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Role of Research and Development Budgets and Socio-economic Conditions for Greener Energy Transition in Emerging Economies: Do Internal and external conflicts matter?

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Abstract

In the contemporary times, with the major conflict of the Russo-Ukrainian War, the global economies are facing several challenges and disputes in various economic, energy, and financial sectors. Still, policymakers and scholars are concerned about exploring factors affecting greener energy. The present study examines the impact of research and development (R&D) budgets, financial globalization and socio-economic conditions on greener energy adoption. Besides, this study considers the role of internal and external conflicts on greener energy adoption in the "Emerging Seven" economies during the period 1990–2020. Using various diagnostic and cointegration tests, the results revealed the presence of cross-sectional dependence, heterogeneous slopes and a long-run equilibrium relationship. This study employes panel quantile regression and finds that R&D budgets, financial globalization, socio-economic conditions and internal and external conflicts significantly promote greener energy adoption. Still, the influence of socio-economic conditions is inconsistent across quantiles. Using the autoregressive distributed lag model as a robustness measure, this study validates the positive impact of variables on greener energy adoption, except external conflicts. However, all the variables adversely influence greener energy adoption in the short run. The empirical results also validate bidirectional and unidirectional causal associations of the variables. Following the results, this study recommends further enhancement in the R&D budgets and financial globalization and limiting conflicts in emerging economies.

Keywords: Greener energies, R&D budgets, socio-economic conditions, internal conflicts, external conflicts, financial globalization, emerging economies

JEL Classification: Q50, H50, K20

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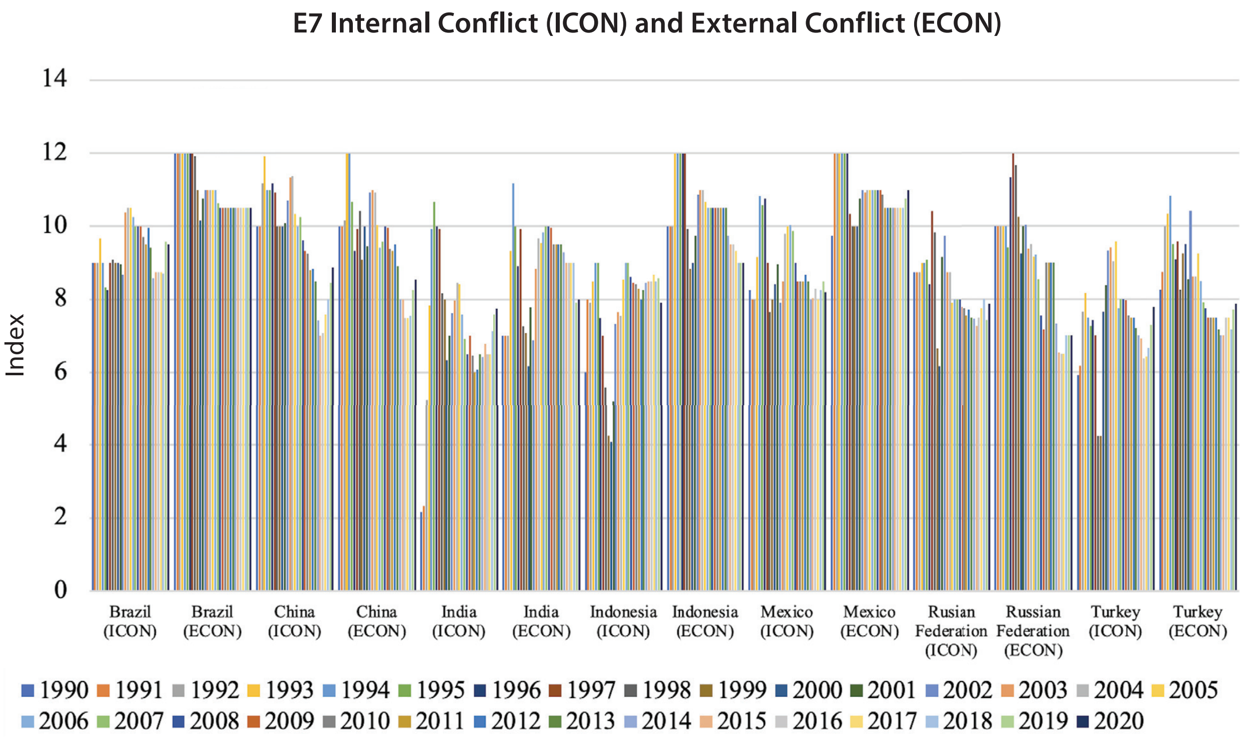
1. Introduction

The climate crisis has become a consistent problem across the globe. This has increased the importance of renewable energy and energy transition to lessen climate disparities and expedite economic growth simultaneously. To reduce the rise in temperatures by 80% by 2030 and nearly 100% by the end of 2050, promoting green energy should be the utmost priority of nations worldwide (Vakulchuk *et al*., 2020). Such issues raise energy demand across the globe. However, increasing demand entices conflicts such as geopolitical tensions or political instability, causing energy sanctions and disturbing financial markets (Chen *et al*., 2023). These vulnerabilities weaken the country economically or sometimes strategically worsen the enforcement plans of policies for sustainability. It happens because economies depend highly on energy consumption required for economic development. Besides, to direct the energy trade or transition towards renewable energy, a high amount of investment or funding is needed alongside developing important socio-economic indicators. The ability of a country to transform into a sustainable energy source depends on energy security, international cooperation, foreign investment and the global energy markets. The internal and external conflicts must be resolved to promote energy security and sustainability for a smooth energy transition. Hence, the present research is essential in exploring the influence of research and development budgets and socio-economic conditions for greener energy adoption in emerging economies during conflicting times.

The "Emerging Seven" (E7) is a group of growing emerging economies that have the potential to affect the world economically and environmentally. However, each economy has its unique structure, evolving geopolitical landscape or policy strategies to tackle economic or environmental challenges. Nevertheless, the complexities of green transition have numerous challenges that sometimes cast a shadow over smooth energy transition/adoption. Among those myriad problems, political or geopolitical conflicts, financial liberalization or socio-economic conditions disrupt the seamless process within the economies when countries compete to obtain energy supplies or when the occurrence of inflation due to internal and external conflicts influences the transition process. Figure 1 presents the trend of internal and external conflicts in E7 nations. The graph shows that both conflict types have shown fluctuating trends from 1990 to 2020, implying that these conflicts negatively affect the renewable transition process alongside overshadowing other economic opportunities. Internal disputes such as the frequent leadership changes that increase policy uncertainty, inconsistent regulations, or external tensions such as global pressure and climate diplomacy cause ambiguity among nations to invest in energy transition and disrupt the energy supply, impeding the renewable transition process.

