Science of Law, 2025, No. 6, pp. 35-46
DOI: 10.55284/mgx1dj32

Impact of Geopolitical Risks and Financial Markets on Renewable Energy Consumption: Evidence from Emerging Countries

Amal BEN ABDALLAH[1]*, Mohamed Sofien NOURI[2], Moez DHIABI[3]

[1,2,3]LEG Laboratory, Department of Economics, Faculty of Economics and Management of Sfax, University of Sfax, Tunisia.

Keywords:
Geopolitical risk,
GMM-system,
Stock markets,
Renewable energy,
COP30.

Abstract. As the world's largest economies, emerging markets play a vital role in driving the energy transition. Though, budget constraints and geopolitical threats may hinder the necessary changes. Fiscal constraints may make it difficult for countries to invest in renewable energy infrastructure and technologies, especially in emerging economies with limited financial resources. The geopolitical risks associated with the transition may also cause uncertainty and hinder investment, such as possible disruptions to energy supply networks. In this research, we evaluate the impact of geopolitical risks and financial markets, especially the stock market turnover ratio, on renewable energy consumption in 10 emerging nations from 1985 to 2021. A two-step Generalized Method of Moments System (GMM-system) is evaluated, and the results show that an increase in our two key variables has a positive and significant effect on renewable energy consumption. Our findings indicate that We emphasize in the long-term special effects of geopolitical risks and stock markets are additional obvious in renewable energy policy. Finally, the main political consequences are highlighted.

1. INTRODUCTION

The initial dual decades of the last century have seen many catastrophic events that have negatively impacted economies around the world. Renewable energy has had a difficult few years and has been severely affected by price volatility, the financial crisis, the battle between Ukraine and Russia, and the COVID-19 pandemic that has resulted in many deaths and damage to businesses around the world (Ha, 2023).

Referring to the International Renewable Energy Agency (IRENA, 2023), the capacity of renewable energy worldwide must quadruple too little over 11.000 GW by 2030, which was published earlier this year in June, maintaining the outlook for limiting global softening to 1.5°C and zero carbon. The G20's decision toward agree supports this goal and to invest more than $4 trillion a year through 2030 and emphasizes the need to treble renewable energy capacity.

The importance of a considerable change in the current trajectory for all energy users in 2021 was stressed by IRENA. Although some progress has been made, it remains tragically insufficient. The pandemic's related stimulus and recovery efforts were also a missed opportunity, with only 6% of the G20's USD 15 trillion in recovery funding going toward renewable energy in 2020 and 2021 (Nahm et al., 2022). Furthermore, the G20 economies account for more than 70% of global CO_2 emissions. As a result, wealthier nations' activities are critical, both in terms of their fossil CO_2 emissions and their financial help to less developed nations' decarburization initiatives.

According to Figure 1, Renewable energy consumption has emerged as a pivotal focus for sustainable development within the G20, particularly among 10 key emerging countries. These nations are strategically working towards bolstering their renewable energy capacities, aligning with global initiatives to mitigate climate change and transition towards sustainable energy sources.

China, as the largest energy consumer globally, has embarked on extensive renewable energy endeavors. Its investments primarily target wind and solar power, every target is to reduce dependence on fossil fuels and combat environmental damage. The same, Russia's renewable energy initiatives primarily focus on hydropower expansion, with increasing efforts in integrating wind and solar energy into its energy matrix.

India stands out with its ambitious renewable energy targets, concentrating efforts on expanding solar and wind power. These initiatives not only address energy access challenges but also align with efforts to curb carbon emissions.

*Corresponding author.

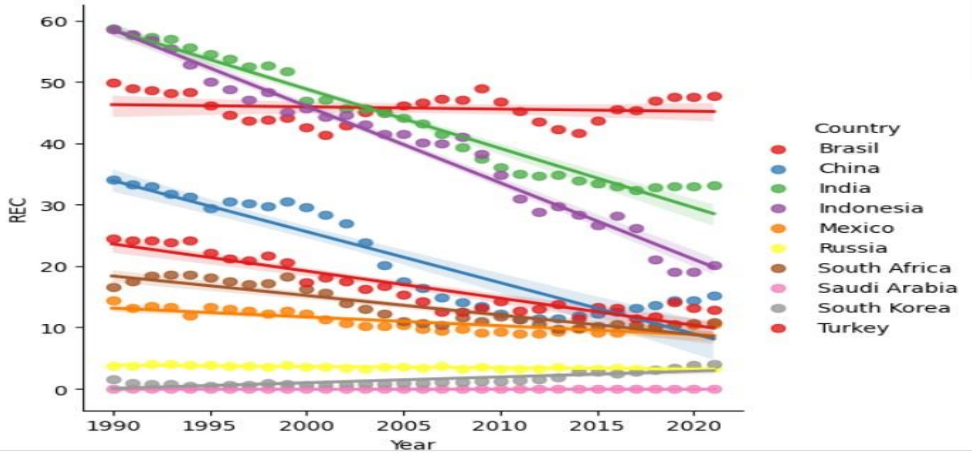

Figure 1. Evolution of Renewable Energy Consumption in emerging nations.

Brazil has long been associated with extensive use of hydropower. However, the country is varying its renewable energy portfolio by incorporating wind and biomass, while maintaining a focus on sustainable biofuels. Indonesia harnesses its abundant geothermal resources while simultaneously expanding its solar and hydroelectric power capacities to drive its renewable energy agenda.

Mexico has intensified investments in wind and solar energy projects, striving to diminish dependence on fossil fuels and strengthen energy security. For Turkey, it is actively promoting many renewable energy sources for example wind, astral, and hydroelectric power. This strategic diversification aims to enhance the sustainability and resilience of its energy infrastructure.

South Africa's renewable energy policy focuses on the development of solar and wind energies to address energy access issues and battle climate change.

Saudi Arabia, traditionally reliant on oil, is venturing into solar energy projects as part of its Vision 2030 plan. This strategy aims to diversify its economy and energy sources, aligning with global sustainable energy trends.

These ten growing G20 countries understand the importance of renewable energy in resolving environmental problems, maintaining energy security, and promoting sustainable development. Their joint efforts to increase renewable energy capacity contribute considerably to global efforts to reduce carbon emissions and transition to a more sustainable energy future.

The transition to renewable energy involves substantial financial expenditures in new energy. However, the relationship between financial development (FD) and renewable energy consumption (REC) is complex and uncertain. Using renewable energy increases financial and economic growth, according to several research (Vasylieva et al., 2019). Other investigations have shown that FD enhances REC (Apergis et al. 2018). As a result, we intend to stress the relationship between the stock market and REC in emerging markets.

In addition to financial development, geopolitical risk (GPR) plays an essential role in emerging countries' energy transition. Caldara and Iacoviello (2018) describe the GPR as the threats posed by armed conflicts, terrorism, and interstate warfare to regular and diplomatic international relations. Furthermore, important economic participants (bankers, equities market dealers, and industrialists) feel geopolitical concerns have an impact on capital market dynamics and impede investor decision-making.

Figure 2 also shows how geopolitical risk and economic growth can both slow consumer spending and prevent businesses from investing in order to maintain a minimum level of protective savings (Bloom, 2009). Thus, it is said that geopolitical concerns serve as early warning signs of economic and business turmoil. Recent study has demonstrated GPR's role in the transition to clean energy and green finance, with implications for environmental management (Zhang et al., 2023).

