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For Which Countries Is Energy Security a Greater Problem? An Empirical Comparison of Energy-Exporting and Energy-Importing Countries Using Advanced Panel Data Analysis

Abstract. *This study explores the impact of energy security on economic growth by incorporating energy security risk into an expanded production function framework. Using data from 1980 to 2018 for 20 energy-exporting and 20 energy-importing countries, the research examines two hypotheses: (1) increased energy security risks negatively affect economic growth in both groups, and (2) this effect is more severe for energy-exporting countries. Long-term relationships are identified using advanced panel data techniques, including the Westerlund and Edgerton (2008) cointegration test with structural breaks, the Banerjee and Carrion-i-Silvestre (2017) CCE-based cointegration test, and the AMG and CCE estimators. The results reveal that energy security risk has a stronger negative impact on energy-exporting countries (-0.461, AMG; -0.381, CCE) compared to energy-importing countries (-0.240, AMG; -0.163, CCE), confirming the hypotheses. Policy recommendations emphasise the importance of economic diversification for exporters, particularly by investing in technology and tourism, and strengthening energy infrastructure to mitigate supply shocks. For importers, securing long-term energy contracts, improving strategic reserves, and expanding renewable energy utilisation are vital. These measures are critical to achieving sustainable energy security and economic stability, especially as fossil fuel resources face depletion and global energy markets become increasingly volatile.*

Keywords: *economic growth, energy security, energy policies, sustainable futures, energy exporting/importing countries, Panel Data Analysis, CCE-based Cointegration Test, Cointegration Test with structural breaks.*

JEL Classification: C23, O13, O40, O47, Q43.

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1. Introduction

Energy security, according to the IEA (2020), ensures the uninterrupted availability of energy sources at affordable prices. While long-term energy security focuses on investments aligning energy supply with future demands, short-term security emphasises system resilience against sudden supply-demand shocks. Initially rooted in concerns over fossil fuel scarcity, the concept of energy security

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has evolved into a multidimensional framework that is often approached through the 4A model –availability (resource presence), accessibility (distribution risks), affordability (economic feasibility), and acceptability (environmental compatibility)– which collectively highlight the complex balance of economic, environmental, and geopolitical considerations in contemporary energy systems. In this context, the IEA's definition may be expanded as: 'The uninterrupted availability of energy sources that are both environmentally acceptable and affordable.' In addition to this, energy security risks and their economic impacts differ significantly between exporters and importers due to their distinct economic dependencies (To avoid repetition, for deeper insight into the differing meanings and risks of energy security in energy-exporting and energy-importing countries, as well as the distinct policy recommendations arising from these differences, see Kartal 2022a, pp. 488-499). Exporters face vulnerabilities related to revenue fluctuations and environmental impacts, while importers grapple with supply chain reliability and cost management. In this respect, this study investigates how energy security risks influence economic growth across both groups, including 20 energy-exporting and 20 energy-importing and provides a comparative analysis.

According to data from Trade Map (2024), classified by HS-2 code 27 for fuel products, the data reveals the heavy reliance of energy-exporting countries on fuel revenues, with 11 of the 20 energy-exporting countries focused on in this study deriving over half of their export income from energy, and some exceeding 90%. This dependency creates significant vulnerabilities, as illustrated by the stark contrast between their collective foreign trade surplus of $515.2 billion and the $455.8 billion deficit when fuel exports are excluded. The findings underscore the central role of energy in sustaining these economies while revealing their heightened exposure to market fluctuations and limited economic diversification. This dependency influences fiscal stability, with government budgets heavily tied to energy revenues. Declines in these revenues can trigger budget deficits, reduced public spending, and broader economic instability. In addition, the environmental impact of fossil fuel extraction and exports presents long-term challenges, as these countries face a growing pressure to reconcile economic priorities with environmental sustainability. The Energy Security Risk Index (ESRI) further highlights their precarious position, with five energy-exporting countries ranking among the top 10 most at-risk countries globally. This reinforces the urgency for economic diversification and the adoption of sustainable energy policies as global transitions toward renewables accelerate.