Nevertheless, it is still alleged that efficient management supports tackling these encounters (Larsen *et al*., 2018; Akita *et al*., 2020). Economies, whether E7 or any other nation worldwide, need huge funds and investments to accelerate the renewable shift. Figure 2 illustrates the green energy trend in E7 from 1990 to 2020. Over the years, it can be observed that each country has shown an increasing trend in green energy adoption for sustainable development. Among all seven, China has higher green electricity production than Brazil and India. This implies countries need the development of financial markets and institutions, which is necessary to endorse the potential of renewable energy. It increases access to capital and expands the demand for energy investment and ESG bonds for smooth energy transitioning (Ünlü *et al*., 2022). It is probable that when the country encourages foreign investments, green financing, good governance, or transparency, its economy will spur positively (Mehmood *et al*., 2022; Li *et al*., 2023).

Figure 1: E7 countries' conflicts



Source: Authors´ own preparation

Factors such as finance, technology and people substantially influence green energy adoption (Mehmood *et al*., 2022). Hence, the study explores the influence of R&D budgets, financial globalization and socio-economic conditions on renewable energy adoption, controlling for internal and external conflicts in E7, including China, Turkey, Brazil, Mexico, Indonesia, Russia and India. Assessing these is necessary because economies are expected to significantly rush or slacken the transition process. The speed at which we are moving towards global upheaval needs acceleration towards renewable and clean energy adoption to achieve Paris targets. Current regulations and environmental sustainability significantly influence the country depending on its economic structure, emission reduction targets, waste/ resource management and economic statistics. Besides, eventful situations inside or outside the government further obfuscate these goals. Therefore, it is the need of the hour, and it motivated the authors to empirically examine these factors for framing effective policies and strategies to achieve green targets.

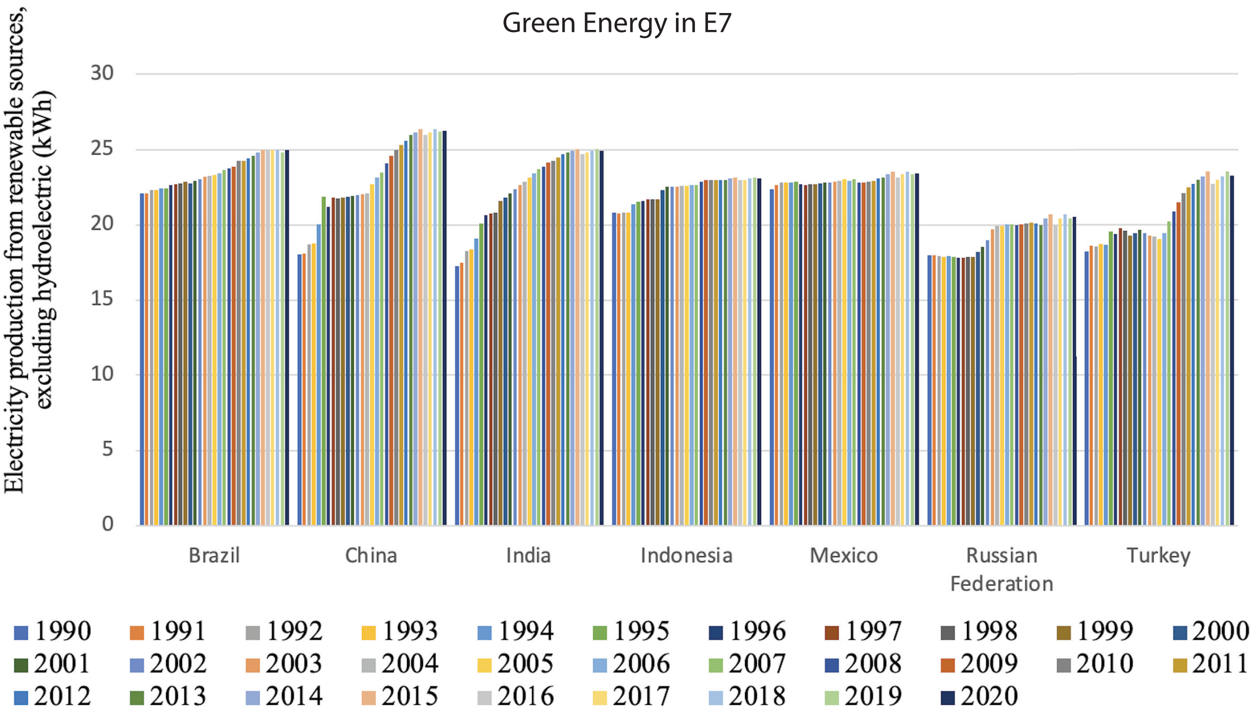
The present study attempts to address the following questions/objectives in the E7:

1. Do internal or external conflicts influence the process of green adoption in E7?
2. Do R&D and socio-economic situations increase or decrease the renewable promotion in E7?

E7 has a prominent portion of the world's population and has diverse economic, political, or geographical contexts. They have a significant influence on global policies and sustainable development strategies. These economies are expected to be highly globalized due to increasing trade liberalization and interconnectedness. Hence, the study objectives might provide insights into policies for attracting investments, promoting innovation and paving a clean way towards a more sustainable energy future.

The study contributes to the literature in the following ways. Firstly, the analysis is a pioneer in inspecting the simultaneous nexus between R&D, financial globalization, socio-economic development and green adoption as prior studies have ignored this nexus in E7. This association significantly highlights how renewable adoption contributes to the stability of the economy and environment. As economies face complex issues while adopting green energy, this study could become a foundation for transformative change and benefit policymaking and green practice in the long term, posing as, an imperative input in the theoretical literature. Secondly, the nexus is observed under two different specifications to highlight the consequences of internal or external conflicts on renewable transition, as no prior study has intended to investigate these specifications in any economy. Therefore, this innovative model is essential in academic research for green policymaking through clean ways of achieving a sustainable economy. Besides, this study extends the discussion of critical areas of research into green transition, which is an imperative agenda of international organizations and COP27, with unique methodological approaches, an updated dataset and periods (*i.e.*, 1990 to 2020), making it a valuable study for the broader research community.

Figure 2: Green energy



Source: Authors´ own preparation

The rest of the manuscript is organized as follows. Section 2 summarizes the literature based on study variables. Section 3 deals with methodology and data. Section 4 documents the results and discussion, and lastly, Section 5 presents the conclusion and policy suggestions.

2. Literature Background

The extant literature is quite rich regarding the role of renewable energy in sustainability (Gyamfi *et al*., 2022). However, the present study deals with the impact of internal or external conflicts, R&D budgets and socio-economic conditions on renewable transition.

2.1 Internal and external conflicts and green energy adoption

Green energy is less carbon-intensive and emits fewer pollutants than conventional energy (Jayaraman *et al*., 2023). However, certain aspects exacerbate the transition process, depending on the severity of those factors. For example, internal conflicts like political instability or external conflicts such as geopolitical tension threaten the renewable transition process (Muoneke *et al*., 2023). A few extant findings establish that disputes over green energy adoption or renewable transition are unavoidable, but efficient management, especially by local parties, helps overcome those challenges (Chang *et al*., 2023; Akita *et al*., 2020). In literature, Awosusi *et al*. (2023) investigated that political instability potentially affects the long-term and short-term renewable transition. Their empirical estimates suggested that the economy needs to stabilize the political situation through governance and enhance financial globalization to promote renewable transitioning across the globe and to overcome internal conflicts.