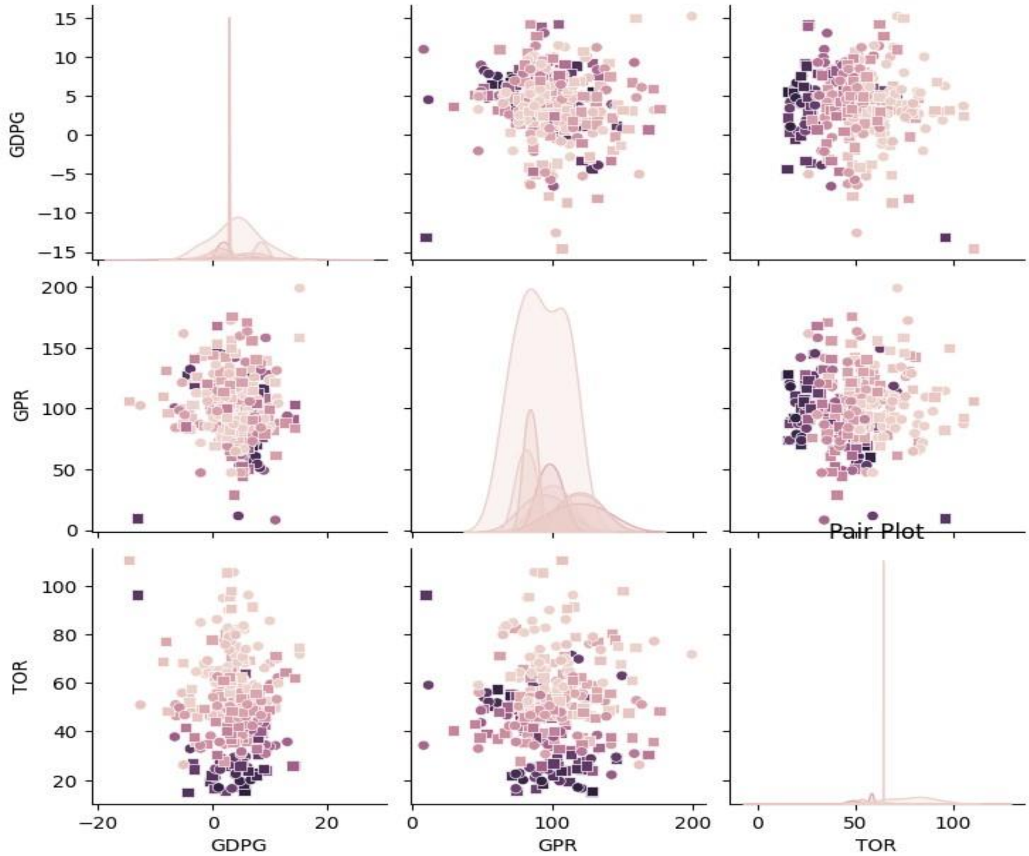

Figure 2. Distribution of GDPG, GPR, and TOR in emerging countries.

Emerging countries, surely, are more sensitive to fast shifts in trade and investment flows (Cheng and Chiu, 2018; Alsagr and Hemmen, 2021). By evaluating the effects of FD and GPR Index on Renewable Energy Consumption in a sample of ten emerging nations for the period between 1985 and 2021. The Two-step System Generalized Methods of Moments is used as part of our empirical approach. We intend to contribute to the literature by considering the significance of the GPR Index and its impact on investment intentions, economic growth, and the broader economy. In addition to macroeconomic constraints, we use several FD proxies like Turnover Ratio (TOR) and the novel GPR Index developed by Caldara and Iacoviello (2018) in our analysis.

The results of this research may have policy consequences for emerging countries' future efforts to increase Renewable Energy. This is the specific research question addressed by this study: *How do geopolitical risk and the stock market affect emerging-market renewable energy consumption?*

To answer the above issue, the determination of this research is to provide beneficial visions into the political process, decision-makers, and investors.

This research sorts three contributions to the works. Firstly, the utilization of the GMM system marks a pioneering methodological advancement in this study, offering a novel approach to examining intricate relationships among variables within the realms of finance, geopolitics, and sustainability. This innovative application of GMM not only sheds light on the complex interplay between the stock market dynamics, geopolitical risk, and renewable energy consumption but also introduces a versatile statistical technique that could potentially be applied across various disciplines.

By integrating these seemingly disparate factors, secondly, this study provides a holistic understanding of their interactions. It goes beyond isolated analyses of finance, geopolitics, or renewable energy consumption, offering a more comprehensive view of how these domains intersect and influence each other. This holistic perspective unveils previously overlooked connections, revealing nuanced relationships that contribute to a profounder comprehension of the intertwined dynamics between financial markets, geopolitical tensions, and sustainable energy initiatives.

The implications of these findings extend beyond academia, potentially impacting policymakers, investors, and businesses. Understanding how geopolitical risk impacts the stock market and renewable energy consumption can inform decision-making processes. Policymakers can use these insights to formulate more effective policies, investors can adjust their strategies to manage risks more prudently, and businesses can align their operations with sustainable energy initiatives, thereby contributing to a more resilient and environmentally conscious economic landscape.

Moreover, this study contributes significantly to the burgeoning field of sustainable finance. Unraveling the association between geopolitical risk and renewable energy consumption within the context of financial markets offers valuable insights for the development of sustainable financial instruments and strategies. These insights could shape the evolution of financial markets, influencing the allocation of capital toward renewable energy projects and fostering innovative approaches to address geopolitical challenges related to sustainable resources.

Finally, this study's pioneering use of GMM to explore the intricate connections between the stock market, geopolitical risk, and renewable energy consumption represents a noteworthy addition to the existing literature. By introducing a unique methodology and providing empirical evidence of these relationships, this research contributes to advancing theoretical frameworks and expanding the knowledge base in finance, geopolitics, and sustainable energy studies.

The remaining sections of the essay are structured to help us reach our objective as follows: Both theoretically and practically, Section 2 describes the linear special effects of the stock market on the REC relationship. The GMM-System is presented in Section 3. The linear impact of the stock market for the case is empirically explored in section 4. The conclusion of the report, which discusses the main findings, is covered in section 5.

2. THEORETICAL FRAMEWORK AND HYPOTHESIS

2.1. The Connection Between Stock Markets and Renewable Energy

Over the past few decades, researchers have extensively examined the correlation between financial advancement and energy consumption in the field of energy economics. Financial progress is frequently regarded as a pivotal driver of economic expansion, particularly in developing nations, suggesting that it is likely to impact energy consumption levels (Sadorsky, 2010).

Monetary development, characterized by a nation's policies promoting activities like enhanced foreign direct investment and the growth of banking and stock markets, presents a pathway to economic advancement intertwined with energy usage (Sadorsky, 2010). Indeed, Minier (2009) suggests that the development of stock markets impacts a country's investment and economic growth through both level and efficiency effects. Specifically, a mature stock market enhances investor confidence, illustrating the level impact.

As per Sadorsky (2011), financial development holds the potential to affect energy consumption through various channels. One direct influence is by easing consumer borrowing costs, thereby promoting significant purchases like vehicles, homes, appliances (such as refrigerators, air conditioners, and washing machines), all of which are energy-intensive commodities with broader implications for a nation's economy. Moreover, enhanced financial development aids businesses by facilitating access to financial capital, enabling expansions of current operations (such as plant purchases or constructions, hiring of employees, and procurement of machinery and equipment) or the initiation of new ventures, consequently amplifying energy usage in production processes.

Moreover, the evolution of equity markets holds particular significance for businesses as it opens up alternative avenues for financing. A surge in stock market participation has the potential to bolster consumer and corporate confidence, spur economic activity, and elevate energy consumption levels. Conversely, the technological dimension implies that financial progress may attract foreign direct investment and streamline access to funds for investment in efficient technologies, consequently reducing energy consumption (Tamazian et al., 2009; Shahbaz et al., 2013 & 2017). Heightened stock market activity can also enhance risk diversification for both individuals and corporations, a pivotal aspect in wealth accumulation within an economy (Sadorsky, 2010). Additionally, according to Zhang et al. (2011), an active stock market attracts more savings, fostering increased investment, economic growth, and subsequently, heightened energy consumption. These theoretical propositions underscore the significant impact of financial development on energy usage, whether positive or negative.

Numerous research projects have attempted to investigate the connection between energy use and the growth of the financial industry. Several scholars have utilized data from several countries, including Sadorsky (2010), Çoban and Topcu (2013), Chang (2015), Mahmood and Saleem (2016), Kahouli (2017), Ulusoy and Dimaralay (2017), Topcu and Payne (2017), Gaies et al. (2019), Yue et al. (2019), and Chiu and Lee (2020). Some have concentrated on research that are specific to a single country, such Salmanai and Atyab (2014), Rafindadi and Ozturk (2016), and Sbia et al (2017). Various authors provide inconsistent, often contradicting results, which can be attributed to differences in the data used, length of study, and technique.

