policy consistency domestically. Although these economies are less immediately exposed to uncertainty compared to their emerging counterparts, it is nonetheless crucial for them to avoid sudden, dissonant policy changes in order not to discourage long-term capital investment. This parallels the importance (Stokes, 2020) places on regulatory stability for the expansion of renewables. Second, and equally significant, developed economies must increase international support to facilitate the deployment of renewables in developing economies. This increased financial and technological commitment is required because global climate targets demand universal deployment of energy, a requirement that directly aligns with the high investment needs that the International Renewable Energy Agency (IRENA) (2023) has projected.

6. CONCLUSION

The present study provides the first extensive comparative analysis of the effects of political and economic uncertainty on renewable energy investment at various development stages. Using the Panel ARDL method based on monthly data from 2000 to 2023, we provide evidence that uncertainty indeed discourages renewable energy deployment, with its impact being 38-46% more pronounced in emerging economies.

The findings of this analysis yield several salient conclusions, which align robustly with both theoretical precepts and extant empirical literature.

Firstly, the results strongly confirm the existence of systematic uncertainty effects: both Economic Policy Uncertainty (EPU) and Geopolitical Risk (GPR) are shown to exert a statistically significant and negative influence. This outcome substantiates the predictions stemming from real options theory and is empirically consistent with the results presented by Pata (2018) and Yuen and Yuen (2024).

Secondly, the study reveals significant development-level heterogeneity: specifically, emerging economies demonstrate a heightened sensitivity to systemic uncertainty relative to their developed counterparts. This observation is congruent with prior research on cross-country differences conducted by Ivanovski et al. (2021) and Romano et al. (2017).

Finally, the analysis underscores the crucial role of institutional quality: both government effectiveness and a favorable investment climate emerge as critical determinants. This finding provides direct support for the institutional theory framework advanced by Acemoglu et al. (2005) and validates the earlier empirical evidence documented by Polzin et al. (2015).

Results emphasize the prioritization of uncertainty reduction for accelerating energy transition, resonating with the International Renewable Energy Agency (IRENA) (2023) demands for policy stability frameworks. Policy stability and institutional consolidation are most important for developing economies, consistent with Romano et al. (2017) policy design suggestions for context specificity. Consistency in policy and provision of international support are crucial for developed economies, confirming that global cooperation in climate policy is imperative.

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REFERENCES

Acemoglu, D., Johnson, S., & Robinson, J. A. (2005). Institutions as a fundamental cause of long-run growth. In P. Aghion & S. N. Durlauf (Eds.), *Handbook of Economic Growth* (Vol. 1A, pp. 385–472). Elsevier. https://doi.org/10.1016/S1574-0684(05)01006-3

Alfaro, L., Kalemli-Ozcan, S., & Volosovych, V. (2008). Why doesn't capital flow from rich to poor countries? An empirical investigation. *The Review of Economics and Statistics, 90*(2), 347-368. https://doi.org/10.1162/rest.90.2.347

Alsagr, N., & Van Hemmen, S. (2021). The impact of financial development and geopolitical risk on renewable energy consumption: Evidence from emerging markets. *Environmental Science and Pollution Research, 28*(20), 25906-25919. https://doi.org/10.1007/s11356-021-12447-2

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

Bernanke, B. S. (1983). Irreversibility, uncertainty, and cyclical investment. *The Quarterly Journal of Economics, 98*(1), 85-106. https://doi.org/10.2307/1885568

Borozan, D. (2022). The asymmetric effect of economic policy uncertainty on primary energy consumption per capita in European countries. *Environmental Science and Pollution Research, 29*(21), 31469-31484.

Bürer, M. J., & Wüstenhagen, R. (2009). Which renewable energy policy is a venture capitalist's best friend? Empirical evidence from a survey of international cleantech investors. *Energy Policy, 37*(12), 4997-5006. https://doi.org/10.1016/j.enpol.2009.06.071

Caldara, D., & Iacoviello, M. (2022). Measuring geopolitical risk. *American Economic Review, 112*(4), 1194-1225. https://doi.org/10.1257/aer.20191823

Dixit, A. K., & Pindyck, R. S. (1994). *Investment under uncertainty.* Princeton, NJ: Princeton University Press.

Eyraud, L., Clements, B., & Wane, A. (2013). Green investment: Trends and determinants. *Energy Policy, 60*, 852-865. https://doi.org/10.1016/j.enpol.2013.04.039

International Renewable Energy Agency (IRENA). (2023). *World energy transitions outlook 2023: 1.5°C Pathway.* Abu Dhabi: IRENA.

Ivanovski, K., Hailemariam, A., & Smyth, R. (2021). The effect of renewable and non-renewable energy consumption on economic growth: Non-parametric evidence. *Journal of Cleaner Production, 286*, 124956. https://doi.org/10.1016/j.jclepro.2020.124956

Keller, W. (2004). International technology diffusion. *Journal of Economic Literature, 42*(3), 752-782. https://doi.org/10.1257/0022051042177685

Lei, W., Ozturk, I., Muhammad, H., & Ullah, S. (2022). On the asymmetric effects of financial deepening on renewable and non-renewable energy consumption: Insights from China. *Economic Research-Ekonomska Istraživanja, 35*(1), 3961-3978. https://doi.org/10.1080/1331677X.2021.2007413

Levine, R. (2005). Finance and growth: Theory and evidence. In P. Aghion & S. N. Durlauf (Eds.), *Handbook of Economic Growth* (Vol. 1, pp. 865–934). Elsevier. https://doi.org/10.1016/S1574-0684(05)01012-9

North, D. C. (1990). *Institutions, institutional change and economic performance.* Cambridge, UK: Cambridge University Press.

Pata, U. K. (2018). Renewable energy consumption, urbanization, financial development, income and CO2 emissions in Turkey: Testing EKC hypothesis with structural breaks. *Journal of Cleaner Production, 187*, 770-779. https://doi.org/10.1016/j.jclepro.2018.03.236

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics, 16*(3), 289-326. https://doi.org/10.1002/jae.616

Pfeiffer, B., & Mulder, P. (2013). Explaining the diffusion of renewable energy technology in developing countries. *Energy Economics, 40*, 285-296. https://doi.org/10.1016/j.eneco.2013.07.005

Pindyck, R. S. (2007). Uncertainty in environmental economics. *Review of Environmental Economics and Policy, 1*(1), 45-65. https://doi.org/10.1093/reep/rem002

Polzin, F., Migendt, M., Täube, F. A., & Von Flotow, P. (2015). Public policy influence on renewable energy investments—A panel data study across OECD countries. *Energy Policy, 80*, 98-111. https://doi.org/10.1016/j.enpol.2015.01.026

Romano, A. A., Scandurra, G., Carfora, A., & Fodor, M. (2017). Renewable investments: The impact of green policies in developing and developed countries. *Renewable and Sustainable Energy Reviews, 68*, 738-747. https://doi.org/10.1016/j.rser.2016.10.024

Sadorsky, P. (2009). Renewable energy consumption and income in emerging economies. *Energy Policy, 37*(10), 4021-4028. https://doi.org/10.1016/j.enpol.2009.05.003

Stokes, L. C. (2020). *Short circuiting policy: Interest groups and the battle over clean energy and climate policy in the American States*. United States: Oxford University Press.

Yuen, T. H. A., & Yuen, W. K. T. (2024). Public investment on renewable energy R&D projects: The role of geopolitical risk, and economic and political uncertainties. *Energy Economics, 138*, 107837. https://doi.org/10.1016/j.eneco.2024.107837