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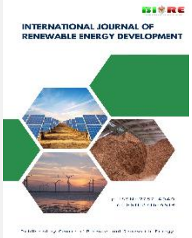

Research Article

Geopolitical risk, renewable energy transition and policy response: evidence from the BRICS economies

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Abstract. This paper empirically examines the dynamic interplay between geopolitical risk, renewable energy transitions, and policy responses within the BRICS (Brazil, Russia, India, China, and South Africa) economies spanning the period from 1990 to 2023, thus addressing the pressing challenge of harmonizing the energy security priorities with the imperative for sustainable economic growth. Employing cross-sectional autoregressive distributed lag and Bayesian structural vector autoregression methodologies for a comprehensive analysis of short-run and long-run dynamics among variables, the findings show a significant negative relationship between geopolitical risks and the adoption and investment in renewable energy sources. Correspondingly, economic policy uncertainties are observed to spur renewable energy consumption under specific economic circumstances characterized by effective policy frameworks; however, policy uncertainties pose a hindrance to renewable energy investment. Furthermore, the study highlights that exchange rate fluctuations have a significant positive impact on renewable investment decisions, whereas demographic pressures stemming from population growth tend to impede energy transition processes. The response strategies to geopolitical shocks underscore the crucial nexus between policy formulation and stability, which collectively mold energy-related outcomes. The central policy recommendation emanating from this study emphasizes the significance of concerted cooperation among the BRICS nations, including measures such as shared supply-chain assurances, regional financing mechanisms, and harmonized regulatory regimes to alleviate barriers associated with geopolitical risks in the transition to renewable energy sources. Finally, the direct applicability of the results pertains to the unique context of the BRICS bloc, which is due to their specific trade dynamics, technological dependencies, and exposure to commodities.

Keywords: Geopolitical Risk, Renewable Energy Transition, Policy Responses, BRICS.

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1. Introduction

Transitioning to renewable sources of energy has taken center stage in the implementation of energy sustainability and mitigation of climate change. The transition in this area is, however, quite a complex activity because of several factors in play, especially the geopolitical risks (GPR). Precariously, the dichotomy of energy security as opposed to transition to cleaner energies has taken the better part in BRICS countries—an acronym for Brazil, Russia, India, China, and South Africa. The BRICS countries, accounting for more than 40% of the world's population and close to 25% of global energy consumption, face a unique set of challenges in their quest for energy sustainability (IEA, 2023). GPR, comprising factors such as trade tensions, military conflicts and economic sanctions, directly impacts the energy markets in these nations, thus affecting both nonrenewable and renewable energy sectors (Tabash *et al.*, 2024; Li *et al.*, 2024).

Increasing volatility within global energy markets has led to geopolitical instability, which is making the BRICS countries revise their energy policies and strategic investments in energy (Zhao *et al.*, 2021). The BRICS, though committed to transitions toward renewable energy, present significant barriers to their objectives in the realms of energy security and sustainability. These challenges have a big scope, ranging from GPRs such as the Russian-Ukrainian conflict, the ongoing Chinese-American trade disputes to rapid fluctuations in energy commodity prices and more complicated issues regarding the planning and financial arrangement of energy infrastructures (Chishti *et al.*, 2023; Wang *et al.*, 2024; Husain *et al.*, 2024). Given the highly interlinked nature of energy markets, instability in vital regions or sectors could spill over into supply chains at any time, further worsening the vulnerabilities of BRICS economies in energy supply (Riti *et al.*, 2022). For example, the geopolitical tensions that abruptly surge the price of oil directly affect the price of energy; this factor hits harder on countries with emerging renewable energy markets such as Brazil and South Africa because of their heavy reliance on foreign investment in energy infrastructure (Zhang *et al.*, 2024). Renewable sources have been hailed as paths to the long-term decline of overreliance on fossil fuels. These further improve energy security; however, its transition similarly holds various risks such as high capital costs, policy uncertainty and inadequate infrastructure (Wang *et al.*, 2024).

There is no doubt that in high GPR events, such as trade wars or military conflicts, renewable energy consumption and investment have been stalled or may show highly volatile behavior (Flouros *et al.*, 2022; Liu *et al.*, 2023). It has been

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noticed that in countries perceived to suffer from acute GPR, there is general avoidance of consumption and investment in long-term projects, such as renewable energy infrastructure, due to political instability and market uncertainty concerns (Zhao *et al*., 2023). However, surging GPR can also foster consumption and investment in green energy because it would drive countries toward energy diversification and reduce dependence on unstable fossil fuel markets (Wang *et al*., 2024). These contradictory influences are a pointer to the fact that the relationship between GPR and renewable energy consumption and investment in BRICS countries needs further investigation.

Policy responses, such as political stability and energy access, can play a very important role in cushioning the negative impacts of geopolitical risks on energy markets. Moreover, measures for the adoption of renewable energy in BRICS economies include a number of policies by governments to that effect such as subsidies and incentives, besides international agreements like the Paris Agreement (Zhang *et al.,* 2024). However, their effectiveness against exogenous geopolitical shocks is highly debatable. Whereas countries like China have been able to develop robust renewable energy infrastructures and policy frameworks, South Africa and India still grapple with various challenges related to energy policy inconsistency and financial constraints (Su *et al.,* 2021; Hoffart *et al.,* 2022). Consequently, the interplay between GPRs and renewable energy markets can be better conceived under different policy control mechanisms in the BRICS countries.

Hence, this study will add to the literature by focusing on the dynamic interaction of GPR and renewable energy transition within BRICS economies with the integral role of policy responses—a subject not well explored in the literature. While Tabash *et al.* (2024) and Sohag *et al.* (2022) basically focused on aggregate energy consumption and its short-term fluctuations, Dong *et al.* (2023) linked renewable energy investment with green finance; thus, the role of renewable energy investment and consumption in reducing geopolitical vulnerabilities and vice versa is explored in the current study. In addition, this work embraces a policy-based approach, unlike Liu *et al.* (2023) and Zhang *et al.* (2023), who more or less studied the issue of energy transition with the absence of policy response mechanisms; therefore, the investigation here is able to discover some tipping points that are quite relevant for effective governance of political stability and energy regulation and management. Apart from that, though several studies like Chrishti *et al.* (2023) and Su *et al.* (2021) incorporated GPR as a moderator, how GPR independently contributed to the transition of renewable energy-relevant static and dynamic interaction has not been well researched.

Consequently, the novel and key contributions of this study are threefold. First, it jointly applies a cross-sectional ARDL (CS-ARDL) framework and a Bayesian structural VAR (BSVAR) to the BRICS context over 1990–2023, thereby capturing both heterogeneous long-run relationships and nonlinear short-run impulse responses — an empirical combination not previously applied to renewable energy consumption and renewable investment responses to geopolitical risk in BRICS. Second, the paper explicitly models policy-control mechanisms (access to electricity and political stability) as moderating factors, allowing for the identification of asymmetric policy-buffering effects on GPR shocks; this provides a clearer mechanistic link between governance variables and renewable transition outcomes. Third, the paper provides actionable, country-sensitive policy recommendations grounded in both long-run elasticity estimates and BSVAR impulse-response analysis, thereby moving beyond aggregate correlation to policy-relevant causal methodology.

Moreover, the most significant methodological step forward in the field is provided by Caldara & Iacoviello (2022) with the development of the GPR index, which quantifies geopolitical tensions by tracking events in the media. Even though it has been extensively applied to studies on conventional energy markets, its application remains at a minimal state in renewable energy transition research. The GPR index also includes sub-indices such as geopolitical threats and geopolitical actions, which require a brief understanding of how different geopolitical events affect market reactions. Similarly, asymmetry in GPR implies that the effect on renewable energy transition through consumption and investment may differ with the type and intensity of the risk. Increased geopolitical threats may encourage renewable energy investments as a hedge, but actual geopolitical events may delay the infrastructure investment process and interrupt the implementation of policies (Pata *et al.,* 2023; Ren *et al.,* 2024).