In South Mediterranean Countries (SMCs), Kahouli (2017) investigates the causal relationships between economic growth, energy consumption, and financial development in South Mediterranean Countries (SMCs) spanning from 1995 to 2015. The study reveals a negative correlation between financial development and energy consumption in Egypt, while a positive causality is observed in Israel, Morocco, and Tunisia in the long run. These findings suggest that financial development may either increase or decrease energy usage across different contexts. On the other hand, Topcu and Payne (2017) analyze the impact of financial development on energy consumption using a panel comprising 32 high-income nations. Their study concludes that there is no statistically significant association between the total financial development index and energy consumption.

In a different study, Gaies et al. (2019) examine how estimates of energy consumption in 18 MENA nations from 1996 to 2014 were impacted by financial development. They show how the financial system's potential increases energy consumption in a positive way. Yue et al. (2019) examine the empirical correlation between financial development and energy consumption for twenty-one transitional countries. According to their findings, all of the countries under investigation have seen increases in energy consumption as a result of the expansion of financial intermediation.

Furthermore, Chiu and Lee (2020) investigated how country risks influence the relationship between energy consumption and financial development across 79 countries. Their results suggest that in stable country risk environments, financial development may contribute to reducing energy consumption.

In a more recent study by Saygin and Iskenderoglu (2022), the impact of financial development on renewable energy consumption was examined using panel data from 23 industrialized nations spanning from 1990 to 2015. Employing a generalized technique of moments estimation and the cross-sectionally augmented autoregressive distributed lag estimator, they found that when banking variables are used to measure financial progress, the coefficients are positive and highly significant. However, when financial development is assessed using stock market variables, the coefficients in all models are negative and statistically insignificant.

In their research, Sun et al. (2023) examined the global impact of financial development on renewable energy utilization using a dynamic panel model and data from 103 economies. Their study explored the influence of financial development across different levels, employing an index system comprising nine variables. Additionally, they investigated national heterogeneity by dividing the samples into established and developing economies. The empirical results indicated that, from a macro perspective, financial development positively affected renewable energy consumption, with the primary driver being the development of financial institutions, particularly banks.

As a consequence of the theoretical overview above, we develop the following first research hypothesis:

H_1: The stock markets are a significant positive predictor of emerging countries impacting the energy renewable.

2.2. The Connection Between Geopolitical Risks and Energy Renewable

Since the late 1950s, much of the literature on energy geopolitics has centered around the intersection of international affairs and petroleum resources, as evidenced by works such as those by Ireland (1958), Yergin (2011), and Krane and Medlock (2018). Both academia and the media have closely monitored this issue, with it being a common subject in university courses covering international relations, global governance, foreign policy, security studies, and energy studies. Even as of 2018, oil and gas continued to dominate the geopolitical research agenda, receiving significantly more attention than renewable energy sources.

However, starting around 2006, there was a notable increase in the growth of solar and wind power installations, leading to a surge in interest in the geopolitics of renewable energy, particularly from around 2010 onward. Many subsequent articles on this topic highlight its emerging importance, as noted by Scholten and Bosman (2016).

The National Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA), as indicated by Donovan (1972), emphasized the strategic significance of solar power for the United States, highlighting the inevitable environmental, social, and political implications associated with its utilization.

Similarly, Williams (1974) argued that widespread adoption and utilization of solar energy could mitigate the international energy crises associated with fossil fuel consumption.

In 1980, the California Academy of Sciences, as documented by McCasker et al.(1980) issued a paper for the United States Federal Emergency Management Agency (FEMA), outlining how renewable energy could diminish the country's energy vulnerability and reduce the potential for conflict.

Examining the geopolitical ramifications of increased renewable energy usage presents a unique challenge due to its novelty. Unlike the well-established framework for analyzing oil and gas geopolitics, which revolves around supply-demand dynamics, there is currently no comprehensive analytical framework capable of fully addressing the complexities of renewable energy geopolitics.

While Scholten (2018) has proposed a new analytical framework grounded in research on socio-technical systems and energy security, it primarily focuses on the direct consequences stemming from the geotechnical aspects of renewables, rather than those resulting from the transition to renewable sources.

A significant challenge arises from the lack of consensus among authors regarding the precise definition of "geopolitics," as noted by Proedrou et al. (2018) and Overland et al. (2019). Consequently, terms such as "geopolitics," "great power rivalry," and "international relations" are at times used interchangeably. Moreover, there is a need for clarification between the concepts of energy geopolitics and energy security, which are often conflated.

Furthermore, only a limited number of authors, such as Stoeglehner et al. (2011) and Bridge et al. (2013), delve into the geographical dimensions of renewable energy, emphasizing the importance of defining the spatial aspects in the context of renewable energy.

Founded on the theoretical background presented, we derive the next second investigation hypothesis:

H_2: The geopolitical risks are a significant positive predictor of emerging countries impacting the energy renewable consumption

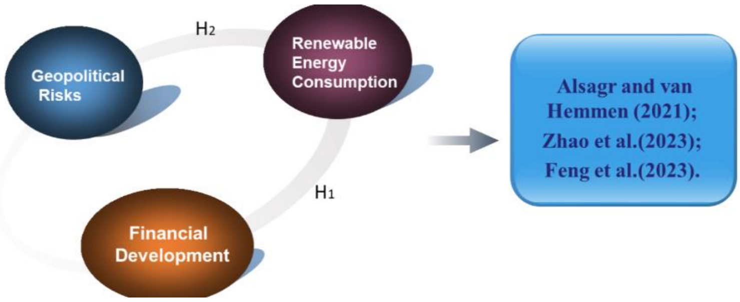

Figure 3. Theoretical framework.

Figure 3 summarizes our conceptual diagram of the two hypotheses developed above.

3. METHODOLOGY

This study utilizes a panel data model to investigate how stock market performance and geopolitical risks affect renewable energy consumption in emerging countries. Drawing from the existing literature discussed in Section 2, and in alignment with microeconomic theory, our model, as outlined by Alsagr and Van Hemmen (2021), is structured and analyzed as follows:

$$RNE_{it} = \beta_0 + \beta_1 GDPG_{it} + \beta_2 INF_{it} + \beta_3 FDI_{it} + \beta_4 GPR_{it} + \beta_5 DL_{it} + \beta_6 TOR_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

The model includes several key variables: RNE represents Renewable Energy Consumption, GDPG denotes Gross Domestic Product Per capita Growth, INF signifies the inflation rate, FDI represents Foreign Direct Investment as a percentage of GDP, GPR stands for the Geopolitical Risks index, DL represents Domestic Loans by Banks, and TOR indicates the stock market Turnover Ratio. Additionally, $\mu_i$captures the country-specific effect, λ_t accounts for relevant time effects, and ε_it represents the random error term. All variables are summarized in Table 1.

Table 1. Variable's description.

Variables	Description	Source
RNE	Renewable Energy Consumption	WDI
GDPG	Growth of Gross Domestic Product per Capita (Annual %)	WDI
INF	Inflation as a percentage of CPI	FRED
FDI	Foreign Direct Investment as a percentage of GDP	WDI
GPRI	Geopolitical Risks index	Caldara and Iacoviello (2018)
DL	Domestic Loans	FAS
SMTR	Stock Market Turnover Ratio	FAS

In our study, the consumption of renewable energy (RNE) serves as the dependent variable. Consistent with recommendations from prior research (e.g., Anton and Nucu, 2020), we utilize the proportion of renewable energy consumption in total energy consumption as a proxy for RNE.

Similarly, we measured our independent variable, monetary development, by drawing on prior research (e.g., Gaies et al., 2019) and using two proxies, the Domestic Loans by Banks (DL) and the Stock Market Turnover Ratio (TOR). Their values are taken from Financial Access Survey database (FAS).

Then, we use the Geopolitical Risks Index (GPR), created by Caldara and Iacoviello (2018) to quantify our second key independent variable, by measuring the frequency with which phrases suggesting geopolitical risks were used. GPR, according to Caldara and Iacoviello (2018), include conflicts, bomber actions, and political disasters that disrupt national and worldwide ties.

Previous studies, such as Anton and Nucu (2020), have extensively documented the influence of GDP per capita Growth ($GDPG$), inflation rate INF, and foreign direct investment FDI on renewable energy utilization. Additionally, we comprehensively analyze all significant country-level variables, sourcing reliable data from reputable databases such as the FRED database for inflation rate (INF) and the World Bank database for GDP per capita growth, FDI as a percentage of GDP, and the proportion of renewable energy consumption relative to total energy consumption.