Similarly, geopolitical tension has an adversely significant influence on promoting green energy adoption. Zhao *et al*. (2023) examined the connection between geopolitical conflicts and renewable promotion in 20 OECD economies. The study depicted that it lessens the demand for renewable energy while increasing climate abnormalities and badly affecting environmental strategies. Therefore, resolving external conflicts is needed to encourage green adoption (Mohammed *et al*., 2023). Conflicts inside or outside the country, such as frequent leadership changes due to political instability, international tensions, or global environmental conflicts, increase policy uncertainty in the country and cause inconsistent regulations, which negatively affect renewable energy adoption by distressing funding, infrastructure, policy stability and international collaboration (Larsen *et al*., 2018). However, adapting strategies and international cooperation are recommended to ensure that renewable energy goals continue to be pursued (Akita *et al*., 2020). Likewise *et al*. (2022) discovered that good governance is positively related to encouraging renewable energy adoption. It increases transparency and access to financial capital, increases energy security, limits supply disruptions and fosters green technologies that support a green economy through green energy towards a sustainable future.

2.2 R&D, globalization and socio-economic conditions for green energy adoption

Renewable energy constitutes almost 11.2% of the world's energy, making it one of the fastest-growing sectors worldwide. Therefore, large budgets are needed to sponsor renewable transition as R&D spending, allocations or investments significantly promote renewable energy. These bring technical advancement and substantially replace non-renewable energy (Gharbi *et al*., 2023; Ahmed *et al*., 2021). Several studies have expressed the positive interaction between R&D and renewable consumption. The present study briefs on R&D budgets and green adoption. For example, Liu *et al*. (2023) underscored the role of R&D expenditures in renewable transition. The study pronounced R&D investments as a stimulator for green adoption and a sustainable environment in G7. They have been labelled as a significant element that matures the renewable transition process (Caglar and Ulug, 2022). In a recent study of similar areas of interest, Li *et al*. (2023) discovered the promising influence of R&D expenses on the green energy transition. The empirical findings described that R&D spending spurs green adoption through the development of financial markets.

Similarly, using panel approaches, Ünlü *et al*. (2022) highlighted the importance of R&D budgets for green adoption in G8 economies. The study demonstrated the positive connection between R&D spending and green adoption, intensifying the renewable demand in the country. In a recent novel study, Gharbi *et al*. (2023) inspected the moderating role of R&D budgets in promoting sustainable development through renewable promotion. The analysis emphasized that R&D investments in the renewable sector substantially surge sustainability and tend to decrease emissions for future generations. Likewise, Song *et al*. (2023) described that R&D budgets play a crucial role in renewable energy adoption. Furthermore, the study suggested that increasing budgets and R&D spending will promote a sustainable environment (Li *et al*., 2023).

Financial globalization tends to deteriorate environmental sustainability, which might be caused by market fluctuation or limited financial or resource capital, but green adoption is positively related to environmental quality since it is beneficial for ecological sustainability (Adebayo *et al*., 2022; Jayaraman *et al*., 2023; Awosusi *et al*., 2023a; Chen *et al*., 2023). It means that less access to finance adversely affects the transition process. For example, Murshed *et al*. (2021) discovered the negative influence of financial globalization on renewable transition in developing economies (*e.g*., Bangladesh). The study established that the outcomes were due to limited access to financial capital in those regions. However, on the contrary, Majeed *et al*. (2022) investigated the positive interaction between economic globalization and renewable energy adoption in BRICS (1990 to 2018). The estimates described liberalized financial markets and institutions that encourage renewable adoption and are positively associated with renewable consumption in the sample economies. This indicates that economic expansion increases green technologies, which help mitigate emissions (Erdogan *et al*., 2023).

Similarly, in the case of China, Li *et al*. (2023) demonstrated that financial globalization is one of the prominent tools for encouraging renewable adoption. It plays a crucial role in technical innovation for green energy generation (Song *et al*., 2023). This indicates the importance of economic development in the economy to remove potential barriers to a green transition. Likewise, Ünlü *et al*. (2022) emphasized the development of financial markets and efficient institutions for renewable production and consumption. It helps in unbridling the potential of renewable energy across regions for sustainable development (Belaïd *et al*., 2021; Yi *et al*., 2023; Sun *et al*., 2023; Ramzan *et al*., 2023). Likewise, for OECD nations, Gozgor *et al*. (2020) described that the economic aspects of globalization are significant to sustainable energy consumption because they increase technical advancement and FDI inflows – these help endorse sustainable energy generation for maintaining a sustainable environment. In a novel study, Miao *et al*. (2022) found that the interaction between financial globalization and renewable energy positively contributes to a sustainable atmosphere and reduces ecological footprint since financial globalization promotes renewable energy technology for sustainable growth (Agrawal *et al*., 2023).

Green energy is an essential sustainable type of energy for preventing climate crises via lessening emissions (Awosusi *et al*., 2023a). Besides, socio-economic conditions significantly affect transitioning towards green energy and its adoption because socio-economic development helps achieve environmental sustainability (Jie *et al*., 2023). For years it has been a known fact that the results of socio-economic conditions provide resolutions to adopt sustainable energy and increase its production (Omer, 2010; Shoaib and Ariaratnam, 2016). According to the International Country Risk Guide Methodology (2011), three indicators are commonly used for socio-economic conditions, *i.e*., financial, political and economic. Several socio-political or financial factors alongside economic ones affect the transition process (Lin and Kaewkhunok, 2021). In this regard, a significant connection between green energy and socio-economic development in another recent study depicted that improvement in socio-economic indicators has a positive impact on green financing, leading to significant adoption of green energy (Lee and Hussain, 2023). This means that education and knowledge about sustainability and green financing help adopt renewable energy at the household level. Mehmood *et al*. (2022) demonstrated that improving socio-economic conditions, such as reduced corruption and upgrading institutional quality, increase renewable adoption in the country. The findings recommend further raising environmental awareness for sustainable growth. At the same time, some factors tend to affect the renewable adoption process oppositely. For instance, energy poverty is initially negatively associated with renewable consumption. However, it reduces energy poverty when it becomes the economy's dominant energy source (Muhammad *et al*., 2023).

2.3 Summary and research gap

The thorough literature background on the interaction between internal or external conflicts, R&D budgets and socio-economic conditions on renewable adoption suggests that renewable energy is a significant type of sustainable energy that helps prevent climate crises. However, certain external or internal factors tend to slow the process. According to the prevailing studies by Akita *et al*. (2020) and Larsen *et al*. (2018), internal and external conflicts over green energy adoption are inevitable, but good governance and a stable political situation help in escalating the transitioning process. Besides, R&D budgets are needed to sponsor renewable transition to replace non-renewable energy through technological advancement (Gharbi *et al*., 2023). For this, the economies need to promote the development of financial markets and efficient institutions to unlock the potential of renewable energy for sustainability (Belaïd *et al*., 2021; Yi *et al*., 2023; Sun *et al*., 2023). Besides, improvement in socio-economic conditions such as reduction in corruption, educational awareness and institutional quality surges renewable adoption alongside creating environmental awareness for sustainable growth in the economies (Mehmood *et al*., 2022; Lee and Hussain, 2023).