The rest of the paper is organized as follows: Section 2 elaborates on the trends and performance of GPR, renewable energy transitions and the policy responses. Section 3 describes the review of the related literature with reference to geopolitical risk and its impacts on the energy markets, with transitions toward renewable energy. Section 4 underpins the model development, data measurement and estimation strategy. Empirical results and implications for energy policy in BRICS countries are discussed in Section 5. Finally, Section 6 covers the recommendations on policy advancements.

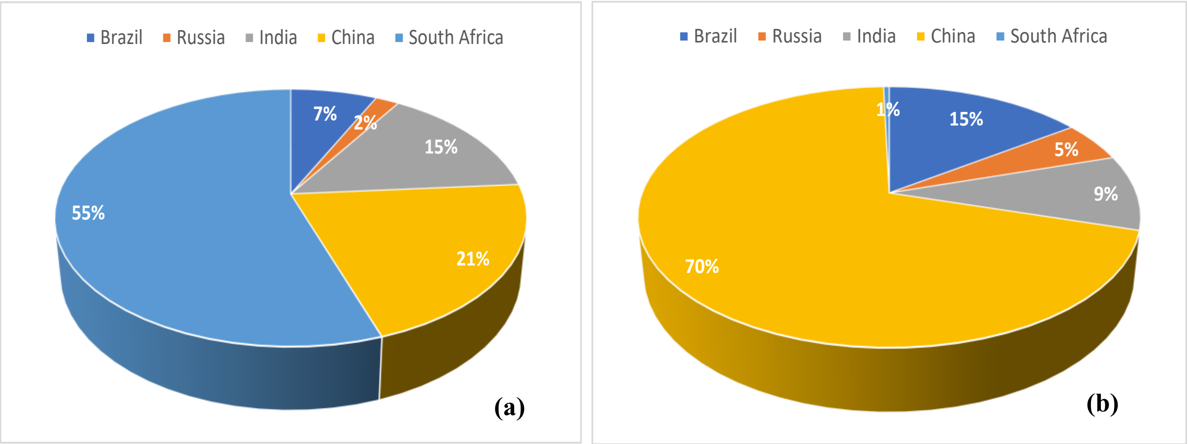

Fig 1. Average Renewable Energy Growth Rate Vs. Shares of Renewable Energy Consumption (2013-2023)
(Source: Authors' Computations via BP Statistical Review of World Energy, 2023 Dataset.)

2. Geopolitical Risk, Renewable Energy Transition, and Policy Response in BRICS

The development of renewable energy in BRICS countries is at variance in that the growth pattern is influenced by national policy, geopolitical risk and investment trends (Fig 1a). The leading position goes to South Africa which demonstrates striking annual renewable energy consumption growth, pushed by the aggressive expansion of solar and wind installations. China and India follow closely, driven by its National Solar Mission, while Russia and Brazil are making very limited progress due to fossil fuel dependence and policy issues.

China dominates renewable energy's share in total energy consumption due to its extensive hydropower and bioenergy resources, surpassing the BRICS average (Fig 1b). Brazil and India show moderate shares, reflecting gradual coal dependency reduction and energy diversification. Russia and South Africa lag behind, they are constrained by structural and geopolitical challenges. These disparities highlight how policy ambition and risk exposure shape BRICS' renewable transition trajectories.

Backed by strong policy targets, international financing and large-scale installations, Brazil records the highest growth of solar energy (151.8%). Equally similar is the uptick observed for wind in Russia (99.8%), but with geothermal and biomass growth still limited in Brazil (3.10%), Russia (6.5%), India (5.20%), and South Africa (-1.50%) for environmental and geographical reasons (Fig 2a). This uneven advancement reflects the differentiated policy response of BRICS to these geopolitical pressures.

China remains the renewable energy generation leader (Fig 2b), with substantial annual increases driven by cutting-edge technology adoption and state-led reforms. India ranks second, propelled by expanding solar and biofuel projects. Conversely, Russia, Brazil and South Africa's limited geothermal, biomass and biofuel generations reveal persistent fossil fuel dependency as they grapple with grid challenges and inconsistent policies.

Renewable energy capacity expansion underscores the critical role of policy support and international financing (Fig 2c). Brazil and Russia lead in solar module manufacturing and wind turbine exports, driving significant capacity growth. India's steady progress aligns with its 175 GW renewable energy target by 2022, while Brazil's capacity expansion stems from bioenergy and hydropower investments. South Africa's limited capacity highlights investment deficits and regulatory delays.

The geopolitical risk index illustrates the influence of geopolitical events on the energy security policy of BRICS (Figure 3). Local peaks in 2014 and 2022 reflect a global crisis—the Russia-Ukraine war and U.S.-China trade tensions—see Caldara & Iacoviello (2022). The energy policy of Russia is one of sustained dependence on hydrocarbons even with geopolitical shocks, whereas renewable investments in China

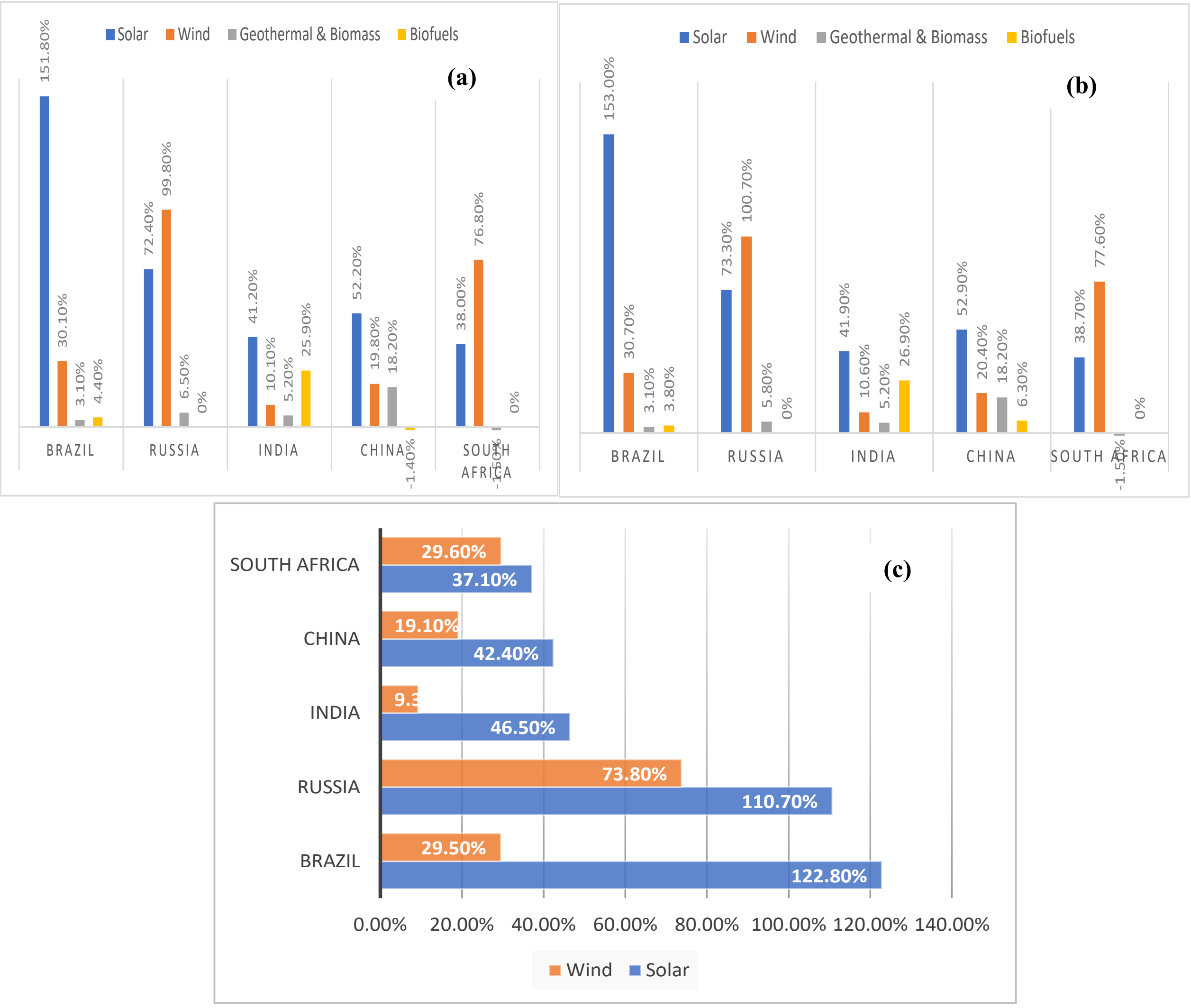

Fig 2. Renewable Energy Consumption Vs. Renewable Energy Generation Vs. Renewable Energy Capacity (2013-2023)
(Source: Authors' Computations via BP Statistical Review of World Energy, 2023 Dataset)