Our sample is made up of a group of 10 emerging countries (Brazil, China, India, Indonesia, Mexico, Russia, Saudi Arabia, South Africa, South Korea, South Korea, and Turkey) between 1985 and 2021.

4. EMPIRICAL RESULTS

4.1. Variable's description

Before proceeding with preliminary tests to evaluate our model, conducting a thorough descriptive analysis of the various variables is essential.

Regarding Table 2, it is evident that the majority of the data variables exhibit leptokurtic and asymmetric distributions. Additionally, the normality of the data series is rejected by the Jarque-Bera (1987) test, and Born and Breitung's (2016) serial autocorrelation test highlights the presence of autocorrelation issues in most of the model variables.

Table 2. Descriptive analysis.

Designation	RNE	GDPG	INF	FDI	GPR	DL	TOR
Observations	370	370	370	370	370	370	370
Mean	20.608	4.039	64.336	1.558	98.853	58.598	48.717
Median	14.175	4.441	6.258	1.196	95.048	51.729	48.761
Standard deviation	18.529	4.624	269.903	1.465	28.169	38.257	18.612
Minimum	0.009	-14.531	-3.203	-2.757	8.268	11.208	12.219
Maximum	62.915	17.013	2947.733	8.496	199.103	182.868	110.577
Skewness	0.669	-0.617	6.602	0.998	0.427	0.934	0.360
Kurtosis	2.147	4.413	54.705	4.913	4.143	3.173	3.207
Jarque-Bera test	38.87	54.31	4.4 e+04	117.9	31.41	54.35	8.673
Jarque-Bera p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.013
Born-Breitung test	5.64	3.67	12.57	2.53	25.04	16.88	50.70
Born-Breitung p-value	0.060	0.159	0.002	0.282	0.000	0.000	0.000

Following the descriptive analysis of model variables, we proceed to investigate the presence of a dependence relationship among individuals using tests proposed by Friedman (1937), Breusch & Pagan (1980), Frees (1995 & 2004), Pesaran (2004), and Pesaran et al. (2008). The results presented in Table 3 indicate that all these tests confirm the existence of such a dependence relationship among individuals, necessitating the application of second-generation unit root tests. Consequently, we proceed to examine the stationarity of variables utilizing Levin et al. (LLC, 2002), Im et al. (IPS, 2003), and Hadri (LM, 2000) unit root tests.

Table 3. The different tests of Cross-Dependence.

Tests	Value	Probability	Decision
Friedman (1937)	28.885	0.000	Dependence
Breusch-Pagan (1980)	89.2	0.000	Dependence
Frees (1995 & 2004)	2.259	0.000	Dependence
Pesaran (2004)	2.367	0.017	Dependence
Pesaran et al. (2008)	11.71	0.000	Dependence

Regarding the outcomes shown in Table 4, every model variable is stationary in the first difference.

Table 4. Unit root test.

Variables	In level				In first difference			
	LLC	IPS	LM	Decision	LLC	IPS	LM	Decision
Ln RNE	-1.120*	1.406*	69.414*	**NS**	-7.195*	-9.646*	3.175*	S
Ln GDPCG	-5.217*	-8.838	6.828*	**NS**	-9.516*	-13.305*	-2.955	S
Ln INF	-3.395*	-3.676*	26.971*	**NS**	-12.989*	-11.522*	-2.725*	S
Ln FDI	-3.456*	-3.126	19.353*	**NS**	-12.218*	-11.137*	-2.075	S
Ln GPRI	-3.814*	-5.238*	17.735*	**NS**	-6.906*	-11.456*	-2.303*	S
Ln DL	1.494*	2.420**	47.599*	**NS**	-8.076*	-10.049*	-1.141	S
LnSMTR	-0.498*	0.115**	40.328*	**NS**	-8.667*	-10.740*	-2.226*	S

Note: *** represents significance at 1%, NS: non stationarity; S: stationarity.

We apply the unit root test of Karavias and Tzavalis (2014) to validate the aforesaid results. Regarding Table 5, all variables are stationary in terms of both level and first difference, despite the fact that there are many shocks associated with the financial, health, and economic shocks brought on by COVID-19 in 2020 for the nations. As a result, the unit root test results are verified. Testing the existence of a cointegration relationship between the model variables is therefore required.

Table 5. Karavias and Tzavalis (2014) unit root test with a break.

Variables	In level	In first difference
RNE	-14.020*** (2020)	-29.880*** (2020)
GDPCG	-26.330*** (2020)	-48.221*** (2020)
INF	-18.860*** (1995)	-39.963*** (2020)
FDI	-17.221*** (2020)	-36.523*** (2020)
GPRI	-18.706*** (1986)	-42.241*** (2020)
DL	-17.084*** (2020)	-34.139*** (2020)
SMTR	-16.840*** (2020)	-40.037*** (2020)

Note: Value between brackets represents break date. *** represents significance at 1%.

In accordance with Table 6, which displays the various cointegration tests conducted by Pedroni (2004), Westerlund (2007), and Kao (1999), we deduce that there exists a minimum of one cointegration relationship among the variables. This implies that these variables have a long-term relationship or equilibrium, indicating a significant relationship in the economic setting under examination.

Table 6. Cointegration tests.

Tests	Value	Probability	Decision
Kao (1999)	1.591	0.055	Cointegration
Pedroni (2004)	0.144	0.442	No Cointegration
Westerlund (2007)	4.076	0.000	Cointegration

After confirming the existence of a cointegrating relationship among model variables, we proceed to estimate our model using the GMM-System estimator proposed by Arellano and Bond (1995) and Blundell and Bond (1998). Employing this technique in econometric modeling offers several significant advantages.

Firstly, it effectively addresses concerns related to endogeneity, mitigating biases in parameter estimates stemming from simultaneous causality among variables. Moreover, it does not require a full specification of the underlying probability distribution, making it adaptable to situations where the true distribution is complex or unknown.

Additionally, the GMM-System estimator can capture dynamic interactions by incorporating lagged variables and time-dependent components, thereby providing a more realistic depiction of evolving economic relationships. The method's efficient use of instrumental variables enhances the precision of estimation, while its robustness to model misspecification ensures reliable results even in the presence of certain modeling errors.

Table 7. Two-step GMM-system results.

Variables	Coefficient	Standard Error	t-statistic	Probability
RNE_{it-1}	0.990	0.021	46.38	0.000
$GDPG_{it}$	0.047	0.019	2.41	0.039
INF_{it}	0.0001	0.00008	2.31	0.046
FDI_{it}	0.509	0.223	2.28	0.049
GPR_{it}	0.012	0.003	3.85	0.000
DL_{it}	0.012	0.005	2.20	0.056
$SMTR_{it}$	0.016	0.008	2.05	0.070
Constant	-1.085	0.641	-1.69	0.125
Diagnostic tests	**Statistics**		**p-value**	
AR(1) test	-2.25		0.024	
AR(2) test	-0.80		0.422	
Sargan test	26.69		0.181	
Hansen test	0.12		1.000	

According to the results presented in Table 7, all variables in the model demonstrate a positive and statistically significant impact on Renewable Energy Consumption (RNE). Specifically, an increase of 1% in the main variables, Geopolitical Risk and Stock Market, leads to respective increases in renewable energy consumption by 0.012% and 0.016%. Furthermore, a 1% increase in economic growth, Foreign Direct Investment (FDI), and domestic loans correlates with increases in clean energy consumption by 0.047%, 0.509%, and 0.012%, respectively. Additionally, inflation exhibits a modest positive and significant effect on renewable energy consumption.

The research of Anton and Nucu (2020) emphasized the crucial role of financial development in promoting Renewable Energy Consumption. They argued that a well-developed financial market facilitates easier access to external financing for investors and companies at lower costs, enabling increased investment in renewable energy projects. Furthermore, an efficient and developed financial sector can enhance access to various financial products and services, stimulating technological innovations and expanding renewable energy initiatives.