Therefore, due to the significance of these variables in the green transition, the present study aims to investigate the simultaneous interaction of the above explanatory factors in E7. The analysis examines the simultaneous nexus between R&D, financial globalization, socio-economic development and green energy adoption under the effect of internal and external conflicts in two different modifications. This novel relationship investigation is crucial in academic research for green policymaking for achieving a sustainable economy even during conflicting times.

3. Data and Methods

3.1 Variables and models

Following the research objectives and existing literature, this study observes that research and development expenditures (RDE: % of GDP), financial globalization (FGL: index), socio-economic condition (index) and conflict are the leading factors of greener energy (GRE) adoption (generally referred to as electricity production from renewable sources, excluding hydroelectric, quoted in kWh). In this instance, the present study follows the empirical model of Zhao *et al*. (2023) and constructs the following models, which are given in the regression form:

Model 1

$$GRE_{ti} = \varphi_1 + \alpha_1 RDE_{ti} + \alpha_2 FGL_{ti} + \alpha_3 SEC_{ti} + \alpha_4 ICON_{ti} + \varepsilon_{ti} \quad (1)$$

In Model 1, it must be noted that φ is the intercept of the model, whereas α*´s* are the intercepts for RDE, FGL, SEC and conflicts, which are herein considered as both internal conflict (ICON) and external conflict (ECON). To analyse the influencing mechanism of conflicts more comprehensively and avoid serial correlation, this study considers both ICON and ECON separately in the models. Model 2, which replaces ICON with ECON in Model 1, is given below:

Model 2

$$GRE_{ti} = \varphi_1 + \alpha_1 RDE_{ti} + \alpha_2 FGL_{ti} + \alpha_3 SEC_{ti} + \alpha_4 ECON_{ti} + \varepsilon_{ti} \quad (2)$$

Moreover, the error terms of the models are indicated by ε in both models, while the time series and cross-sections are depicted with t and i, respectively. Here, t is the period 1990-2020 for the E7 economies *(i)* including India, China, Turkey, Mexico, Brazil, Russian Federation and

Indonesia. Data for these variables have been extracted from various sources, such as the World Bank[1], KOFG[2] and ICRG[3].

3.2 Analytical approach

The study uses a research approach that encompasses many essential stages. The analysis begins by assessing the normality of the panel data to determine their appropriateness for further analysis. The panel data features are evaluated using two diagnostic procedures: tests for slope heterogeneity and panel cross-section dependency. The research subsequently utilizes second-generation unit root tests to investigate the stationarity features of the variables, therefore validating their soundness. The study also establishes the presence of cointegration as statistically significant over an extended period, suggesting a consistent and enduring association between the variables. The research uses quantile regression as a suitable statistical method to effectively address the non-normal data distribution and account for its inherent qualities. To effectively handle mixed-integration order concerns and assess the robustness of the results, a panel autoregressive distributed lag (ARDL) methodology is used. In addition, this study examines the causal linkages between the GRE and the regressors by using the pairwise Granger causality assessment. This comprehensive analytical approach guarantees the robustness and credibility of the study results, enabling a full examination of the factors influencing the GRE in the E7 economies. The thorough methodological setup is discussed below.

The empirical data assessment for this study started by conducting normality and descriptive analyses of the variables. This research aims to calculate the median, range and mean of the given information. The content refers to the set of both the highest and lowest values. This study investigates the standard deviation of all variables, illustrating the inherent unpredictability of data due to the significant variability in the mean and observations. This study further investigates the normality of the data by using the conventional measures of kurtosis and skewness. In contrast, the current research uses the normalcy test devised by Jarque and Bera (1987), which accommodates excess kurtosis and skewness while maintaining their zero values. The procedure for evaluating normalcy statistics using the prescribed methodology is outlined as follows:

$$JB = \frac{N}{6}\left(S^2 + \frac{(K-3)^2}{4}\right) \tag{3}$$

1 For GRE and R&D, visit: https://databank.worldbank.org/source/world-development-indicators#

2 For FGL, visit: https://kof.ethz.ch/en/forecasts-and-indicators/indicators/kof-globalisation-index.html

3 For SEC, ICON and ECON, visit: https://www.prsgroup.com/explore-our-products/icrg/

The present study examines the presence of slope coefficient heterogeneity (SCH) and panel cross-section dependency (PCD) after evaluating the data normality. The period between 1760 and 1840 saw a significant growth in trade and rapid internationalization, leading to the specialization of nations in particular services and goods, while some achieved notable success. Therefore, certain economies need other nations' support to attain their financial, scientific, social, economic and other goals. Due to this interdependence, government administrations and officials may enact policies that urge one nation to emulate others, underscoring the need for consistency in the slope of variables. The lack of slope uniformity might make panel data analysis impractical and non-robust (Wei *et al*., 2022). The issue at hand is effectively addressed using the Pesaran and Yamagata (2008) SCH methodology. The validity of this evaluation is shown by its inclusion of both SCH and adjusted SCH.

$$\hat{\Delta}_{SCH} = \sqrt{N\left(2k\right)^{-1}}\left(N^{-1} \ - \mathrm{K}\right) \tag{4}$$

$$\hat{\Delta}_{ASCH} = \sqrt{N}\sqrt{\frac{T+1}{2K.\left(T-K-1\right)}}\left(N^{-1} \ - \ \mathrm{K}\right) \tag{5}$$

The symbol $\hat{\Delta}_{SCH}$ denotes the statistical values about SCH as derived from Equation (4), whereas $\hat{\Delta}_{ASCH}$ reflects the same data for ASCH as obtained from Equation (5). Therefore, the null hypothesis (H_0) suggests homogeneity of slope coefficients.

The engagement in cross-border commerce and the process of globalization contribute to the development of a nation's expertise in producing and providing goods and services that have significance on an international scale. These nations increasingly rely on highly specialized economies. The potential consequence of disregarding the panel issue, namely PCD, is that empirical findings may be subject to bias, as highlighted by Campello *et al*. (2019). Therefore, the PCD test, as proposed by Pesaran (2004), serves to detect the presence of cross-sectional dependency among the selected economies. The following is the equation for cross-sectional dependence detection:

$$\mathrm{CD}_{Test} = \frac{\sqrt{2T}}{\left[N\left(N-1\right)\right]^{1/2}}\sum_{i=1}^{N-1}\sum_{k=1+i}^{N}T_{ik} \tag{6}$$

The null hypothesis, denoted as H_0, posits that the cross-sections of panels exhibit independence.

The evaluation of the stationary behaviour of variables is complemented with diagnostic outcomes. This study uses the Pesaran (2007) CIPS stationarity testing approach, an enhanced version of the Pesaran (2006) test, to detect the presence of a unit root, a crucial factor for long-term predictions. The underlying assumption of the test (H_0) is that the unit root exists. The null hypothesis (H_0) may be rejected if the statistical findings surpass the predetermined significance levels of 1%, 5% or 10%. If the parameter(s) exhibit non-stationarity at level, it is possible to do a test for stationarity at first difference. Besides mitigating panel challenges, the CIPS testing technique also tackles problems related to PCD and SCH.