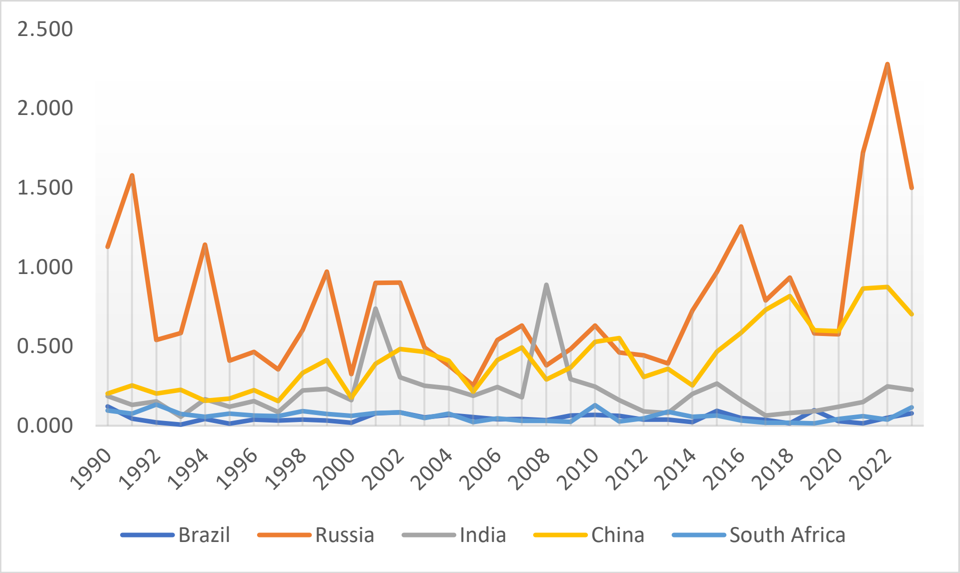

Fig 3. Geopolitical Risk Index (1990-2023)
(Source: Caldara, D., & Iacoviello, M. (2022). Measuring geopolitical risk. American Economic Review, 112(4), 1194-1225. Data Link: https://www.matteoiacoviello.com/gpr_country.htm)

rocketed after the trade restrictions. This is where the geopolitical risks constitute the binding constraints and catalysts of renewable energy transitions for BRICS, prompting the energy diversification and policy innovation (Rasoulinezhad *et al.,* 2020).

3. Literature Review

Geopolitical risk has increasingly been one of the pivotal frameworks through which dynamics in energy within BRICS economies have come to be viewed as part of emerging transitions across the globe toward renewable energies. A number of studies generate diverse insight into this interplay by often pointing to various impacts on energy systems and environmental outcomes. Indeed, Tabash *et al.* (2024) prove that GPR dampens consumption of fossil fuels while increasing the adoption of renewable energies by showing that different factors (like FDI, economic growth and inflation) have asymmetric interaction with the pattern of energy consumption. They emphasize flexible policies in order to manage energy security when a country is in a region with geopolitical instability. Moreover, Li *et al.* (2024) explore the impact of GPR on the ecological footprint and establish that though renewable energy decreases environmental degradation, economic policy uncertainty and dependence on non-renewable energy sources increase it.

The asymmetric effects of GPR on energy and environmental indicators have also been widely studied. Zhao *et al.* (2021) show that GPR decreases energy consumption in some BRICS countries, but it has a mixed impact on carbon emissions, thus requiring country-specific policy responses. Liu *et al.* (2023) also provide a two-sided outlook: GPR accelerates renewable energy investments owing to the increase in the prices of traditional energy and simultaneously hinders them because of uncertainty. Their findings align with Tuna (2024), who focuses on the relationship between GPR and the prices of clean energy metals. He detects the existence of bidirectional causality from GPR to metals such as aluminum, copper and nickel and vice versa; he shows that these resources are crucial in renewable energy transitions and that policies should be put in place to stabilize their markets.

Existing literature also tends to illustrate how environmental regulation and green innovation interact with GPR in influencing the dynamics of energy transition. Wang *et al.* (2024) add that GPR has a positive effect on energy transition, especially in the case of tight environmental policy and technological advancement. Nonlinear analysis results show that over time, the shocks of GPR increase; thus, this calls for long-term policy planning. Chishti *et al.* (2023) extend this narrative to examine how GPR moderates the impact of green financing, green technologies and environmental policies. They find that though these drivers substantially increase energy transition, GPR acts as a significant deterrent and therefore requires sequential policy frameworks that might insulate transitions from geopolitical disruptions.

The interaction of GPR with governance structures is also widely discussed in the literature. For instance, Uddin *et al.* (2023) prove that good governance and regulation reduce negative impacts of GPR on environmental quality measured by carbon emissions, while corruption and political instability amplify these effects. These findings are in line with the study of Bakhsh *et al.* (2024), who identify and stress the mediating role played by GPR in developing the influence of environmental governance and economic complexity on energy transitions in the OECD. They also show that while good governance and resilient economies foster energy transition, GPR actually undermines such relationships, with the implication that governance reforms need to be pursued to nullify geopolitical challenges.

Nonetheless, GPR has raised highly debated broader implications with respect to renewable energy investments and market dynamics. For example, the findings of Flouros *et al.* (2022) have proved that GPR exerts a significant shock to green investments in both the short and long run and equally across alternative measures of risk. They suggest that geopolitics should be a factor when policymakers design strategies to stabilize investments and support energy transitions. This finding is complemented by the global perspective of Liu *et al.* (2023), who show that even though the adoption of renewable energy can ease geopolitical tensions, it is still vulnerable to conflicts arising from resource competition and policy changes.

Shu *et al.* (2024) further show how GPR and economic uncertainty aggravate carbon intensity in the high-risk countries, hence requiring long-run policy measures with respect to reducing carbon emissions in line with achieving SDG 12 and 13. Zhao *et al.* (2023) also argue that geopolitical instability suppresses renewable energy demands in OECD countries, increases CO2 emissions and weakens climate change policies. Indeed, their findings tend to prove the fact that economic globalization as well as increasing income levels would, in turn, eliminate some of these negative influences by enhancing demand for renewable energy.

The relationship with financial development also makes GPR very relevant with regard to renewable energy adoption. Alsagr & Van Hemmen (2021) discuss the role of financial development as a mitigator to geopolitical risk and, despite the turbulence in geopolitical situations, find that financial markets provide an impetus to renewable energy consumption even in developing economies. This is further explicated by Chu *et al.* (2023) who analyze the interactions of shadow economies and GPR, hence indicating that geopolitical instability has blocked renewable energy investments in middle-income countries and high-income ones are resilient since strong institutional frameworks are in existence. Their findings clearly illustrate the roles being played by financial and regulatory structures in ensuring renewable energy development functions amid the uncertain geopolitical atmosphere.

More precisely, Husain *et al.* (2024) look at the asymmetric effect of GPR on renewable energy production. They use evidence that favorable geopolitical shocks improve the generation of renewable energy where green energy turns to a main priority of policymakers and a disincentive for investment because of uncertainty over economic policies. Similarly, Pata *et al.* (2023) indicate that economic policy uncertainty and GPR negatively influence renewable energy investments in G7 countries, implying that such uncertainties should be minimized through consistent policy frameworks in order to sustain the investment flows.