Furthermore, Foreign Direct Investment (FDI) and the development of the stock market are influenced by other significant determinants that positively impact Renewable Energy Consumption. An increase in FDI and stock market development can facilitate the transmission of better management practices and cleaner technology, enhance access to external financing, and encourage investment in renewable energy projects. This ultimately contributes to a higher share of renewable energy in the energy supply, promoting environmental sustainability (Brown et al., 2009; Ferrier et al., 2016; Inglesi-Lotz, 2016).

Given the substantial financial resources required for investment in renewable energy, the role of the financial sector is paramount. According to Wu and Broadstock (2021), the financial sector contributes to renewable energy consumption by promoting capital accumulation, facilitating technological innovation, and allocating funds to profitable projects. This suggests that a well-functioning financial sector can mitigate liquidity risks and mobilize funds at lower costs for investment in energy-efficient technologies, including renewable energy (Amuakwa-Mensah and Näsström, 2022).

The positive correlation between market capitalization and renewable energy consumption suggests that larger banks may benefit from scale advantages, making them more inclined to invest in renewable energy technology. Additionally, large banks can offer leverage for the state when acquiring energy technologies that are capital-intensive (Amuakwa-Mensah et al., 2018).

Moreover, financial institutions play a vital role in resolving asymmetric information issues through their activities, leveraging their knowledge of both lenders and borrowers. This leads to reduced business costs, enhanced efficiency, and potentially lower risks associated with renewable energy projects. Additionally, financial institutions can redistribute funds from less energy-efficient appliances and non-renewable energy sources to environmentally friendly or renewable energy options based on their regulatory frameworks (Amuakwa-Mensah and Näsström, 2022).

The Covid-19 pandemic has significantly impacted the economy, financial markets, and energy markets, all of which are crucial in addressing environmental and societal challenges. Furthermore, there is an ongoing transition from fossil fuels to renewable energy sources, which has been accelerated by the conflict in Ukraine that began in February 2022.

Furthermore, the utilization of renewable energy is positively influenced by shocks in geopolitical risk. Given the world's polarized geopolitics, which have been marked by events such as the 9/11 terrorist attack, the Gulf War, the invasion of Kuwait, and the invasion of Iraq, there are significant geopolitical challenges to global energy security, leading to dramatic fluctuations in oil prices in recent decades.

Geopolitical risks have contributed to an increased adoption of renewable energy, which serves as a cleaner alternative to fossil fuels known for their emissions and reliance on rare earth materials. Moreover, renewable energy has the potential to reduce geopolitical risks. Unlike fossil fuels, which are unevenly distributed globally, the resources needed for renewable energy are widely available. Therefore, developing renewable energy presents the most viable option for energy-poor countries (Cai and Wu, 2021).

The long-term implications of this issue appear to be closely tied to how Geopolitical Risk influences the demand for fossil fuels. According to Saadaoui et al. (2023), the impact of the GPR Index is particularly noticeable in oil prices, underscoring the growing significance of renewable energy production and consumption. Additionally, Geopolitical Risk stimulates the utilization of renewable energy sources, potentially mitigating environmental pollution (Alsagr and Van Hemmen, 2021).

Recent studies by Ji et al. (2019) and Zhang et al. (2019) have highlighted a positive correlation between geopolitical risk and oil prices, as corroborated by Gaies et al. (2019). This relationship can be elucidated through the economic principle of the law of demand. Drawing on Marshall's (1892) economic law of demand, which posits that, under regulated conditions, an increase in the price of a commodity leads to a decrease in its demand, we can better understand the positive correlation between Geopolitical Risk and oil prices. The rise in costs of non-renewable energy leads to reduced energy consumption. Consequently, in line with the substitution effect, there is a surge in the utilization of renewable energy sources.

Geopolitical risk significantly influences the fluctuations of oil prices, impacting both the supply and demand dynamics (Cunado et al., 2019; Demirer et al., 2019). This influence extends to clean energy assets, as oil and renewable energy prices are interconnected (Marques et al., 2018).

There are four primary channels through which geopolitical risk can affect renewable energy assets. Firstly, heightened geopolitical risk tends to elevate crude oil prices, potentially prompting a shift from traditional to renewable energy sources. This transition can enhance the operational environment for new energy firms, positively affecting their stock performance (Yang et al., 2021). Secondly, investor perceptions of the alternative energy industry and subsequent investment decisions may be influenced by their expectations of future changes in oil supply and demand. This, in turn, can impact returns on clean energy assets (Song et al., 2019).

The global transition towards renewable energy sources offers several advantages, including enhanced energy self-reliance and a decrease in geopolitical tensions. This shift incentivizes policymakers and investors to prioritize clean energy investments as a strategy to mitigate geopolitical risks, consequently bolstering the renewable energy asset class. However, heightened geopolitical tensions often lead to increased uncertainty, which can disrupt economic activities and impact financial markets, including stocks, exchange rates, and commodities. Consequently, clean energy assets, closely tied to these markets, become vulnerable to such uncertainty. (Aysan et al., 2021; Lee, 2019; Park and Park, 2019).

Conversely, geopolitical conflicts tend to escalate military expenditures and activities, exacerbating environmental degradation. For instance, conflicts like the Russia-Ukraine war spur the development and deployment of military technologies, resulting in environmental damage through bombings and property destruction. Moreover, as geopolitical risks intensify, financial resources that could have been allocated to renewable energy solutions are diverted towards military endeavors, hindering progress in transitioning to renewable energies. Additionally, during periods of geopolitical tension, the financial burden of military activities extends beyond the countries directly involved in conflicts. (Acheampong et al., 2023).

Furthermore, our research highlights a positive correlation between GDP growth and the adoption of renewable energy, indicating that increased usage of renewable energy contributes to a reduction in global CO_2 emissions. This suggests that, all else being equal, higher utilization of renewable energy leads to a decrease in CO_2 emissions. Consequently, renewable technologies, utilizing cleaner energy sources, not only fulfill current and future energy demands but also play a crucial role in mitigating CO_2 emissions on a global scale.

Multiple studies suggest a positive correlation between economic growth and the adoption of renewable energy, emphasizing the potential synergy between economic advancement and sustainable energy uptake. For example, research by Apergis and Payne (2014) and Ohlan (2016) indicates a significant and positive relationship between economic growth and the proportion of renewable energy utilized.

This positive relationship implies that as a country experiences economic growth, it tends to invest more in renewable energy sources. Additionally, Soytas and Sari (2009) observed a positive connection between economic growth and renewable energy consumption, emphasizing the role of economic factors in driving the shift towards cleaner energy sources.

Economic growth often leads to increased investment in research and development of renewable energy technologies. As economies expand, there's a greater tendency for governments, businesses, and individuals to allocate resources for the advancement and deployment of clean energy solutions. Furthermore, economic growth contributes to cost reductions in renewable energy technologies, as increased production scales down manufacturing, installation, and maintenance expenses, thereby enhancing the competitiveness of renewables.

Furthermore, robust economies typically enact policies that support sustainability and the adoption of renewable energy, such as implementing feed-in tariffs, tax incentives, or government subsidies. These measures foster an environment conducive to the expansion of renewable energy usage. Consequently, as energy consumption increases alongside economic growth, integrating renewable sources becomes a sustainable approach to meet rising demand, ensuring greater energy accessibility while diminishing dependence on fossil fuels. Moreover, economic expansion accelerates technological advancements, driving the development of more sophisticated and efficient renewable energy sources. The current wave of innovation is leading to the creation of new technologies that enhance the efficiency and economic feasibility of renewable energy systems.

Foreign Direct Investment (FDI) impacts renewable energy through three main effects. Firstly, the scale effect occurs as FDI boosts energy production by improving GDP through its activities. Secondly, the technique effect highlights FDI's positive contribution to enhancing energy efficiency and promoting clean power. Thirdly, the composition effect suggests that the impact of FDI depends on its sectoral distribution and the stage of economic development in host countries (Acheampong et al., 2019).

Additionally, the positive impact of capital stock on renewable energy stems from increased capital supply reducing financing costs, thereby stimulating economic activity and energy consumption. Consequently, to meet the growing demand for energy, investments in the installed capacity of energy also increase (Lee and Chen, 2010; Lee et al., 2008). Following this logic, economic dynamics facilitate the transmission of the impact of capital stock to the installed capacity of renewable energy.