Given that each variable exhibits the characteristic of stationarity, it is essential to examine the enduring stability among the parameters of interest. To address this issue, the current study uses two-panel cointegration tests, namely those proposed by Kao (1999) and Pedroni (2004). More specifically, Pedroni (2004) introduces estimates of modified Phillips-Perron *t*, Phillips-Perron *t* and augmented Dickey-Fuller *t*. Kao (1999) provides statistical parameters for several cointegration tests, including the modified Dickey-Fuller *t*, Dickey-Fuller *t*, augmented Dickey-Fuller *t*, unadjusted modified Dickey-Fuller *t* and unadjusted Dickey-Fuller *t*. The fundamental presumptions of the test posit the absence of cointegration among the variables. However, by significant statistical values, it is possible to get substantial estimates that may reject the null hypothesis and support the assertion that cointegration exists between the variables.

The quantile regression approach developed by Koenker and Bassett Jr. (1978) thoroughly examines the long-term impact of the factors under investigation on greener energy adoption. This analysis is conducted after conducting tests for cross-sectional dependency and cointegration. Due to the non-normality that exists in the data being analysed, the use of quantile regression is preferred over standard approaches. Moreover, this methodology offers the estimated coefficient for each chosen quantile to mitigate the biases of over- and under-estimation often seen in conventional techniques. Panel quantile regression is a valuable analytical approach offering meaningful insights into the examined factors since it considers individualized and distributional heterogeneity (Cheng *et al*., 2019). According to Qin *et al*. (2021), quantile regression has superior predictive capability compared to linear regression, which offers an average estimation of error effects. The estimator mentioned above is advantageous due to its effectiveness in addressing the problem of PCD (Amin *et al*., 2020). The panel quantile regression equations (Equations (7) and (8)) may be obtained from the study models discussed before (Equations (1) and (2)):

$$Q_{GRE_{it}}\left(\theta \middle| \varphi_i,\, \alpha_t,\, X_{it}\right) = \varphi_i + \alpha_t + \alpha_{1,\theta}RDE_{it} + \alpha_{2,\theta}FGL_{it} + \alpha_{3,\theta}SEC_{it} + \alpha_{4,\theta}ICON_{it} + \varepsilon_{it} \quad (7)$$

$$Q_{GRE_{it}}\left(\theta \middle| \varphi_i,\, \alpha_t,\, X_{it}\right) = \varphi_i + \alpha_t + \alpha_{1,\theta}RDE_{it} + \alpha_{2,\theta}FGL_{it} + \alpha_{3,\theta}SEC_{it} + \alpha_{4,\theta}ECON_{it} + \varepsilon_{it} \quad (8)$$

The symbol θ is used in both formulations to represent selected quantiles, namely $Q^{0.10th}$, $Q^{0.20th}$, …, and $Q^{0.90th}$. These quantiles are employed to empirically evaluate the influence of our key variables of interest (RDE, FGL, SEC, ICON and ECON) on greener energy adoption.

After attaining the empirical results, it must be noted that the unit root tests provide varying degrees of integration for the variables being examined. The use of an efficient robustness estimator that takes into account mixed integration order is utilized by the present research. The research necessitates a proficient estimation methodology to ascertain the long and short-run correlation between the variables. To examine these correlations, the current work uses the ARDL testing methodology introduced by Pesaran and Shin (1997), with further enhancements presented by Pesaran *et al*. (2001). With a limited variable sample size, this approach accounts for the missing variables. Additionally, the ARDL approximation may distinguish between independent and dependent variables while examining the association between mixed-order integrating variables, *i.e*., I(0) and I(1) (Pesaran and Shin 1997). The study models could adopt the following form while employing the ARDL approach:

$$\begin{aligned}
&\Delta GRE = \varphi_1 + \sum_{i=1}^{p}\alpha_1 \Delta RDE_{t-r} + \sum_{i=0}^{q}\alpha_2 \Delta FGL_{t-r} + \sum_{i=0}^{r}\alpha_3 \Delta SEC_{t-r} + \\
&\sum_{i=0}^{s}\alpha_4 \Delta ICON_{t-r} + \lambda_1 RDE_{t-1} + \lambda_2 FGL_{t-1} + \lambda_3 SEC_{t-1} + \lambda_4 ICON_{t-1} + \varepsilon_t \\
&\Delta GRE = \varphi_1 + \sum_{i=1}^{p}\alpha_1 \Delta RDE_{t-r} + \sum_{i=0}^{q}\alpha_2 \Delta FGL_{t-r} + \sum_{i=0}^{r}\alpha_3 \Delta SEC_{t-r} + \\
&\sum_{i=0}^{s}\alpha_4 \Delta ECON_{t-r} + \lambda_1 RDE_{t-1} + \lambda_2 FGL_{t-1} + \lambda_3 SEC_{t-1} + \lambda_4 ECON_{t-1} + \varepsilon_t
\end{aligned} \tag{9}$$

This study uses the pairwise Granger causality test proposed by Dumitrescu and Hurlin (2012) to examine the causal link between the variables, considering the limitations imposed by the earlier estimators. This examination will provide more insights into the policy-level relevance or importance of certain variables concerning adoption of greener energies while accounting for the panel data issues of PCD and SCH.

4. Results and Discussions

The results and their discussion are provided in this section. First, descriptive statistics of each variable are presented in Table 1. According to the test statistics, each variable has a little difference in their mean and median values, demonstrating data imbalance. Also, all values are positive, indicating positive growth among variables. The data spread from the mean position is presented by standard deviation statistics, denoting how much each variable deviates from its mean value. The minimum and maximum values depict the range of each study variable. The skewness and kurtosis further validate the data asymmetry, as the weights do not express normal distribution. The overall descriptive analysis demonstrates that the variables are unbalanced, asymmetrical and have a non-normal distribution, which leads us to apply quantile regressions. However, specific diagnostic tests are used to confirm the estimation procedure.

Table 1: Descriptive statistics

	GRE	RDE	FGL	SEC	ICON	ECON
Mean	22.056	0.839	58.950	5.832	8.328	9.721
Median	22.668	0.793	60.800	6.000	8.420	10.000
Maximum	26.371	2.400	72.600	8.880	11.920	12.000
Minimum	17.281	0.047	32.100	2.000	2.170	6.170
Std. dev.	2.161	0.515	9.157	1.587	1.507	1.441
Skewness	−0.333	1.012	−0.725	−0.593	−0.742	−0.413
Kurtosis	2.414	4.138	3.118	2.943	4.987	2.503
Jarque-Bera	7.111	48.767	19.150	12.787	55.680	8.418
Probability	0.028	0.000	0.000	0.001	0.000	0.015
Observations	217	217	217	217	217	217

Source: Authors' own preparation

Table 2 illustrates the results of the heterogeneity coefficient. The p values are significant at a 1% significance level, denoting rejection of the null hypothesis. The tests confirm the diversity of variance and reject the homogeneity among variables with 14.86 (SCH) and 16.88 (SCH_{adj}). The diversity of the variables leads to a cross-sectional dependence test.