On the other hand, according to data from Trade Map (2024), classified by HS-2 code 27 for fuel products, the data highlights the substantial reliance of the energy-importing countries focused on in this study on fuel imports, with fuel comprising a significant share of their total imports. This dependency emphasises energy's critical role as an economic input while also exposing these countries to considerable energy security risks. The data reveals that excluding fuel imports transforms the collective trade deficit of $778.6 billion into a surplus of $429.8 billion, underscoring the weight of energy costs in their trade balances. This heavy reliance makes importing countries particularly vulnerable to price volatility, supply chain disruptions, and geopolitical tensions, which can destabilise energy flows and hinder economic performance. The precariousness of this dependency underscores the importance of strategies to enhance energy security, including diversifying energy sources, increasing renewable energy adoption, and securing long-term energy supply agreements. As the global energy landscape evolves, these countries must balance their reliance on imports with policies that mitigate risks and ensure sustainable economic growth.

These findings collectively reveal a fundamental asymmetry between energy-exporting and importing countries: while exporters face structural fragility due to overdependence on volatile energy revenues and limited diversification, as well as environmental sustainability challenges stemming from fossil fuel extraction – importers grapple with the economic burden and strategic uncertainty of securing external energy supplies. Although the nature of exposure differs, both groups must also contend with shared environmental pressures linked to global decarbonisation goals. These complex and contrasting vulnerabilities demand tailored policy responses that account for each group’s structural realities while fostering coordinated action to enhance energy security and advance sustainable development.

The energy security challenges faced by energy-exporting and energy-importing countries, though distinct, share a common gap in the literature regarding the broader implications of energy security risks, particularly their impact on economic growth. This study highlights a significant shortcoming in the empirical literature, which largely overlooks the differential effects of energy security risks on economic growth, especially in terms of the nuanced relationship between these risks and the economic performance of different types of countries. In this regard, the study tests two central hypotheses: first, that heightened energy security risk levels exert a negative influence on economic growth in both energy-exporting and energy-importing countries, and second, that this negative impact is more pronounced in energy-exporting countries, owing to their greater exposure to disruptions in energy markets and the vital role of energy revenues in their economies. To investigate these hypotheses, the study follows a comprehensive approach, beginning with a detailed literature review that identifies the existing gaps in the empirical examination of energy security’s economic effects. This review sets the stage for the study's objectives and aligns them with relevant scholarly discourse. Data sources and methodologies are then meticulously outlined, ensuring methodological transparency and rigor. Rigorous tests for cross-section dependence and homogeneity validate the chosen approach, while cointegration tests and coefficient estimates provide robust insights into the intricate relationship between energy security and economic growth.

2. Literature Review

The landscape of empirical research on energy security is vast and multifaceted, encompassing various dimensions and factors that intricately shape a country's energy security outlook. Researchers have delved into understanding not only the dimensions of energy security, but also the myriad factors that influence it. These factors, ranging from geopolitical dynamics and resource availability to technological advancements and policy frameworks, collectively influence a country's energy security landscape. In this context, some empirical studies analyse the intricacies of the current energy security situations in various countries rather than their impact on economic variables, utilising specifically crafted indicators or composite indices. However, a subset of these studies indirectly examines the economic implications of energy security through variables such as fuel stability, natural gas consumption, electricity accessibility, and environmental sustainability pressure. Moreover, several researchers have analysed the macroeconomic effects of energy price shocks – a dimension of energy security, demonstrating the broader economic consequences of fluctuations in energy markets. While not explicitly labelled as energy security variables, these economic analyses indirectly capture critical facets of energy security, shedding light on the interplay between energy dynamics and economic stability, thereby enhancing understanding of its broader implications.