The impact of financial openness on the installed capacity of renewable energy operates indirectly. Increased financial integration leads to a reduction in credit costs, stimulating the consumption of goods and services, thereby fueling economic activity and energy consumption. Consequently, to meet the rising demand for energy, greater investments are directed towards the installed capacity of renewable energy. This relationship is supported by studies such as Koengkan et al. (2018), Shahbaz et al. (2013), and Islam et al. (2013).

Moreover, inflation can inadvertently drive the adoption of renewable energy by reshaping economic priorities and incentivizing sustainable practices. As inflation drives up the price of conventional fossil fuels, both consumers and businesses seek more stable and affordable alternatives, thus potentially increasing investments in renewable energy technologies. Furthermore, as part of broader strategies for economic resilience, governments may be prompted to allocate funding for sustainable projects. Consequently, inflation can serve as a catalyst for countries to transition towards cleaner and more sustainable energy sources in the future.

To validate our estimation, we conducted the autocorrelation test proposed by Arellano and Bond (1991), as well as the Over-Identification tests by Sargan (1958) and Hansen (1982). The results, detailed in the second panel of Table 7, confirm the absence of second-order autocorrelation and demonstrate over-identification of instruments.

These diagnostic tests provide further confirmation, reinforcing the robustness and reliability of our estimation findings. The absence of second-order autocorrelation indicates that residuals do not exhibit systematic patterns over time, thereby bolstering the credibility of our model. Additionally, the over-identification of instruments suggests that the instruments we selected are not correlated with the error term, supporting the validity of our estimation approach.

5. CONCLUSION AND POLICY IMPLICATIONS

The objective of this research was to examine the influence of geopolitical risk and financial development on renewable energy (RNE) consumption using panel data from ten emerging countries spanning from 1985 to 2021. Through empirical analysis grounded in theory and literature, the study investigated the impact of finance development and geopolitical risk on the adoption of renewable energy sources. Both the banking industry and the stock market were utilized as proxies for financial development. The key findings derived from employing the two-step GMM-system technique revealed that all independent variables had a positive and significant effect on RNE consumption. Notably, the two primary variables of interest, geopolitical risk, and stock market turnover ratio, were found to positively and significantly influence the consumption of renewable energy sources.

These findings carry significant policy implications for policymakers in emerging economies. Navigating the intricate realm of environmental sustainability presents emerging countries with a multitude of challenges, deeply influenced by the complex interplay of geopolitical dynamics and pressures from the financial sector. To effectively address these multifaceted issues, it is imperative to devise unique policy approaches. Firstly, fostering regional geopolitical stability through collaborative frameworks among emerging nations can serve as a catalyst for shared endeavors towards environmental conservation. This may entail the establishment of joint research initiatives and technology-sharing agreements, thereby harnessing collective resources for sustainable development. Additionally, incentivizing green diplomacy and fostering bilateral agreements with developed nations can facilitate the transfer of technology and investment in sustainable projects, thereby mitigating the disruptive impact of geopolitical tensions on environmental initiatives.

Secondly, the implementation of innovative carbon pricing mechanisms holds promise in internalizing environmental costs and incentivizing green investments within emerging economies. Leveraging the revenue generated from such mechanisms, these countries can finance sustainable projects and bolster technology transfer programs aimed at curtailing carbon emissions. Moreover, prioritizing green finance within the financial sector, through measures such as tax incentives and preferential loan terms, can expedite the transition towards sustainable practices. The development of green bonds and investment funds, tailored to finance renewable energy and conservation initiatives, can unlock vital financial resources for environmental projects.

Thirdly, the establishment of technology transfer platforms tailored to the specific needs of emerging countries can facilitate the exchange of sustainable technologies. Supported by public-private partnerships and international collaborations, these platforms can ensure equitable access to environmentally friendly innovations. Furthermore, investment in capacity building programs and knowledge-sharing initiatives can empower local communities and businesses to effectively adopt sustainable practices. By augmenting technical expertise and fostering innovation, emerging countries can surmount technological barriers and propel sustainable development forward.

Fourthly, the adoption of sustainable urban planning practices is pivotal in addressing the environmental ramifications of rapid urbanization. By advocating for eco-friendly infrastructure, public transportation, and green spaces, emerging countries can mitigate environmental degradation in urban areas. Strengthening natural resource management policies is equally indispensable in safeguarding ecosystems and biodiversity. Regulations aimed at forestalling deforestation, promoting sustainable agriculture, and safeguarding water resources can help alleviate the repercussions of geopolitical and economic pressures on natural environments.

Lastly, nurturing a culture of innovation through the establishment of green innovation hubs or technology parks can expedite the development and uptake of sustainable solutions. By fostering collaboration among academia, industry, and government, these innovation hubs can propel research and development endeavors in clean energy, green technologies, and eco-friendly products. Such an approach not only fosters economic growth but also enriches environmental stewardship, positioning emerging countries as trailblazers in sustainable innovation on the global stage. In conclusion, by embracing these tailored policy suggestions, emerging countries can adeptly navigate the intricate web of geopolitical factors, financial sector dynamics, and technological transfers to achieve enduring environmental sustainability.

However, it's essential to acknowledge the limitations of this study for future research endeavors. Challenges related to the reliability and accessibility of data on financial progress, geopolitical risk, and renewable energy consumption pose significant constraints. Conducting comprehensive studies may prove challenging due to potential inaccuracies, outdated information, or inconsistencies across nations. Additionally, the interrelated nature of financial development, geopolitical risk, and renewable energy consumption may lead to phenomena where changes in one variable influence others. Therefore, researchers must carefully consider endogeneity to prevent biased estimates and draw accurate conclusions.

While the Generalized Method of Moments (GMM) technique provides a robust statistical framework, it has certain limitations when applied to explore the interplay between the stock market, geopolitical risk, and renewable energy consumption. One key limitation lies in its assumption of employing instruments that are exogenous and not correlated with the error term in the regression model.

In investigations concerning intricate relationships such as those involving stock markets, geopolitical risk, and renewable energy consumption, endogeneity issues may arise. This can lead to biased estimates and pose challenges in identifying causal relationships accurately. Furthermore, in studies incorporating macroeconomic or geopolitical factors, identifying instruments that meet the necessary conditions (validity, relevance, homogeneity) can be arduous. Such difficulties in instrument selection may impact the precision and dependability of the estimates.

Availability of Data and Materials:

Data are available from data from the FRED database, the World Bank (WDI) database, the Financial Access Survey (FAS) database, and Caldara and Iacoviello (2018). The data is available on request from the corresponding author.

REFERENCES

Acheampong, A. O., Adams, S., & Boateng, E. (2019). Do globalization and renewable energy contribute to carbon emissions mitigation in Sub-Saharan Africa? *Science of the Total Environment, 677*, 436–446. https://doi.org/10.1016/j.scitotenv.2019.04.353

Acheampong, A. O., Opoku, E. E. O., & Aluko, O. A. (2023). The roadmap to net-zero emission: Do geopolitical risk and energy transition matter? *Journal of Public Affairs, 23*(4), e2882. https://doi.org/10.1002/pa.2882

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*, 25906–25919. https://doi.org/10.1007/s11356-021-12447-2

Amuakwa-Mensah, F., & Näsström, E. (2022). Role of banking sector performance in renewable energy consumption. *Applied Energy, 306*, 118023. https://doi.org/10.1016/j.apenergy.2021.118023

Amuakwa-Mensah, F., Klege, R. A., Adom, P. K., Amoah, A., & Hagan, E. (2018). Unveiling the energy saving role of banking performance in Sub-Saharan Africa. *Energy Economics, 74*, 828–842. https://doi.org/10.1016/j.eneco.2018.07.031

Anton, S. G., & Nucu, A. E. A. (2020). The effect of financial development on renewable energy consumption: A panel data approach. *Renewable Energy, 147*, 330–338. https://doi.org/10.1016/j.renene.2019.09.005

Apergis, N., & Payne, J. E. (2014). Renewable energy, output, CO_2 emissions, and fossil fuel prices in Central America: Evidence from a nonlinear panel smooth transition vector error correction model. *Energy Economics, 42*, 226–232. https://doi.org/10.1016/j.eneco.2014.01.003