Attention has also been paid to the policy-driven responses to GPR. Wang *et al.* (2024) discuss how geopolitical threats act as a double threshold effect of natural resource rents and trade openness in the energy transition. They suggest that policy actions toward reducing geopolitical uncertainty might provide a boost to the spread of green technology. According to Hoffart *et al.* (2022), the energy transitions, climate risks and geopolitical crises are strongly interconnected. The exclusion of climate-related financial risks can result in instability in the financial systems and retard progress within renewable energy.

To broaden the interdisciplinary grounding of this study, we also draw on recent climate/change and environmental management literature that informs policy relevance and sectoral mitigation practice. For instance, Nydrioti *et al.* (2024) examine climate scenario management for urban water resources in semiarid Mediterranean areas, highlighting the importance of adaptive infrastructure and policy sequencing under uncertain climate shocks. Similarly, Bozoudis and Sebos (2021) provide a sectoral case study of transport-related carbon footprints within a hospital setting, underlining the practical mitigation measures and monitoring schemes applicable to institutional energy management. Decomposition studies such as Tsepi *et al.* (2024) demonstrate how GDP growth, energy intensity improvements and population effects combine to drive CO_2 trends, reinforcing the need to include decomposition-style control variables (e.g., GDP, population, energy access) when assessing geopolitical risk impacts on renewable transitions.

Furthermore, Michailidis *et al.* (2025) examine governance frameworks and energy policy instruments in developing MENA countries and find that coherent regulatory design, combined with targeted investment guarantees, materially accelerates renewable infrastructure deployment even under adverse geopolitical conditions. Similarly, Zafeiriou *et al.* (2023) analyze energy–economic growth interlinkages in EU agriculture and show that sector-specific policy mixes and institutional capacity can mitigate environmental degradation while promoting green investments. These studies reinforce our emphasis on policy controls (electricity access, political stability and regulatory certainty) as critical moderators of geopolitical risk impacts on renewable consumption and investment.

The case of the energy transition in Russia provides a country-specific perspective. Rasoulinezhad *et al.* (2020) find that while economic growth, population expansion and inflation have hindering impacts on energy transitions, CO2 emissions, GPR and financial openness are drivers of these processes. It is in such dynamics that one can find an appeal for the balancing of long-term decarbonization strategies with imperatives of energy security. Lastly, regarding environmental degradation, Riti *et al.* (2022) critically review this within the BRICS countries and discuss the dual effects of GPR at an aggregate and disaggregate level. Their results caution against generalizations based on aggregate-level estimates; instead, they recommend country-specific policy frameworks that can capture varied impacts of geopolitical risks on environmental sustainability.

4. Model Development, Data Measurement and Estimation Strategy

Building on the methodologies of both Rasoulinezhad *et al.* (2020) and Bakhsh *et al.* (2024), this study investigates the dynamism in the nexus of geopolitical risk and transition toward renewable energy in BRICS countries. These countries were chosen because they (i) occupy distinct positions in global energy and commodity markets (e.g., Russia's role as a major fossil-fuel exporter, China's dominant position in renewable manufacturing and technology deployment), (ii) display diverse institutional and financial architectures that shape how geopolitical shocks transmit to investment (for example, differing access to concessional finance and domestic capital markets), and (iii) face heterogeneous import-dependency for critical renewable components (affecting sensitivity to supply-chain disruptions). These characteristics make BRICS a particularly informative case to study the interaction of geopolitical risk, policy controls and renewable transitions while still providing lessons for other emerging and middle-income economies. Using a multivariate framework specially designed for the geopolitical influence of challenges on renewable energy policy adoption, the energy transition model is given as:

$$E_{it} = f(GPR, THRM, EPU, ECI, EXR, GDP, POP)_{it} \qquad (1)$$

Where E_{it} represents renewable energy transition variables $f(REC, RINV, GHG)_{it}$ for country i (BRICS) at time t (1990-2023); this signifies renewable energy consumption (REC), renewable energy investment (RINV) and greenhouse emissions (GHG). Furthermore, GPR, $THRM$, EPU and ECI denote geopolitical risk, military threat mitigation, economic policy uncertainty and economic complexity index respectively. For control variables, EXR, GDP and POP respectively represent exchange rate, gross domestic product and population growth. Next is incorporating the policy control variables ($ELEC$, POL) between renewable energy transition and

Table 1
Variable Description, Measurement and Source (***Source:*** Authors' Compilations, 2024.)

Variable	Description	Measurement	Source
REC	Share of renewable energy in primary energy.	% of total energy (EJ)	BP Energy Review, 2024
RINV	Public renewable energy investments.	Billion USD (2021)	IRENA, 2024
GHG	Greenhouse gas emissions per capita.	T CO2e/capita	World Bank
GPR	Geopolitical risk index.	Index	Caldara & Iacoviello, 2022
THRM	Military expenditure (% of GDP).	% of GDP	World Bank
EPU	Economic policy uncertainty index.	Index	Economic Intelligence Unit
ECI	Economic complexity index.	Index	World Bank
ELEC	Access to electricity.	% of population	World Bank
POL	Political stability index.	Estimate	World Bank
EXR	Official exchange rate.	Local currency/USD	World Bank
GDP	GDP per capita growth.	Annual %	World Bank
POP	Population growth rate.	Annual %	World Bank

geopolitical risk, thereby ensuring effective policy implementation and risk mitigation in asymmetric settings.

$$E_{it} * ELEC_{it} = f(GPR * POL, THRM * POL, ECI * POL)_{it} \qquad (2)$$

Where ELEC represents electricity access and POL denotes political stability. Undoubtedly, electricity access can enhance renewable energy transition by enabling equitable distribution and fostering adoption, while political stability can mitigate geopolitical risks by ensuring consistent policies and reducing investment uncertainties.
Econometrically;

$$E_{it} = \beta_0 + \beta_1 GPR_{it} + \beta_2 THRM_{it} + \beta_2 EPU_{it} + \beta_4 ECI_{it} + \beta_5 EXR_{it} + \beta_6 GDP_{it} + \beta_7 POP_{it} + \varepsilon_{it} \qquad (3)$$

Where β_0 is the constant intercept, $\beta_1 - \beta_7$ are the unknown parameter estimates, Eit is the stochastic error term. Consequently, the description, measurement and source of variables employed for this study are summarized in Table 1.

Furthermore, Table 2 summarizes the a-priori theoretical expectations of the variables, showing the expected direction of the relationships based on previous economic theories and empirical evidence, and thus serving as a benchmark for interpreting the estimated results in subsequent analyses. To ensure robustness, preliminary tests will be conducted. Descriptive statistics will verify variable characteristics, and a correlation matrix will examine associations. Pesaran's (2015) cross-sectional dependency test will check interdependencies, while slope homogeneity tests (Pesaran & Yamagata, 2008; Blomquist & Westerlund, 2013) will assess consistency across data groups. Stationarity will be evaluated using second-generation panel unit root tests (CIPS and CADF), and Westerlund's (2008) cointegration test will examine long-run relationships. These steps inform the use of CS-ARDL and B-SVAR estimation methods. Consequently, the CS-ARDL model, following Chudik & Pesaran (2015), is represented as:

$$D_{i,t} = \sum_{I=0}^{PD} \vartheta_{I,i} D_{i,t-I} + \sum_{I=0}^{PX} \delta_{I,i} X_{i,t-I} + \epsilon_{i,t} \qquad (4)$$