Despite this breadth of works indirectly addressing energy security through proxies, few studies comprehensively explore the direct impact of energy security on economic growth, integrating the 4A dimensions of energy security: availability, accessibility, affordability, and acceptability. These studies offer invaluable guidance to policymakers in the energy sector by providing critical insights into the multifaceted effects of energy security on economic growth and stability. In this context, Kartal's research represents a significant portion of this corpus. Beginning with studies such as Kartal (2018) and Kartal and Öztürk (2020), which examined 15 Middle Eastern countries from 1996 to 2014, these works applied first-generation unit-root and cointegration techniques to demonstrate that a 1% increase in energy security risk levels corresponded to a significant decrease in GDP per capita, underscoring the pivotal role of energy security in economic performance. Kartal (2022b) extended this analysis with 16 Middle Eastern countries from 1980 to 2016 and second-generation unit-root and cointegration techniques, reaffirming that higher energy security risk levels led to reduced economic growth. Moving beyond the Middle East, Kartal (2022c) explored similar dynamics in the Turkic World from 1992 to 2016, highlighting the negative impact of energy security risks on economic growth across Türkiye, Azerbaijan, Kazakhstan, Turkmenistan, and Uzbekistan. Additionally, Kartal (2022d) and Kartal (2022a) utilised innovative methods like the Asymmetric Causality Test proposed by Hatemi-J (2012) and NARDL models to uncover asymmetric effects of energy security on economic growth in Türkiye from 1980 to 2018, providing nuanced insights into short- and long-term impacts. In this context, Kartal (2022d) reveals one-way causality from energy security risk levels to negative shocks in GDP, on the other hand; Kartal (2022a) reveals a 1% increase in energy security risk level leads to a significant decrease in approximately 0.60% in economic growth, whereas a 1% decrease in energy security risk level results in a substantial increase of about 1.72% in economic growth. Kartal (2022e) expanded the scope globally, identifying different causality patterns between energy security risk levels and GDP across 74 countries using the Kónya Bootstrap Panel Granger Causality, emphasising the need for tailored policies based on economic contexts. The study found varying causal relationships between energy security risk levels and GDP across different income groups, with unidirectional causality from energy security risk to GDP in 14 countries, from GDP to energy security risk in 20 countries, bidirectional causality in 22 countries, and no observed causality in 18 countries, demonstrating an increasing detection rate of these relationships as countries transition from high-income to lower-middle-income categories. Furthermore, Kartal (2023) examined the interaction between military expenditures and energy security risk levels in 16 energy-exporting countries from 1990 to 2018, using the Kónya Bootstrap Panel Granger Causality approach. The study underscored the complex dynamics and emphasised energy security's pivotal role as a policy lever influencing military expenditures, alongside its interaction with economic performance. Together, these studies demonstrate energy security's critical role in economic stability and underline the need for proactive policy measures.

Another significant contribution comes from Le and Nguyen (2019), who investigated energy security's impact on economic growth across 74 countries from 2002 to 2013, using ten energy security indicators. Their findings, which underscore a positive correlation between energy security and economic growth, reveal that energy security fosters sustainable economic growth, while insecurity poses significant risks. Stavytskyy et al. (2018) introduced the New Energy Security Index (NESI) for 29 European countries from 1997 to 2016, finding a positive association between GDP growth and NESI, and a negative correlation with the Consumer Price Index (CPI). Fang et al. (2018) introduced the China's Sustainable Energy Security (CSES) index, analysing China's energy landscape from 2005 to 2015. Their findings highlighted dynamic trends, emphasising availability and developability as crucial factors, urging adaptive policy considerations. Huq et al. (2024) analysed China's transition to high-quality economic development (HQED) and its impact on energy insecurity (EIS), using provincial panel data from 2011 to 2017. They found that HQED mitigates EIS, whereas traditional economic growth exacerbates it. The study emphasised the importance of industrial structure upgrading, green innovation, and digital financial inclusion in reducing energy insecurity. Tugcu and Menegaki (2024) examined the nexus between renewable energy generation and energy security in G7 countries from 1980 to 2018, finding that renewable energy generation significantly reduces long-term energy security risks. Their study underscored the critical role of renewable energy in enhancing energy security, particularly amidst the ongoing energy crisis in Europe.