Apergis, N., Can, M., Gozgor, G., & Lau, C. K. M. (2018). Effects of export concentration on CO_2 emissions in developed countries: An empirical analysis. *Environmental Science and Pollution Research, 25*(14), 14106–14116. https://doi.org/10.1007/s11356-018-1634-x

Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *Review of Economic Studies, 58*(2), 277–297. https://doi.org/10.2307/2297968

Arellano, M., & Bover, O. (1995). Another look at the instrumental variable estimation of error-components models. *Journal of Econometrics, 68*(1), 29–51. https://doi.org/10.1016/0304-4076(94)01642-D

Bloom, N. (2009). The impact of uncertainty shocks. *Econometrica, 77*(3), 623–685. https://doi.org/10.3982/ECTA6248

Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics, 87*(1), 115–143. https://doi.org/10.1016/S0304-4076(98)00009-8

Born, B., & Breitung, J. (2016). Testing for serial correlation in fixed-effects panel data models. *Econometric Reviews, 35*(7), 1290–1316. https://doi.org/10.1080/07474938.2014.976524

Breusch, T. S., & Pagan, A. R. (1980). The Lagrange multiplier test and its applications to model specification in econometrics. *Review of Economic Studies, 47*(1), 239–253. https://doi.org/10.2307/2297111

Bridge, G., Bouzarovski, S., Bradshaw, M., & Eyre, N. (2013). Geographies of energy transition: Space, place and the low-carbon economy. *Energy Policy, 53*, 331–340. https://doi.org/10.1016/j.enpol.2012.10.066

Brown, J. R., Fazzari, S. M., & Petersen, B. C. (2009). Financing innovation and growth: Cash flow, external equity, and the 1990s R&D boom. *Journal of Finance, 64*(1), 151–185. https://doi.org/10.1111/j.1540-6261.2008.01431.x

Cai, Y., & Wu, Y. (2021). Time-varying interactions between geopolitical risks and renewable energy consumption. *International Review of Economics & Finance, 74*, 116–137. https://doi.org/10.1016/j.iref.2021.02.006

Caldara, D., & Iacoviello, M. (2018). *Measuring geopolitical risk* (International Finance Discussion Papers No. 1222). Board of Governors of the Federal Reserve System.

Chang, S. C. (2015). Effects of financial developments and income on energy consumption. *International Review of Economics & Finance, 35*, 28–44. https://doi.org/10.1016/j.iref.2014.08.011

Cheng, C. H. J., & Chiu, C. W. J. (2018). How important are global geopolitical risks to emerging countries? *International Economics, 156*, 305–325. https://doi.org/10.1016/j.inteco.2018.05.002

Chiu, Y. B., & Lee, C. C. (2020). Effects of financial development on energy consumption: The role of country risks. *Energy Economics, 90*, 104833. https://doi.org/10.1016/j.eneco.2020.104833

Çoban, S., & Topcu, M. (2013). The nexus between financial development and energy consumption in the EU: A dynamic panel data analysis. *Energy Economics, 39*, 81–88. https://doi.org/10.1016/j.eneco.2013.04.001

Demirer, R., Gupta, R., Ji, Q., & Tiwari, A. K. (2019). Geopolitical risks and the predictability of regional oil returns and volatility. *OPEC Energy Review, 43*(3), 342–361. https://doi.org/10.1111/opec.12160

Donovan, P. (1972). *An assessment of solar energy as a national energy resource*. U.S. Government Printing Office.

Ferrier, G. D., Reyes, J., & Zhu, Z. (2016). Technology diffusion on the international trade network. *Journal of Public Economic Theory, 18*(2), 291–312. https://doi.org/10.1111/jpet.12186

Frees, E. W. (1995). Assessing cross-sectional correlation in panel data. *Journal of Econometrics, 69*(2), 393–414. https://doi.org/10.1016/0304-4076(94)01658-M

Frees, E. W. (2004). *Longitudinal and panel data: Analysis and applications in the social sciences*. Cambridge University Press. https://doi.org/10.1017/CBO9780511790928

Friedman, M. (1937). The use of ranks to avoid the assumption of normality implicit in the analysis of variance. *Journal of the American Statistical Association, 32*(200), 675–701. https://doi.org/10.1080/01621459.1937.10503522

Gaies, B., Kaabia, O., Ayadi, R., Guesmi, K., & Abid, I. (2019). Financial development and energy consumption: Is the MENA region different? *Energy Policy, 135*, 111000. https://doi.org/10.1016/j.enpol.2019.111000

Hansen, L. P. (1982). Large sample properties of generalized method of moments estimators. *Econometrica, 50*(4), 1029–1054. https://doi.org/10.2307/1912775

Inglesi-Lotz, R. (2016). The impact of renewable energy consumption to economic growth: A panel data application. *Energy Economics, 53*, 58–63. https://doi.org/10.1016/j.eneco.2015.01.003

Ireland, H. A. (1958). *Geopolitics and oil development in the Middle East*. Middle East Institute.

International Renewable Energy Agency. (2023). *Renewable energy statistics 2023*. IRENA.

Islam, F., Shahbaz, M., Ahmed, A. U., & Alam, M. (2013). Financial development and energy consumption nexus in Malaysia: A multivariate time series analysis. *Economic Modelling, 30*, 435–441. https://doi.org/10.1016/j.econmod.2012.09.033

Jarque, C. M., & Bera, A. K. (1987). A test for normality of observations and regression residuals. *International Statistical Review, 55*(2), 163–172. https://doi.org/10.2307/1403192

Ji, Q., Li, J., & Sun, X. (2019). Measuring the interdependence between investor sentiment and crude oil returns: New evidence from the CFTC's disaggregated reports. *Finance Research Letters, 30*, 420–425. https://doi.org/10.1016/j.frl.2019.02.005

Kahouli, B. (2017). The short and long run causality relationship among economic growth, energy consumption and financial development: Evidence from South Mediterranean countries. *Energy Economics, 68*, 19–30. https://doi.org/10.1016/j.eneco.2017.09.013

Kao, C. (1999). Spurious regression and residual-based tests for cointegration in panel data. *Journal of Econometrics, 90*(1), 1–44. https://doi.org/10.1016/S0304-4076(98)00023-2

Karavias, Y., & Tzavalis, E. (2014). Testing for unit roots in short panels allowing for a structural break. *Computational Statistics & Data Analysis, 76*, 391–407. https://doi.org/10.1016/j.csda.2012.10.014

Koengkan, M. (2018). The decline of environmental degradation by renewable energy consumption in the MERCOSUR countries: An approach with ARDL modeling. *Environment Systems and Decisions, 38*(3), 415–425. https://doi.org/10.1007/s10669-018-9671-z

Krane, J., & Medlock, K. B., III. (2018). Geopolitical dimensions of U.S. oil security. *Energy Policy, 114*, 558–565. https://doi.org/10.1016/j.enpol.2017.12.050

Lee, C.-C., & Chen, P.-F. (2010). Dynamic modelling of energy consumption, capital stock, and real income in G-7 countries. *Energy Economics, 32*(3), 564–581. https://doi.org/10.1016/j.eneco.2009.08.022

Lee, C.-C., Chang, C.-P., & Chen, P.-F. (2008). Energy–income causality in OECD countries revisited: The key role of capital stock. *Energy Economics, 30*(5), 2359–2373. https://doi.org/10.1016/j.eneco.2008.01.005

Lee, J. E. (2019). The world stock markets under geopolitical risks: Dependence structure. *The World Economy, 42*(6), 1898–1930. https://doi.org/10.1111/twec.12731

Lv, X., Dong, X., & Dong, W. (2021). Oil prices and stock prices of clean energy: New evidence from Chinese subsectoral data. *Emerging Markets Finance and Trade, 57*(4), 1088–1102. https://doi.org/10.1080/1540496X.2019.1689810

Mahmood, F., & Saleem, M. (2016). An empirical analysis of the impact of energy consumption on the financial development of emerging economies: A moderating role of oil prices. *International Journal of Economics and Finance, 8*(9), 26–33.