Addressing cross-sectional dependency and slope heterogeneity, the extended equation is provided as:

$$D_{i,t} = \sum_{I=0}^{PD} \vartheta_{I,i} W_{i,t-I} + \sum_{I=0}^{PX} \delta_{I,i} X_{i,t-I} + \sum_{I=0}^{PZ} \sigma_i IZ_{t-I} + \epsilon_{i,t} \qquad (5)$$

where PD, PX and PZ are the lags value. $D_{i,t}$ is the dependent variable, while $X_{i,t}$ are independent variables. Consequently, the long- run and short- run estimates are respectively given in equations (6-9) as:

$$\theta_{CS-ARDL,i} = \frac{\sum_{I=0}^{PX} \delta_{I,i}}{1 - \sum_{I=0}^{PD} \vartheta_{I,i}} \qquad (6)$$

Table 2
Expected Signs of Variables' Coefficients

Independent Variables	REC	RINV	GHG	Justification
GPR	Negative	Negative	Positive	Higher geopolitical risks discourage renewable investment/consumption but increase reliance on fossil fuels.
THRM	Positive	Positive	Negative	Effective mitigation reduces risks and promotes renewable energy, decreasing greenhouse emissions.
EPU	Negative	Negative	Positive	Policy uncertainty hinders renewable investment/consumption and favors emissions-intensive sources.
ECI	Positive	Positive	Negative	Higher complexity encourages innovation and adoption of renewables, reducing emissions.
GDP	Positive	Positive	Negative	Higher income facilitates investment in and consumption of renewable energy, reducing emissions.
EXR	Mixed	Mixed	Mixed	Effects depend on currency appreciation or depreciation influencing import/export costs for renewables.
POP	Positive	Negative	Positive	Higher population increases energy demand but may lower per capita renewable investment efficiency.

Source: *Authors' Compilations, 2024.**

$$\Delta D_{i,t} = \vartheta_i\left[D_{i,t-I} - \theta_i X_{i,t}\right] - \sum_{I=0}^{PD-I} \vartheta_{I,i}\Delta_I W_{i,t-I} + \sum_{I=0}^{PX} \delta_{I,i}\Delta_I X_{i,t-I} + \sum_{I=0}^{PZ} \sigma_i I Z_t + \varepsilon_{i,t} \tag{7}$$

$$\breve{\alpha}_i = -\left(1 - \sum_{I=1}^{PD} \breve{\vartheta}_{I,i}\right) \tag{8}$$

$$\breve{\vartheta}_i = \frac{\sum_{I=0}^{PX} \breve{\delta}_{I,i}}{\breve{\alpha}_i} \tag{9}$$

For clarity, $y_{i,t}$ denotes the dependent variable for country i at time t (either REC or RINV); $X_{i,t}$ is a vector of explanatory variables (GPR, EPU, EXR, POP, GDP, ELEC, POL); c_i is a country fixed effect capturing time-invariant heterogeneity; ϕ_i denotes short-run autoregressive coefficients; and $\varepsilon_{i,t}$ is the idiosyncratic error. Lag polynomials and cross-sectional averages are included to account for cross-section dependence as in Chudik & Pesaran (2015).

Nonetheless, Baumeister & Hamilton (2019) support policy control using the BSVAR estimation, which integrates prior information with observed data. Their model, based on the Cholesky approach, will be applied to analyze the nonlinear responses of renewable energy transitions to geopolitical shocks:

$$Ay_{it} = Bx_{it-1} + \mu_{it} \tag{10}$$

Where y_{it} is an n×1 vector of observed variables, A is an n×n structural matrix, andx_{it-1} is an $(mn$+1)×1 vector that includes a constant and m lags. The prior information about D given A is represented as p($D|A$), and that for lag structure coefficients B given A and D is $p(B|D, A)$.

$$p(D|A) = \prod_{i=1}^{n} p(d_{ii}|A) \tag{11}$$

$$p(B|D, A) = \prod_{i=1}^{n} p(b_i\,|D, A) \tag{12}$$

Starting with prior information A, derived from A and equations (11) and (12), Bayesian inference updates these beliefs. Bayes' theorem revises the prior using observed data Y_T from a sample of size T, producing the posterior distribution:

$$p(A, D, B|Y_T) = p(A|Y_T)p(D|A, Y_T)p(B|A, D, Y_T) \tag{13}$$

This distribution reflects parameter uncertainty after observing Y_T. Even with an infinite sample size, under-identification persists, leaving some uncertainty. The updated system of equations is expressed as:

$$A = \begin{bmatrix} 1 & 0 & -a_{qp} & 0 & 0 \\ 0 & 1 & -a_{mp} & 0 & 0 \\ 1 & -\beta_{qm} & -\beta_{qp} & -X^{-1} & 0 \\ \varphi_1 & \varphi_2 & \varphi_3 & 1 & 0 \\ -a_{qg} & -a_{mg} & -a_{pg} & -a_{ig} & 1 \end{bmatrix}, \mu_t = \begin{matrix} \mu_{1it}^{*} \\ \mu_{2it}^{*} \\ \mu_{3it}^{*} \\ X\mu_{4it}^{*} \\ \mu_{5it}^{*} \end{matrix} \tag{14}$$

Here, parameters φ_1 and φ_3 have unrestricted Student t priors, and φ_2 is set to zero.

It is worthwhile to note that two complementary estimators are used for distinct purposes. CS-ARDL estimates heterogeneous long-run elasticities and short-run dynamics across countries while accommodating cross-sectional dependence and slope heterogeneity. By contrast, the BSVAR focuses on identifying structural shocks and tracing their time-path (impulse responses and confidence bands) under prior beliefs — it thus captures nonlinear and time-varying short-run responses to specific shocks, for example, an abrupt GPR spike. Using both together therefore supplies policymakers with complementary evidence on (a) how large the long-run policy levers are and (b) how quickly and through which channels shocks propagate in the short run.

5.Empirical Result and Discussion

5.1. Result

The empirical investigation looks into the interrelation between geopolitical risk, renewable energy transition and policy responses within BRICS countries from 1990 to 2023. Table 3 presents basic descriptive statistics of the researched variables. The average REC is 3.143 with high variability (Std. Dev. = 4.580) along with a wide range going from 0.001 up to 27.489, which indicates heterogeneity in renewable adoption. The series of RINV is modest, with a mean of 0.804, while GHG emissions average 7.992, reflecting environmental concerns. The GPR and EPU are relatively low on average but highly dispersed, which indicates that vulnerabilities are highly diverse. ELEC is 77.079% on average, reflecting energy inequalities. POL and GDP show mixed dynamics, while ECI reflects moderate industrial sophistication.

The correlation matrix in Table 4 primarily confirms expected associations (for example, negative correlation between GPR and REC/RINV), but its policy value lies in highlighting plausible channels for intervention. Of particular note is the negative association between population growth and per-capita renewable adoption: rapid urbanization in India and internal migration and megacity growth in China create concentrated demand pressures and distribution challenges

Table 3
Descriptive Statistics of Variables (1990-2023)

Var.	Description	Obs.	Mean	Std. Dev.	Min	Max
REC	Renewable energy consumption	170	3.143	4.580	0.001	27.489
RINV	Renewable energy investment	170	0.804	1.814	0.000	9.972
GHG	Greenhouse gas emission	170	7.992	5.079	0.000	20.628
GPR	Geopolitical risk	170	0.302	0.360	0.007	2.281
THRM	Military threat mitigation	170	2.159	1.057	0.000	5.425
EPU	Economic policy uncertainty	170	0.073	0.076	0.000	0.540
ECI	Economic complexity index	170	0.322	0.368	-0.180	1.380
POL	Political stability	170	-0.425	0.439	-1.515	0.328
ELEC	Electricity access	170	77.079	33.728	0.000	100.000
GDP	Gross domestic product	170	3.021	4.673	-14.614	13.636
EXR	Exchange rate	170	20.017	22.521	0.000	85.162
POP	Population growth	170	0.922	0.697	-0.460	2.781

Table 4
Correlation Results

Dependent	Independent Variables								
	GPR	**THRM**	**EPU**	**ECI**	**POL**	**ELEC**	**GDP**	**EXR**	**POP**
REC	0.25	-0.21	-0.04	0.56	-0.03	0.19	0.21	-0.19	-0.33
RINV	-0.17	-0.10	0.06	-0.03	-0.25	0.18	0.00	0.25	0.11
GHG	0.49	0.34	0.18	0.01	0.00	0.44	-0.30	-0.12	-0.64