Extensive scholarly inquiry has explored the multifaceted dimensions of energy security and its implications for economic development. While previous studies have extensively examined the general dynamics of energy security, there remains a lack of comparative analysis focused on the differential economic impacts across these two groups of countries. Contemporary scholarly endeavours often circumscribe their scope to specific temporal and geographic parameters, thereby overlooking the diverse and complex energy security challenges encountered globally. While certain studies indirectly allude to energy security through proxy indicators, few undertake a comprehensive examination of the direct nexus between energy security and economic growth, encompassing critical dimensions such as availability, affordability, and environmental sustainability. This lacuna becomes particularly pronounced when considering the divergent challenges faced by energy exporters and importers. Comparative analyses are sparse, leaving unaddressed inquiries regarding how each group navigates energy security dynamics and their consequential economic impacts. To address these research gaps, this study endeavours to illuminate these critical areas. By systematically evaluating energy security risks across 20 major energy-exporting and importing countries utilising an extensive index, the study seeks to unravel the distinct energy landscapes characterising these countries. This pursuit aims to yield novel insights that can underpin policy initiatives tailored to fortify energy security frameworks and stimulate sustainable economic growth across diverse geopolitical contexts.

3. Data and Methodology

Standard economic theory emphasises capital and labour as key production factors, but the critical role of energy as a catalyst for productivity is often overlooked. Hence, the standard theory of growth does not consider account energy availability or prices (Ayres et al., 2013, p. 2). However, without energy, modern production becomes unsustainable, thus necessitating its inclusion in the production function. In this regard, in some studies, energy is included as a third production factor. However, these studies primarily focus on energy's role in physical consumption rather than its broader implications for economic dynamics. On the other hand, this study argues that if there is a problem in uninterrupted access to energy at an affordable price in production -that is, if the risk level of energy security increases- the productivity of labour and capital will also be negatively influenced. This study bridges this gap by integrating energy security – defined by availability, accessibility, affordability, and acceptability – into the production function, emphasising its critical impact on economic growth. By doing so, it explores how energy security risk affects economic growth, providing a nuanced comparison between energy-exporting and energy-importing countries. In this context, the study posits two primary hypotheses: increases in energy security risk negatively influence the economic growth of all countries, but this adverse effect is more pronounced for energy-exporting nations.

The dependent variable in this study is real GDP (Y), measured using the *rgdpe* series from the Penn World Table (2020), which represents expenditure-side real GDP at chained PPPs (in million 2017 US dollars). Capital stock (K) and labour input (L), the other independent variables used in the analysis, are also obtained from the Penn World Table (2020). Capital stock is measured using the *rnna* series, defined as capital stock at constant 2017 national prices (in million 2017 US dollars), while labour input is measured using the *emp* series, which reflects the number of persons engaged (in millions). The key explanatory variable, energy security (E), is quantified using the Energy Security Risk Index (ESRI) developed by the Global Energy Institute (2020). Unlike many studies that rely on single indicators or proxies, this composite index consolidates 29 structural, market-based, environmental, and geopolitical indicators that jointly reflect the multidimensional nature of energy security – namely availability, accessibility, affordability, and acceptability. These indicators include, among others, energy intensity, CO_2 emissions, crude oil price volatility, electricity prices, and fuel import dependence (For the variables utilised in the creation of the index and their detailed explanations, see Global Energy Institute 2018, pp. 71–75). This unified framework enables the ESRI to reflect both short-term vulnerabilities and long-term structural risks in a way that individual variables cannot, while its standardised construction ensures comparability across countries and over time. For these reasons, ESRI provides a more reliable and holistic assessment of energy security, rendering the inclusion of separate indicators unnecessary. All variables in the analysis, including Y, K, L, and E, were transformed into natural logarithms prior to estimation.

The composition of the sample and the length of the period are determined entirely by data availability. Specifically, the ESRI database is only published up to 2018, and this data consistently covers a limited set of countries between 1980 and 2018. Therefore, only countries with complete and consistent ESRI data for the full period were included, ensuring cross-country comparability, temporal consistency, and the integrity of the panel dataset. In this sense, the sample selection reflects a methodological constraint rather than a discretionary choice. Accordingly, the country selection followed a two-step procedure: first, the countries with the largest exports and imports of mineral fuels (HS-2 code 27) were identified; second, only those with complete ESRI data were retained. As a result, the empirical analysis covers 40 countries – 20 energy exporters and 20 energy importers – over the 1980–2018 period.