Table 2: Coefficient heterogeneity test

Slope heterogeneity		
	Delta	***p*-Value**
SCH	14.860***	0.000
SCH^{adj}	16.889***	0.000

Note: $p < 0.01$ (***), $p < 0.05$ (**), $p < 0.10$ (*).
Source: Authors' own preparation

The cross-sectional dependence test demonstrates whether macroeconomic factors or geographical locations might affect the data. Therefore, a CD test is applied to assess cross-sectional dependence and correlation across different entities in the cross-sectional data. The results are presented in Table 3. The test denotes that all the variables are statistically significant at a 1% significance level except R&D budgets. The general interpretation shows that when excluding R&D budgets, all the variables are cross-sectionally correlated.

Table 3: Cross-sectional dependence test

Cross-sectional dependence		
Variable	**CD-test**	***p*-value**
GRE	22.294***	0.000
RDE	−0.606	0.544
FGL	24.58***	0.000
SEC	8.15***	0.000
ICON	6.238***	0.000
ECON	11.065***	0.000

Note: $p < 0.01$ (***), $p < 0.05$ (**), $p < 0.10$ (*).
Source: Authors' own preparation

Table 4 presents the stationarity results of the CIPS assessment. All the variables are significant at level as well as at first difference. The results are significant at both levels I(0) and at first difference I(1), depicting that the variables are stationary at both levels, and there is an absence of unit roots among the study variables at I(0) and I(1). Next, the study utilizes cointegration tests to inspect the correlation among the study data.

Table 4: Stationarity testing

CIPS (Pesaran 2007)		
Variable	**I(0)**	**I(1)**
GRE	−1.723	−5.146***
RDE	−3.181***	−5.128***
FGL	−2.898**	−5.446***
SEC	−2.753*	−4.903***
ICON	−2.778*	−4.959***
ECON	−2.878**	−5.764***

Note: $p < 0.01$ (***), $p < 0.05$ (**), $p < 0.10$ (*).
Source: Authors' own preparation

Table 5 shows the cointegration results of the Kao and Pedroni tests. This test describes whether the study variables are correlated in the long run. The general interpretation of the testing shows that all variables are correlated in the long run. R&D budgets, external or internal conflicts, financial globalization and socio-economic situation are connected in the long run with green energy adoption. After the diagnostic analysis of variables, we move towards the estimation process to examine the direction of the variables.

Table 5: Cointegration assessments

Kao			Pedroni		
Tests	**Model 1**	**Model 2**	**Tests**	**Model 1**	**Model 2**
Modified DF *t*	−1.285*	−1.216	**Modified PP *t***	1.627*	1.525*
DF *t*	−2.004**	−2.124**	**PP *t***	−0.462	−0.941
Augmented DF *t*	−1.380*	−1.550*	**Augmented DF *t***	−0.552	−0.853
Unadjusted modified DF *t*	−1.039	−0.894	—	—	—
Unadjusted DF *t*	−1.892**	−1.977**	—	—	—

Note: $p < 0.01$ (***), $p < 0.05$ (**), $p < 0.10$ (*).
Source: Authors' own preparation

Now, quantile regressions are applied to the study variables, whose outcomes are presented in Table 6. Firstly, the connection between R&D budgets and greener energy adoption is initially negative and significantly related, then it eventually becomes positively significant throughout the quantile regressions in the latter quantiles. This implies that the economy initially has fewer resources for the green transition. Still, the impact becomes positive later, denoting that increasing funding promotes renewable transition, embracing green energy solutions in the country. Similar outcomes are presented for Model 2 under the presence of external conflicts. Secondly, the role of financial globalization is positive across all quantiles at a 1% significance level in Model 1. Likewise, the impact of financial globalization is positive in all quantiles in Model 2, implying that increasing financial globalization increases the promotion of renewable energy in the sample economies. It improves the financial markets and institutional liberalization, which helps in energy adoption.