Table 5
Cross-section Dependence Test

Variable	CD-test	p-value	average joint	mean ρ	mean abs(ρ)
REC	13.762***	0.000	34	0.75	0.75
RINV	2.909**	0.004	34	0.16	0.17
GHG	13.150***	0.000	34	0.71	0.71
GPR	1.636*	0.102	34	0.09	0.16
THRM	8.481***	0.000	34	0.46	0.52
EPU	4.223***	0.000	34	0.23	0.23
ECI	5.697***	0.000	34	0.31	0.41
POL	8.390***	0.000	34	0.45	0.45
ELEC	10.824***	0.000	34	0.59	0.59
GDP	7.391***	0.000	34	0.4	0.41
EXR	10.143***	0.000	34	0.55	0.61
POP	7.786***	0.000	34	0.42	0.45

*** (1% sig), ** (5% sig), and * (10% sig)

that can slow per-capita renewable uptake unless offset by decentralized solutions. For policymakers, this implies prioritizing off-grid and mini-grid solutions in rapidly urbanizing districts and investment in urban distribution infrastructure to avoid bottlenecks that negate national renewable capacity gains.

While Table 5 reports high CD-test values and the correspondingly low p-values for most variables' cross-sectional dependence at the 1% significance level, there are indications of weaker dependence at a 10% significance level concerning geopolitical risk. In the case of mean and absolute mean correlations, interconnection is also strong in renewable energy consumption at 0.75 and greenhouse emissions at 0.71

According to the slope homogeneity tests in Table 6, the results of the Pesaran & Yamagata and Blomquist & Westerlund statistics show that significant heterogeneity exists in renewable energy consumption and greenhouse gas emissions models, while the statistics show highly significant results, which underline the varied policy impacts and country-specific dynamics within BRICS. Conversely, renewable energy investment is homogenous across countries under the assumption of the Pesaran & Yamagata test, but it is heterogenous when the Blomquist & Westerlund statistic is employed, indicating a response in unison to the respective investment policies.

In Table 7, lag selection criteria show some inconsistencies, as the AIC and FPE choose lag 4, while SC and HQ suggest lower lags. In resolving this, the lag exclusion test was considered, and lag 2 was chosen because both lags 1 and 2 were statistically significant for REC, RINV, and GHG at $p < 0.05$. This selection does indeed guarantee the robust modeling of dynamic interactions, short-run and long-run policy effects being relevant for analyzing energy transitions and geopolitical influences within BRICS countries.

Table 8 presents the stationarity tests for the variables using CIPS and CADF methods. Some variables are stationary at level I (0) from the CIPS test, that is, REC, RINV, GHG, GPR, EPU, POL, GDP, and EXR, while a few of them require differencing I (1), which includes ELEC, ECI, and POP. However, under the CADF analysis, variables like REC and

Table 6
Slope Homogeneity Tests

	REC	**RINV**	***GHG***
Pesaran & Yamagata (2008):			
Delta	2.613** (0.009)	1.079 (0.281)	7.513*** (0.000)
Adj.	3.177** (0.001)	1.312 (0.190)	9.135*** (0.000)
Blomquist & Westerlund (2013):			
Delta	4.225*** (0.000)	2.443** (0.015)	1.497 (0.134)
Adj.	5.137*** (0.000)	2.97** (0.003)	1.82* (0.069)

P-values are in parentheses. *** (1% sig), ** (5% sig), and * (10% sig)

Table 7
Lag Selection Test

Lag Length Criteria:

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1090.80	NA	550.39	14.82	15.24	14.99
1	-541.39	1025.55	0.40	7.61	8.22*	7.86
2	-527.25	25.83	0.38	7.55	8.33	7.86
3	-506.46	37.14	0.32	7.39	8.35	7.78*
4	-494.11	21.56*	0.31*	7.34*	8.49	7.81

Lag Exclusion Test:

Variable	REC	RINV	GHG	Joint
Lag 1	129.267***	10.608**	44.327***	181.943***
	(0.000)	(0.014)	(0.000)	(0.000)
Lag 2	8.964**	4.665	16.100**	30.64683***
	(0.029)	(0.198)	(0.001)	(0.000)
df	**3**	**3**	**3**	**9**

P-values are in parentheses. *** (1% sig), ** (5% sig), and * (10% sig)

Table 8
Stationarity Tests

	CIPS			CADF		
Variable	Level	1st Diff.	Order	Level	1st Diff.	Order
REC	-2.779***	-5.795	I (0)	-2.092	-3.273***	I (1)
$RINV$	-3.110***	-4.352	I (0)	-1.646	-2.851**	I (1)
GHG	-3.086***	-3.154	I (0)	-2.983**	-2.050	I (0)
GPR	-4.123***	-6.190	I (0)	-2.221	-4.283***	I (1)
$THRM$	-3.272***	-3.349	I (0)	-1.860	-3.419***	I (1)
EPU	-4.786***	-6.142	I (0)	-2.754***	-4.565	I (0)
ECI	-1.641	-6.009***	I (1)	-0.932	-1.979	Nil
POL	-2.329*	-6.098	I (0)	-1.376	-3.377***	I (1)
$ELEC$	-2.136	-3.414***	I (1)	-2.327	-3.104***	I (1)
GDP	-3.791***	-6.071	I (0)	-2.740**	-4.024	I (0)
EXR	-2.872***	-5.006	I (0)	-2.744**	-3.343	I (0)
POP	-1.028	-2.446**	I (1)	-0.930	-1.365	Nil
$C-V$	10% (-2.210)	5% (-2.330)	1% (-2.550)	10% (-2.210)	5% (-2.330)	1% (-2.550)

C-V represents critical value region. *** (1% sig), ** (5% sig), and * (10% sig)

RINV were found to become stationary after taking first difference I (1). Some of the variables, like ECI and POP are found to be weakly stationary under CADF. On the whole, the mixed stationarity pattern necessitates the dynamic panel method, which is CS-ARDL, thus accommodating both I (0) and I (1) variables that ensure reliable and consistent estimation.

The following Table 9 shows the results of the Westerlund cointegration test. In Model 1 (REC), the variance ratio statistic is significant at 1% (p-value = 0.000); therefore, there is cointegration among the panels. In Model 2, for RINV, this statistic is negative (-1.373) and only significant at 10% (p-value = 0.081), implying weak cointegration. Both models have panel

Table 9
Westerlund Cointegration Result

	Model 1: REC		Model 2: RINV	
Test	Statistic	p-value	Statistic	p-value
Variance Ratio	4.081***	0.000	-1.373*	0.081
No. of Panel	5		5	
No. of Period	34		34	
Panel Means	Included			
Time Trend	Included			
AR Parameter	Same			
H0:	No cointegration			
H1:	All panels are cointegrated			

*** (1% sig), ** (5% sig), and * (10% sig)

Table 10
CS-ARDL Model Estimation Results

	Model 1: ΔREC		**Model 2: ΔRINV**	
Variable	**Short-run**	**Long-run**	**Short-run**	**Long-run**
$REC\ (-1)$	-0.411* (0.060)			
$RINV\ (-1)$			-0.643** (0.001)	
GPR	-0.492** (0.023)	-0.397** (0.027)	-2.824* (0.098)	-1.474* (0.078)
$THRM$	0.004 (0.930)	-0.006 (0.862)	0.389 (0.589)	0.164 (0.659)
EPU	0.822* (0.058)	0.732* (0.095)	-7.888** (0.012)	-4.745** (0.030)
ECI	0.060 (0.587)	0.065 (0.330)	-0.573 (0.645)	-0.268 (0.701)
GDP	-0.002 (0.728)	-0.002 (0.637)	-0.052 (0.276)	-0.031 (0.265)
EXR	-0.040 (0.121)	-0.032 (0.131)	0.172** (0.038)	0.089** (0.046)
POP	-0.568* (0.081)	-0.377** (0.059)	-1.227 (0.133)	-0.719 (0.134)
$ECT\ (-1)$	-1.411*** (0.000)		-1.643*** (0.000)	
R^2	0.573		0.537	
F	0.701		0.811	
$RMSE$	0.139		1.255	
N	165		165	

Source: Authors' Computation, Stata 15.0. P-values are in parentheses. *** (1% sig), ** (5% sig), and * (10% sig)

means and time trends but the same AR parameter. The findings suggest that whereas REC exhibits strong and consistent cointegration, RINV shows weak long-term relationships across panels.