In this context, the empirical strategy – based on Eq. (1) – aims to assess the impact of energy security on economic growth using two panel datasets comprising 39 time periods (t = 1, 2, ..., 39) and 20 cross-sectional units (i = 1, 2, ..., 20). The panel models specified in Eq. (2) and (3) were estimated separately for energy-exporting and importing countries within the following methodological framework:

$$Y = f(K, L, E) \quad (1)$$

Panel 1: Energy exporter countries:

$$\ln Y_{i,t} = \alpha_0 + \alpha_1 \ln K_{i,t} + \alpha_2 \ln L_{i,t} + \alpha_3 \ln E_{i,t} + \varepsilon_{i,t} \quad (2)$$

Panel 2: Energy importer countries:

$$\ln Y_{i,t} = \beta_0 + \beta_1 \ln K_{i,t} + \beta_2 \ln L_{i,t} + \beta_3 \ln E_{i,t} + \upsilon_{i,t} \quad (3)$$

Preliminary Tests: Preliminary tests, including assessments of slope homogeneity and cross-sectional dependence, were conducted using second-generation panel techniques to determine the appropriate cointegration and estimation methods for the model. In this regard, the Pesaran and Yamagata (2008) Slope Homogeneity Test is applied to determine if the coefficients are homogeneous across the panel. While the null hypothesis of these tests is that the parameters are homogeneous, the alternative hypothesis is that the parameters are heterogeneous.

The LM_{BP} Test (Breusch and Pagan, 1980), the CD_{LM} Test (Pesaran 2004), the CD Test (Pesaran, 2004), and the LM_{adj} (Pesaran et al., 2008) is used for this purpose, evaluating whether there are significant cross-country interactions that could bias the results if left unaddressed. The null hypothesis of these tests is that there is no cross-sectional dependence, while the alternative hypothesis is that there is a cross-sectional dependence. Once these preliminary tests are conducted, unit root tests are applied to determine whether the variables are stationary – in other words, whether they tend to return to a long-term equilibrium after being affected by a shock. If the variables are not stationary, their levels change over time, potentially leading to misleading results. The CIPS test, developed by Pesaran (2007) and which is one of the second-generation unit root tests, is used to account for cross-sectional dependence when assessing the stationarity of the data. This test, which can be employed in conditions where there is both T>N and N>T, is computed by averaging of the CADF statistics computed for each cross-section. The null hypothesis of these tests is that the series is not stationary, while the alternative hypothesis is that the series is stationary.

Cointegration: Building upon the preliminary tests conducted in the study, the analysis proceeds with the application of two robust econometric techniques – Westerlund and Edgerton's (2008) cointegration test with structural breaks and Banerjee and Carrion-i-Silvestre (2017) CCE-based cointegration test – to examine the long-term relationship between energy security and economic growth across energy-exporting and importing countries. These methods address critical econometric challenges such as cross-sectional dependence, heterogeneity, and structural breaks, ensuring a reliable framework for global energy market analysis. Westerlund and Edgerton's (2008) test is based on a panel cointegration framework that accommodates structural breaks in both intercepts and slopes. By utilising a factor model to capture cross-sectional dependencies, the test offers robustness against heteroskedasticity and serial correlation. Its ability to detect unknown breakpoints, grounded in the Lagrange Multiplier principle, enables precise identification of long-term relationships, making it particularly well-suited for analysing global energy dynamics. On the other hand, Banerjee and Carrion-i-Silvestre (2017) extend Pesaran's (2006) Common Correlated Effects (CCE) approach to panel data, addressing cross-sectional dependence by incorporating cross-sectional averages. This method ensures consistent long-run parameter estimates, even in the presence of non-stationary common factors. The validity of this test is supported by Monte Carlo simulations, demonstrating its robustness across different cross-sectional dependence scenarios. The two-step process begins by estimating long-run coefficients using the PCCE estimator, followed by testing the residuals' stationarity with the Cross-sectional Augmented Dickey-Fuller (CADF) statistic. If the residuals are stationary, the null hypothesis of no cointegration is rejected, confirming the presence of a long-term equilibrium relationship. Together, these methods offer a robust framework to analyse energy security–growth dynamics under cross-sectional dependence and structural breaks.