Marques, A. C., Fuinhas, J. A., & Pereira, D. A. (2018). Have fossil fuels been substituted by renewables? An empirical assessment for 10 European countries. *Energy Policy, 116*, 257–265. https://doi.org/10.1016/j.enpol.2018.02.021

Marshall, A. (1892). *Elements of economics of industry*. Macmillan.

McCaskey, J., Clark, W., & California Academy of Sciences. (1980). *Dispersed, decentralized and renewable energy sources: Alternatives to national vulnerability and war*. California Academy of Sciences.

Minier, J. (2009). Opening a stock exchange. *Journal of Development Economics, 90*(1), 135–143. https://doi.org/10.1016/j.jdeveco.2008.10.002

Nahm, J. M., Miller, S. M., & Urpelainen, J. (2022). G20's US $14-trillion economic stimulus reneges on emissions pledges. *Nature, 603*(7899), 28–31. https://doi.org/10.1038/d41586-022-00540-5

Ohlan, R. (2016). Renewable and nonrenewable energy consumption and economic growth in India. *Energy Sources, Part B: Economics, Planning, and Policy, 11*(11), 1050–1054. https://doi.org/10.1080/15567249.2016.1190801

Overland, I., Bazilian, M., Uulu, T. I., Vakulchuk, R., & Westphal, K. (2019). The GeGaLo index: Geopolitical gains and losses after energy transition. *Energy Strategy Reviews, 26*, 100406. https://doi.org/10.1016/j.esr.2019.100406

Pedroni, P. (2004). Panel cointegration: Asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. *Econometric Theory, 20*(3), 597–625. https://doi.org/10.1017/S0266466604203073

Pesaran, M. H., Ullah, A., & Yamagata, T. (2008). A bias-adjusted LM test of error cross-section independence. *The Econometrics Journal, 11*(1), 105–127. https://doi.org/10.1111/j.1368-423X.2007.00227.x

Pesaran, M. H. (2004). *General diagnostic tests for cross section dependence in panels* (CESifo Working Paper No. 1229; Cambridge Working Papers in Economics No. 435). University of Cambridge. https://doi.org/10.17863/CAM.5113

Proedrou, F. (2018). Geopolitics and development in a steady-state world. In *Energy policy and security under climate change* (pp. 145–175). Palgrave Macmillan.

Rafindadi, A. A., & Ozturk, I. (2016). Effects of financial development, economic growth and trade on electricity consumption: Evidence from post-Fukushima Japan. *Renewable and Sustainable Energy Reviews, 54*, 1073–1084. https://doi.org/10.1016/j.rser.2015.10.023

Saadaoui, H., Dogan, M., & Omri, A. (2023). The impacts of hydroelectricity generation, financial development, geopolitical risk, income, and foreign direct investment on carbon emissions in Turkey. *Environmental Economics and Policy Studies*, 1–23. https://doi.org/10.1007/s10018-023-00384-y

Sadorsky, P. (2010). The impact of financial development on energy consumption in emerging economies. *Energy Policy, 38*(5), 2528–2535. https://doi.org/10.1016/j.enpol.2009.12.048

Sadorsky, P. (2011). Financial development and energy consumption in Central and Eastern European frontier economies. *Energy Policy, 39*(2), 999–1006. https://doi.org/10.1016/j.enpol.2010.11.034

Salmanai, D. M., & Atyab, E. M. (2014). What is the role of financial development and energy consumption on economic growth? New evidence from North African countries. *International Journal of Finance & Banking Studies, 3*(1), 137–149. https://doi.org/10.20525/ijfbs.v3i1.175

Sargan, J. D. (1958). The estimation of economic relationships using instrumental variables. *Econometrica, 26*(3), 393–415. https://doi.org/10.2307/1907619

Saygin, O., & Iskenderoglu, O. (2022). The nexus between financial development and renewable energy consumption: A review for emerging countries. *Environmental Science and Pollution Research, 29*(10), 14522–14533. https://doi.org/10.1007/s11356-021-16690-5

Sbia, R., Shahbaz, M., & Ozturk, I. (2017). Economic growth, financial development, urbanisation and electricity consumption nexus in UAE. *Economic Research–Ekonomska Istraživanja, 30*(1), 527–549. https://doi.org/10.1080/1331677X.2017.1305792

Scholten, D. (2018). *The geopolitics of renewables: An introduction and expectations*. Springer.

Scholten, D., & Bosman, R. (2016). The geopolitics of renewables: Exploring the political implications of renewable energy systems. *Technological Forecasting and Social Change, 103*, 273–283. https://doi.org/10.1016/j.techfore.2015.10.014

Shahbaz, M., Khan, S., & Tahir, M. I. (2013). The dynamic links between energy consumption, economic growth, financial development and trade in China. *Energy Economics, 40*, 8–21. https://doi.org/10.1016/j.eneco.2013.06.006

Shahbaz, M., Van Hoang, T. H., Mahalik, M. K., & Roubaud, D. (2017). Energy consumption, financial development and economic growth in India: New evidence from a nonlinear and asymmetric analysis. *Energy Economics, 63*, 199–212. https://doi.org/10.1016/j.eneco.2017.01.023

Song, Y., Ji, Q., Du, Y. J., & Geng, J. B. (2019). The dynamic dependence of fossil energy, investor sentiment and renewable energy stock markets. *Energy Economics, 84*, 104564. https://doi.org/10.1016/j.eneco.2019.104564

Soytas, U., & Sari, R. (2009). Energy consumption, economic growth, and carbon emissions: Challenges faced by an EU candidate member. *Ecological Economics, 68*(6), 1667–1675. https://doi.org/10.1016/j.ecolecon.2007.06.014

Stoeglehner, G., Niemetz, N., & Kettl, K. H. (2011). Spatial dimensions of sustainable energy systems: New visions for integrated spatial and energy planning. *Energy, Sustainability and Society, 1*(1), 1–9. https://doi.org/10.1186/2192-0567-1-2

Sun, Z., Zhang, X., & Gao, Y. (2023). The impact of financial development on renewable energy consumption: A multidimensional analysis based on global panel data. *International Journal of Environmental Research and Public Health, 20*(4), 3124. https://doi.org/10.3390/ijerph20043124

Tamazian, A., Chousa, J. P., & Vadlamannati, K. C. (2009). Does higher economic and financial development lead to environmental degradation? Evidence from BRIC countries. *Energy Policy, 37*(1), 246–253. https://doi.org/10.1016/j.enpol.2008.08.025

Topcu, M., & Payne, J. E. (2017). The financial development–energy consumption nexus revisited. *Energy Sources, Part B: Economics, Planning, and Policy, 12*(9), 822–830. https://doi.org/10.1080/15567249.2017.1300959

Vasylieva, T., Lyulyov, O., Bilan, Y., & Streimikiene, D. (2019). Sustainable economic development and greenhouse gas emissions: The dynamic impact of renewable energy consumption, GDP, and corruption. *Energies, 12*(17), 3289. https://doi.org/10.3390/en12173289

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

Williams, J. R. (1974). *Solar energy: Technology and applications* (NASA Technical Report No. 75-12425). NASA.

Yang, K., Wei, Y., Li, S., & He, J. (2021). Geopolitical risk and renewable energy stock markets: An insight from multiscale dynamic risk spillover. *Journal of Cleaner Production, 279*, 123429. https://doi.org/10.1016/j.jclepro.2020.123429

Yue, S., Lu, R., Shen, Y., & Chen, H. (2019). How does financial development affect energy consumption? Evidence from 21 transitional countries. *Energy Policy, 130*, 253–262. https://doi.org/10.1016/j.enpol.2019.03.029

Zhang, D., Chen, X. H., Lau, C. K. M., & Cai, Y. (2023). The causal relationship between green finance and geopolitical risk: Implications for environmental management. *Journal of Environmental Management, 327*, 116949. https://doi.org/10.1016/j.jenvman.2022.116949

Zhang, D., Ji, Q., & Kutan, A. M. (2019). Dynamic transmission mechanisms in global crude oil prices: Estimation and implications. *Energy, 175*, 1181–1193. https://doi.org/10.1016/j.energy.2019.03.162

Zhang, Y. J., Fan, J. L., & Chang, H. R. (2011). Impact of China's stock market development on energy consumption: An empirical analysis. *Energy Procedia, 5*, 1927–1931. https://doi.org/10.1016/j.egypro.2011.03.331