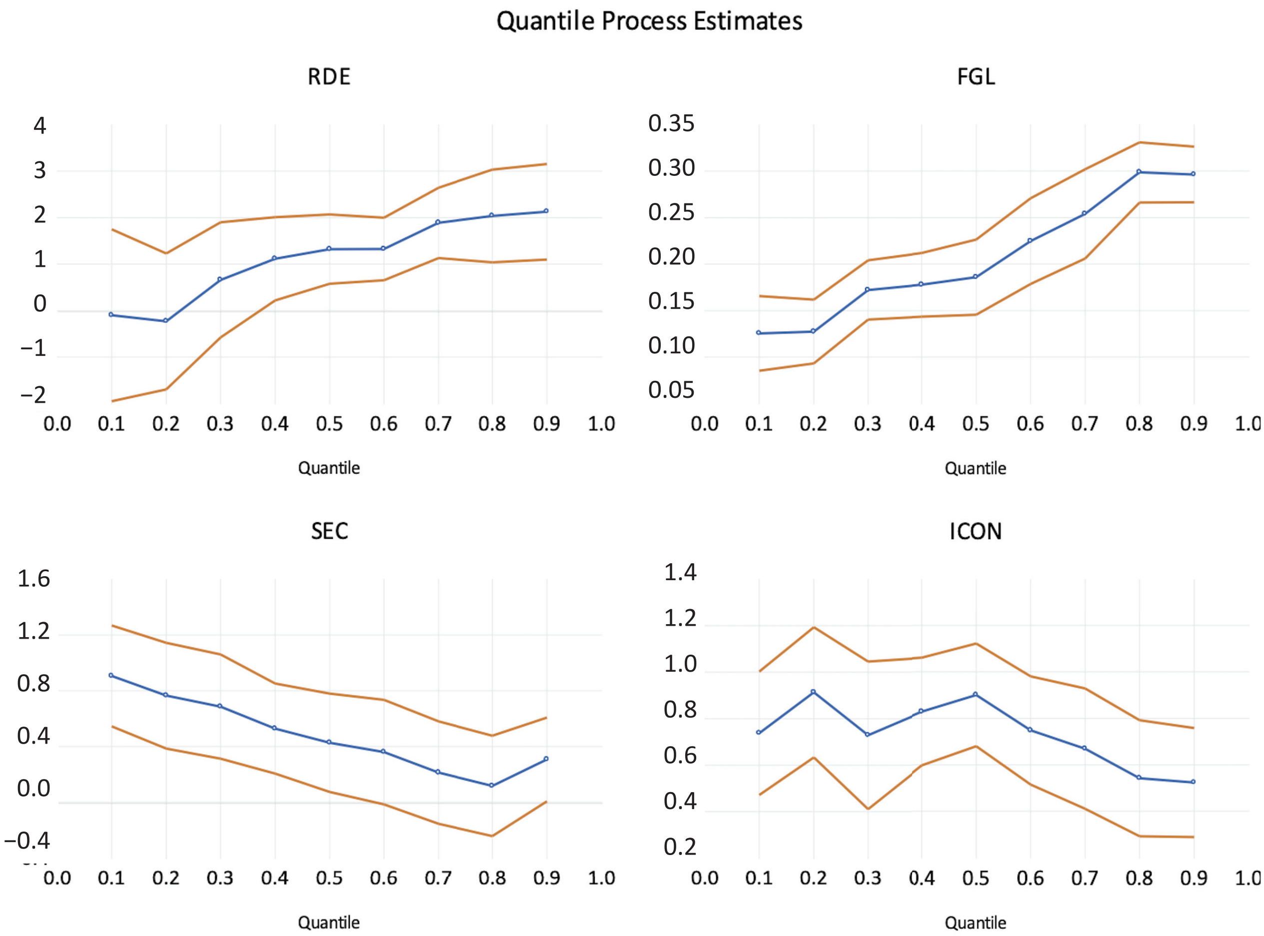
Table 6: Quantile estimates

Var.	Model 1 (quantiles)								
	$Q_{.10}$	$Q_{.20}$	$Q_{.30}$	$Q_{.40}$	$Q_{.50}$	$Q_{.60}$	$Q_{.70}$	$Q_{.80}$	$Q_{.90}$
RDE	−0.099	−0.233	0.660	1.116**	1.321***	1.326***	1.886***	2.036***	2.126***
FGL	0.125***	0.127***	0.172***	0.178***	0.186***	0.225***	0.254***	0.299***	0.296***
SEC	0.907***	0.765***	0.686***	0.529***	0.427**	0.360*	0.214	0.118	0.308**
ICON	0.737***	0.913***	0.729***	0.829***	0.901***	0.748***	0.670***	0.542***	0.524***
	Model 2								
RDE	−0.269	0.346	1.184**	1.753***	1.873***	1.818***	1.781***	1.938***	1.587***
FGL	0.127***	0.133***	0.135***	0.137***	0.179***	0.185***	0.209***	0.225***	0.250***
SEC	0.757***	0.669***	0.430***	0.330***	0.222	0.227	0.153	0.117	0.139
ECON	0.775***	0.835***	0.976***	1.026***	0.920***	0.914***	0.871***	0.834***	0.772***

Note: $p < 0.01$ (***), $p < 0.05$ (**), $p < 0.10$ (*).
Source: Authors' own preparation

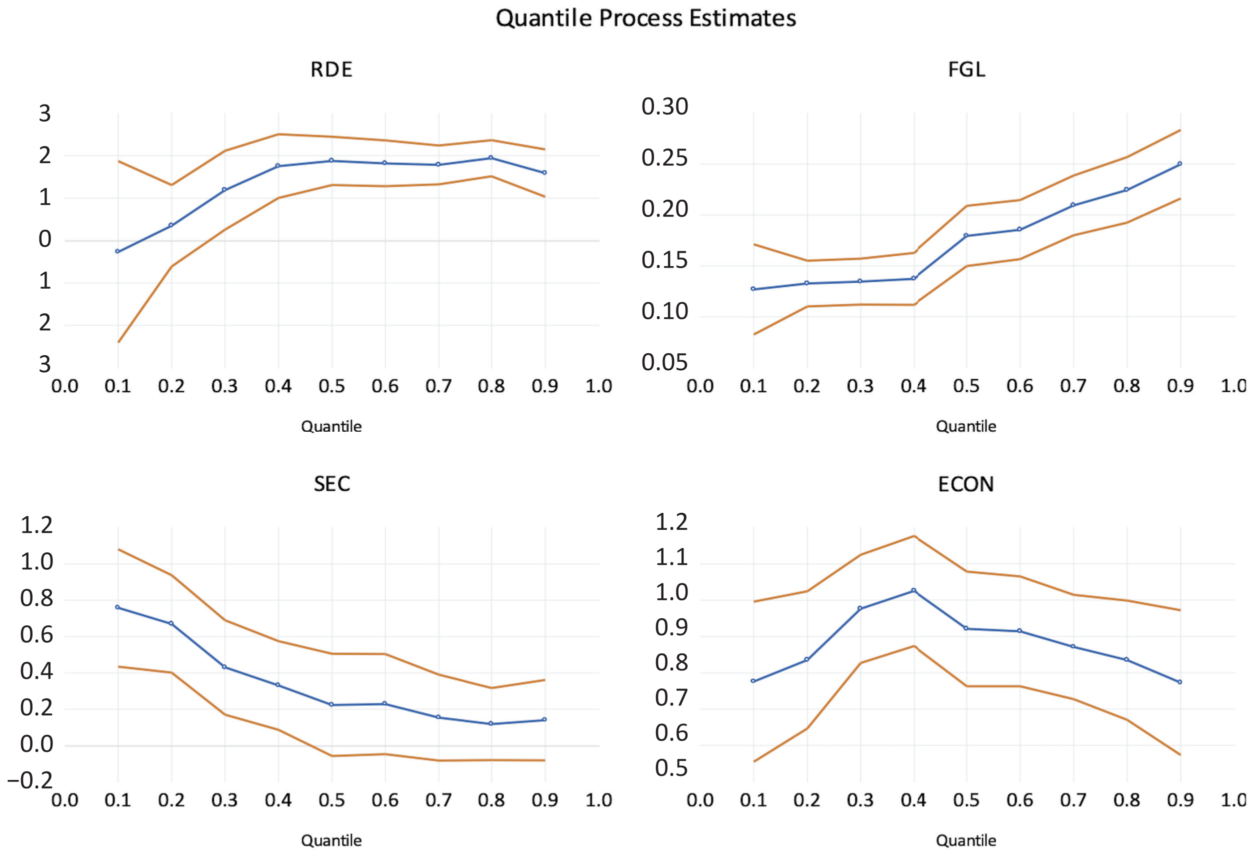
The influence of socio-economic conditions in both models (1 and 2) is positively related to green energy adoption. This implies that socio-economic development helps promote green energy adoption and successfully transitioning towards renewable energy even during conflicting times. Lastly, the interaction of internal and external conflicts is positive in both models (1 and 2). This implies that the study countries have more resilient and adaptable energy solutions, such as renewable energy as a means of reducing dependence on conventional energy, or emerging countries have improved energy security to reduce imported fossil fuel dependence, especially during conflicting times or geopolitical tensions. The results demonstrate that the economies are adopting green energy during times of war or political conflicts, which signifies that these economies prioritize adapting, innovating and building a robust and sustainable future.

Figure 3: Quantile estimates (Model 1)



Source: Authors' own preparation

Figure 4: Quantile estimates (Model 2)



Source: Authors' own preparation

Figures 3 and 4 demonstrate the symbolic presentation of all estimated quantiles from Models 1 and 2. The graphs depict each variable illustrating how they interact (positively or negatively) with green energy adoption under internal or external conflicts in emerging economies.

For a more nuanced and comprehensive analysis of the above nexus, the study employs ARDL estimates presenting the long-run and short-run statistics. The variables again show a long-run relationship with green energy adoption in both models (1 and 2). In the short term, some variables show insignificant linkage with renewable adoption, whereas FGL and socio-economic conditions show insignificant but positive associations (similar to the above) with green adoption in the case of emerging countries. These inclusive ARDL estimates show that financial globalization, R&D and socio-economic indicators are crucial for green adoption even during conflicting times (internal or external).