The results of the CS-ARDL model in Table 10 present critical information on the short- and long-run dynamics of renewable energy consumption and renewable energy investment across BRICS countries. In Model 1, geopolitical risk exerts a significant negative influence on renewable energy consumption in both the short run (-0.492, $p < 0.05$) and long run (-0.397, $p < 0.05$), suggesting that heightened geopolitical tensions impede renewable energy adoption. On the other hand, economic policy uncertainty positively influences renewable energy consumption in the short run (0.822, $p < 0.10$) and the long run (0.732, $p < 0.10$), suggesting that effective policy implementation may stimulate renewable energy consumption during periods of uncertainty. In contrast, the growth of population negatively influences renewable energy consumption in both the short- and long-run periods (-0.568 and -0.377, $p < 0.10$), respectively, hence indicating demographic pressure on energy transitions. The error correction term is highly significant (-1.411, $p < 0.01$), which confirms the robust adjustment mechanism to long-run equilibrium.

In Model 2, geopolitical risk also significantly decreases renewable energy investment in both the short-run level of -2.824 ($p < 0.10$) and the long-run level of -1.474 ($p < 0.10$), underscoring the negative impact of geopolitical instability on investment flows. Economic policy uncertainty shows a significant negative impact on renewable energy investment (-7.888 and -4.745, $p < 0.05$), thus emphasizing the adverse contribution of macroeconomic instability. Surprisingly, exchange rate positively influences renewable energy investment: its short-run coefficient is 0.172 and long-run is 0.089, $p < 0.05$, showing that favorable currency fluctuations encourage renewable energy investments. The error correction term is -1.643, $p < 0.01$, indicating strong adjustment to equilibrium. Finally, with R-squared values of 0.573 and 0.537, both models exhibit moderate explanatory power.

The responses of renewable energy transition variables REC, RINV and GHG to three geopolitical risk shocks—shock 1 is GPR, shock 2 is THRM, and shock 3 is EPU—are presented in Figure 7. Responses are over a 12-period horizon. Purple confidence bands reflect upper and lower boundaries. For GPR, REC gives an initial positive response that is declining over the horizon. The confidence band shows statistical significance early, that is, in the short run, but the long-run period cannot maintain such an impact. This argument is based on the fact that political stability cannot be sustained overtime to mitigate the impact of geopolitical risk on renewable energy consumption. For THRM, REC generates a minimal response in the short run, oscillating within the confidence interval and lacking significance. However, it reveals a positive and significant response to military threat mitigation in the long run. This attests to the fact that policy control—access to electricity and political stability—can ensure improvement in military expenditure in order to mitigate the impact of geopolitical tension. On the opposite side, REC reveals a positive initial response to shock in economic policy uncertainty over the short and long- run horizons, indicating sensitivity in terms of policy control toward economic uncertainty.

For RINV, the response to Shock 1 (GPR) reveals a marginally negative short-run effect, turning positively and

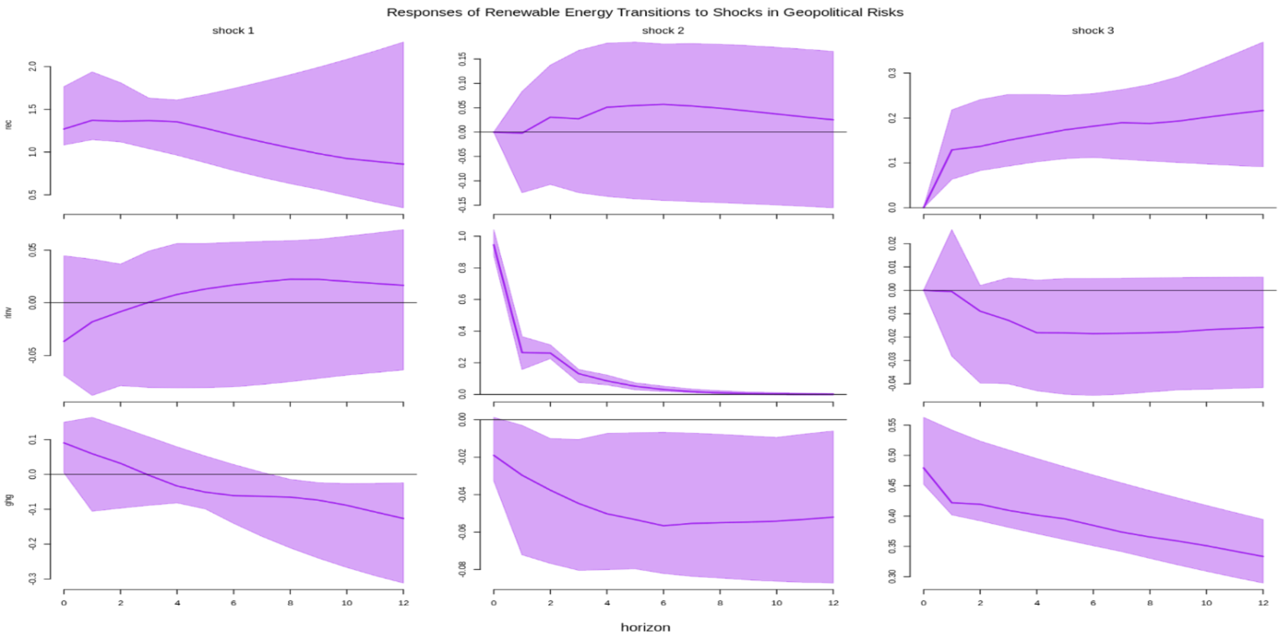

Fig 4. Response of Renewable Energy Transition to Shocks Geopolitical Risk Under the Assumptions of Policy Control Mechanism
Source: Authors' Computation, R-statistical Package

statistically significant at around the mid-horizon, indicating gradual strengthening in renewable energy investment responses to geopolitical risk. However, Shock 2 (THRM) yields a sharp positive short-run impact, which rapidly diminishes over the long-run horizon and stabilizes near zero, suggesting that the diminution of military threat mitigation has a rather diminishing impact on renewable energy investment in the long run. The shock 3 (EPU) just created negative and minor oscillations for RINV without obvious deviation, which means that economic policy uncertainty negatively impacts renewable energy investment to a limited extent over time.

For GHG, all three shocks have significant immediate responses. Specifically, for instance, in Shock 1, GPR leads to a decline in the emission of GHGs through time, implying that political stability serves effectively in reducing emissions by mitigating geopolitical risks. The effect is negative but diminishing over time in the case of Shock 2, THRM, showing that military threat mitigation cuts emissions initially but less so in the long run. Shock 3 (EPU) elicits a positive response at the beginning, which then turns into a permanent decline. This is indicative of the two-phase effect of economic policy uncertainty, whereby the initial responses of policy may inadvertently increase emissions, while the long-term measures eventually lead to a reduction.