Table 7: Robustness: ARDL Estimates

Variable	Model 1		Model 2	
	Coef.	Std. Er.	Coef.	Std. Er.
Long run equation				
RDE	1.578***	0.288	2.281***	0.140
FGL	0.127***	0.006	0.098***	0.012
SEC	0.100***	0.023	−0.165**	0.063
ICON	0.304***	0.056	—	—
ECON	—	—	−0.274***	0.059
Short run equation				
GRE(−1)	−0.213	0.167	0.081	0.205
ΔRDE	−0.817**	0.389	1.280**	0.610
ΔFGL	−0.029	0.035	0.013	0.058
ΔSEC	0.016	0.039	0.019	0.107
ΔICON	−0.069***	0.018	—	—
ΔECON	—	—	−0.019	0.113
C	3.128***	0.939	7.957	4.880
ECT	−0.287***	0.080	−0.443*	0.262

Note: $p < 0.01$ (***), $p < 0.05$ (**), $p < 0.10$ (*).
Source: Authors' own preparation

The above outcomes do not portray the direction of explanatory factors, *i.e.*, whether financial globalization, R&D and socio-economic indicators cause or affect green adoption. Therefore, the study employs causality analysis in which ten pairs are formed, presented in Table 8. The causality findings show that research and development funding is bi-directionally related to green energy adoption. At the same time, the remaining variables are unidirectionally associated with green energy adoption. It shows that socio-economic conditions and internal and external conflicts significantly cause adoption of green energy in emerging economies.

Table 8: Pairwise causality

Pairwise DH panel causality			
H_0:	W-stat.	Zbar-stat.	Prob.
RDE → GRE	12.865***	5.819	6.E-09
GRE → RDE	11.280***	4.716	2.E-06
FGL → GRE	16.422***	8.294	0.0000
GRE → FGL	6.244	1.213	0.2249
SEC → GRE	7.896**	2.362	0.0181
GRE → SEC	6.267	1.229	0.2189
ICON → GRE	8.315***	2.654	0.0079
GRE → ICON	5.624	0.782	0.4342
ECON → GRE	7.111*	1.816	0.0693
GRE → ECON	6.500	1.391	0.1640

Note: $p < 0.01$ (***), $p < 0.05$ (**), $p < 0.10$ (*).
Source: Authors' own preparation

Hence, it can be claimed that R&D budgets initially deteriorate green energy adoption. Still, eventually, when they receive funding, the impact of research and development budgets for renewable energy on green adoption becomes positive. In line with these findings, it is implied that the role of R&D expenditures drives green adoption, which develops the renewable transition process. Similar arguments are claimed in existing studies such as Caglar and Ulug (2022) and Liu *et al*. (2023). Besides, the adoption process continues even during internal or external conflicts, denoting either the economies are open to new economic opportunities or the international community supports funding for reconstruction efforts. Secondly, the connection between financial globalization and green adoption is positive overall, showing that financial globalization encourages renewable adoption. This implies the importance of finances for removing potential barriers to a green transition across regions for sustainable development. Similar findings have been reported in the studies of Li *et al*. (2023) and Ünlü *et al*. (2022). This shows that the promotion of financial development increases cross-border capital flows and access to global capital markets, and increases energy security to lessen vulnerabilities during conflicts. Thirdly, the nexus between socio-economic conditions and renewable energy adoption is also positive in emerging economies.

This could be possible because the socio-economic conditions are a long-term phenomenon with several indicators that signify positive interaction. The emerging economies are pursuing sustainable development goals to improve climate disparities and energy security. Therefore, the positive nexus implies that the exchange is efficient for alleviating energy scarcity, creating job opportunities and cutting energy prices, which stimulates the economies and improves society's overall well-being. It is labelled as an investment for the future and a sustainable way to build an economy resilient against vulnerabilities. The results are consistent with the findings of Mehmood *et al*. (2022). This implies improved socio-economic conditions, such as good governance, and increases awareness of sustainable growth regardless of vulnerabilities, as reasoned by Ariaratnam (2016). Lastly, the interaction of internal and external conflicts with green energy adoption is positive, which aligns with findings of Awosusi *et al*. (2023) and Zhao *et al*. (2023). It is implied that eventful situations over renewable transition are unescapable, but investment support, innovation, resource diversification and efficient management help incapacitate those conflicts (Akita *et al*., 2020).

5. Conclusion and Policy Suggestions

5.1 Conclusion

The E7 are rapidly growing economies, and they are expected to expand more. The expansion demands more energy not just for fulfilling sustainable environmental resolutions but also works as a catalyst for economic growth. However, their increasing potential attracts other vulnerabilities such as internal or external conflicts. Internal political conflicts or external conflicts such as the Russo-Ukrainian War have adversely affected economies worldwide, causing disruptions in energy markets, financial markets and energy security, besides troubling regional stability and the investment environment. This has also influenced the E7 countries directly or indirectly, causing widespread obstacles to green energy adoption by affecting resource allocation and policy development, or troubling infrastructure development and international corporations. However, with this background, the present study investigated the impact of research and development budgets and socio-economic conditions on greener energy adoption in E7 during conflicting times from 1990 to 2020. The empirical nexus using quantile regressions, ARDL analysis and causality assessment revealed that all the variables have significant long-run associations and are drivers of green energy adoption. Furthermore, the study answered the research questions, finding that R&D budgets initially reduce green adoption but later promote renewable adoption. On the other hand, financial globalization and socio-economic conditions tend to increase green energy adoption in these economies despite internal or external conflicts.

5.2 Policy suggestions

The E7 are rapidly growing economies, and they are expected to expand more. The expansion demands more energy not just for fulfilling sustainable environmental resolutions but also works as a catalyst for economic growth. However, their increasing potential attracts other vulnerabilities such as internal or external conflicts. Internal political conflicts or external conflicts such as the Russo-Ukrainian War have adversely affected economies worldwide, causing disruptions in energy markets, financial markets and energy security, besides troubling regional stability and the investment environment. This has also influenced the E7 countries directly or indirectly, causing widespread obstacles to green energy adoption by affecting resource allocation and policy development, or troubling infrastructure development and international corporations. However, with this background, the present study investigated the impact of research and development budgets and socio-economic conditions on greener energy adoption in E7 during conflicting times from 1990 to 2020. The empirical nexus using quantile regressions, ARDL analysis and causality assessment revealed that all the variables have significant long-run associations and are drivers of green energy adoption. Furthermore, the study answered the research questions, finding that R&D budgets initially reduce green adoption but later promote renewable adoption. On the other hand, financial globalization and socio-economic conditions tend to increase green energy adoption in these economies despite internal or external conflicts.

5.3 Limitations and future recommendations

The study has the following limitations and future recommendations. Due to data unavailability, the data are limited to the period from 1990 to 2020. Hence, for future research, it is recommended to consider updated data for robust analysis capturing the present scenarios of the economies. Additionally, it is proposed that researchers compare and contrast the experiences of E7 with other countries facing similar conflicts or circumstances for more thorough policy implications.

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