5.2. Discussion

The findings provide significant evidence on the transition towards renewable energy in BRICS economies, highlighting a complicated interaction of geopolitical risks, economic uncertainties and demographic pressures. In this regard, geopolitical risks negatively affect renewable energy consumption and investment significantly, which confirms the findings of studies like Rasoulinezhad *et al.* (2020) and Liu *et al.* (2023), who noted that political instability disrupts long-term energy planning and deters investment. This is even more critical in the BRICS countries, whose energy systems rely so much on stable governance for the implementation of policies. The results also depict that the relationship between economic policy uncertainty and renewable energy consumption can be somewhat complex: though the findings present its positive impact, this does not necessarily follow that economic uncertainty leads to renewable energy consumption; rather, the positive effect reflects the efficient behavior of policymakers and stakeholders of the sector who, in turn, try to reduce risks associated with the uncertain state of their economy. This partial agreement goes in line with the findings of Husain *et al.* (2021), who noted the role of governance in driving out uncertainty but were not able to establish whether uncertainty acts as a driver for renewable energy consumption in the context of the US. However, such uncertainty is inimical to investment and supports the notion by Hoffart *et al.* (2022) that volatile macroeconomic conditions are a setback to investment in energy infrastructure. On the other hand, exchange rate volatility has been found to positively affect investment in renewable energy; this would imply that the appreciation of the currency lowers the import cost of technologies and equipment in renewable energy and therefore encourages investment. This reflects the import-intensive nature of capital equipment for many BRICS countries: when national currencies appreciate (or depreciate less), the local cost of imported modules, turbines, inverters and balance-of-system equipment declines, lowering upfront capital costs and improving project bankability.

Furthermore, the adverse influence of population growth on renewable energy consumption points out demographic pressure and the challenge in trying to balance the emerging demand with the sustainable transition goal as affirmed by Li *et al.* (2024). Finally, the different responses of the energy transitions to shocks in geopolitical risks further bring out a two-phase impact, where initial policy measures would increase the transitions before declining, as corroborated by the findings of Pata *et al.* (2023).

Our empirical strategy distinguishes short-run responses from BSVAR from long-run elasticities from CS-ARDL. For policymakers, this translates into two types of interventions: (i) short-run measures, that is, quick and targeted actions that stabilize consumption and protect existing projects when a GPR spike occurs, for example, temporary demand subsidies, emergency procurement of critical components through strategic reserves, expedited permitting for distributed systems, short-term credit lines from national green banks; and (ii) long-run measures — structural reforms that change the underlying elasticities and resilience, for instance, establishing clear long-term feed-in tariffs or auction calendars, developing domestic renewable manufacturing capacity, institutionalizing currency-hedging facilities for green imports and strengthening property-rights-consistent permitting regimes.

Comparative analysis with other recent empirical studies clarifies where our findings align and where they diverge. For instance, Michailidis *et al.* (2025) report that stronger governance and explicit investment guarantees reduce the effective cost of renewable infrastructure in MENA countries, which resonates with our finding that political stability and policy controls reduce the negative impact of geopolitical shocks on investment. However, they place greater emphasis on targeted fiscal guarantees than our study, which highlights exchange-rate effects and macroeconomic uncertainty as prominent channels in BRICS; this contrast underscores the role of financial instruments versus macroeconomic management across different regional contexts. Moreover, Zafeiriou *et al.* (2023) find that sectoral policy mixes in EU agriculture can decouple economic growth from environmental degradation — a result that aligns with our evidence that well-designed policy controls can offset GPR-driven setbacks. Where our results differ from some prior work (for instance, studies that find a uniformly positive role of policy uncertainty on renewable investment), the divergence appears driven by the BRICS' heterogeneity in financial markets and import-dependency for clean technologies; this explains why economic policy uncertainty in our sample stimulates short-run consumption but deters investment.

Supporting the above divergence, it is important to note that policy responses across BRICS are not uniform because institutional capacity, domestic manufacturing of renewable components, exchange-rate regimes and the share of energy trade in GDP differ substantially across members. For example, China's significant domestic renewable manufacturing and state-led financing can buffer supply-chain shocks better than countries dependent on imports; Russia's heavy fossil-fuel export orientation creates both revenues and geopolitical exposure that alter incentive structures; India's large rural population and fast urbanization create distributional bottlenecks that favor decentralized renewables; South Africa's grid constraints require targeted grid-modernization policies; and Brazil's bioenergy strengths require tailored regulatory support.

6. Conclusions

6.1 Main Conclusions

This paper gauges the interplay of geopolitical risk, transition to renewable energies and policy responses among BRICS economies between 1990 and 2023, using advanced econometric approaches such as the CS-ARDL and BSVAR models in order to jointly determine both the short-run and long-run dynamics. Some of the key findings indicate that geopolitical risks significantly and negatively impact renewable energy consumption and investment, but economic policy uncertainty, under some conditions, stimulates renewable energy consumption by prompting effective mechanisms in policy; however, it harms renewable energy investment. Moreover, the exchange rate is found to increase investment, while demographic pressures reduce energy transitions and indicate constraints from population growth. In addition, the response of geopolitical shocks is depicted to be heterogeneous across investment, consumption and the various greenhouse gas emissions, thus underpinning the subtle role of policy and stability in securing energy transitions.

This pattern is consistent with Michailidis *et al.* (2025) and Zafeiriou *et al.* (2023), who both emphasize governance and targeted policy mixes as decisive for successful green transitions. Our contribution differs in highlighting exchange-rate and demographic channels as especially salient in BRICS, whereas Michailidis *et al.* (2025) emphasize fiscal guarantees and Zafeiriou *et al.* (2023) emphasize sectoral policy mixes. Thus, while governance is a universal lever, the policy instruments that work best are country and region specific.

6.2 Policy Implications

Consequently, policymakers need to undertake strong and focused strategies toward the mitigation of geopolitical risks. Firstly, given the consistent negative effect of geopolitical risk on both renewable energy consumption and investment, BRICS policymakers should prioritize multilateral diplomatic engagement and regional cooperation mechanisms that reduce supply-chain fragility and cross-border trade disruptions affecting clean energy equipment. Secondly, because political stability and electricity access operate as policy-control mechanisms, governments should invest in regulatory certainty (clear, long-term support schemes for renewable projects), grid expansion for equitable electricity access, and transparent permitting processes to reduce investor uncertainty. Thirdly, the positive short-run relationship between economic policy uncertainty and renewable consumption, paired with negative effects for investment, suggests targeted instruments: short-term demand-side incentives (for instance, temporary subsidies or voucher schemes) can sustain consumption during uncertainty, while investment-oriented instruments require macro-prudential stability — for example, dedicated green investment facilities, government guarantees, or concessional financing to de-risk capital for long-term renewable infrastructure. Fourthly, demographic pressures that reduce per-capita transition rates indicate the need for scalable, decentralized renewables (for example, mini-grids, distributed solar) and complementary social policies that expand access while maintaining affordability. Finally, exchange-rate sensitivity of investment suggests that trade and currency policies (such as hedging facilities or import duty schemes on renewable technologies) can materially affect the cost of technology imports and therefore investment flows.

For the BRICS country-specific policy, China should expand domestic renewable manufacturing and stabilize investment frameworks; India needs stronger support for decentralized systems and faster permitting; Russia should use fiscal tools to de-risk green projects; Brazil must reinforce regulatory certainty and improve financing partnerships; and South Africa should modernize its grid, support storage and strengthen local content to build resilience.

6.3 Limitations and Directions for Future Research

It is significant to note that this study has several limitations that point to opportunities for future research. Firstly, while the dataset spans 1990–2023 and covers five BRICS economies, country-level institutional detail (for example, subnational policy heterogeneity and project-level financing data) is limited; future work should exploit more granular project or firm-level data to trace micro-mechanisms of investment responses.

Secondly, our analysis uses the Caldara & Iacoviello GPR index and composite policy indices; although these are widely accepted, alternative measures such as event-level coding or real-time trade-disruption indices could be used to test robustness to different operationalizations of geopolitical stress. Thirdly, climate and sector-specific feedback loops, for example, water–energy–food interactions as emphasized in Nydrioti *et al.,* (2024), deserve integrated modelling to assess compound risks. Moreover, future studies can also include an empirical investigation by incorporating COVID-19 supply disruptions, OPEC+ production agreements and supply cuts, or major global trade-policy episodes into the methodological frameworks. Finally, future research could broaden the geographical scope, for instance, compare BRICS with OECD or MINT countries and examine the role of green finance instruments and commodity-price volatility as further channels mediating geopolitical risk.

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