Estimation Techniques: The long-term relationships are estimated using two methods that address cross-sectional dependence: the Common Correlated Effects Mean Group (CCE) estimator, proposed by Pesaran (2006), and the Augmented

Mean Group (AMG) estimator, suggested by Bond & Eberhardt (2009) and Eberhardt & Teal (2010). Both estimators are designed to account for cross-sectional dependence in panel data, but they differ in their approaches. The CCE estimator incorporates cross-sectional averages to capture unobserved common factors affecting all units in the panel, allowing for heterogeneity in slope coefficients and treating cross-sectional dependence in a non-parametric manner. This flexibility is particularly useful for modelling heterogeneous responses to common shocks, such as a global recession that impacts both energy-exporting and energy-importing countries. By capturing these shared factors, the CCE estimator provides a robust analysis of the relationship between energy security and economic growth. In contrast, the AMG estimator extends the standard Mean Group estimator by modelling common dynamic processes (or shocks) that affect all units. This method is especially well-suited for panels with strong common dynamic components, such as fluctuations in global energy prices or geopolitical risks. By modelling these common trends, the AMG estimator provides a more nuanced understanding of how energy security and economic growth are interlinked in different countries. Overall, CCE is more flexible for heterogeneous shocks, while AMG excels in panels with strong common dynamics.

4. Empirical Results

This section presents the empirical findings of the study, structured into subsections that correspond to the key stages of the analysis: preliminary tests to ensure the robustness of the analysis, cointegration tests to confirm the long-term relationships, and long-term coefficient estimates. The results are interpreted with reference to energy-exporting and energy-importing countries, emphasising comparative insights.

4.1 Pre-Estimation Tests

The cross-sectional dependence and slope homogeneity test results (Table 1) reveal significant interdependence and heterogeneity across both energy-exporting and energy-importing countries. This indicates that energy security shocks in one country can spill over to others, reflecting the interconnected nature of global energy markets. This regard, the findings necessitate to use second-generation econometric methods that account for these dynamics.

Table 1. Cross-Section Dependence and Slope Homogeneity Tests Results

Test	**lny**	**lnk**	**lnl**	**lne**	**Panel**
			Model 1: Energy-Exporting Countries		
LM (B&P, 1980)	419.34***	288.93***	269.72***	425.12***	7,265.80***
CD_{LM} (Pesaran 2004)	11.77***	5.08***	4.09***	12.06***	82.68***
CD (Pesaran 2004)	0.55	-1.02	-2.52***	-1.31*	53.54***
LM_{adj} (PUY, 2008)	1.13	55.65***	37.88***	8.87***	98.72***
Delta	6.75***	21.61***	9.31***	1.90**	34.26***
$Delta_{Adj}$	7.03***	22.51***	9.70***	1.98**	36.62***

Test	lny	lnk	lnl	lne	Panel
			Model 2: Energy-Importing Countries		
LM (B&P, 1980)	462.18***	445.60***	303.94***	415.93***	8,679.38***
CD_{LM} (Pesaran 2004)	13.96***	13.11***	5.85***	11.59***	104.94***
CD (Pesaran 2004)	-2.63***	1.39*	-1.35*	-3.01***	36.05***
LM_{adj} (PUY, 2008)	4.35***	31.88***	2.51***	25.94***	108.22***
Delta	8.90***	28.03***	13.95***	1.46*	41.88***
$Delta_{Adj}$	9.28***	29.21***	14.54***	1.52*	44.77***

Note: ***, **, and * denote significance at 1%, 5%, and 10% levels, respectively.
Source: Calculated by the authors.

On the other hand, Table 2 presents the results of the CIPS unit root tests, which confirm that the variables are non-stationary at level but become stationary after first differences. This finding strengthens the possibility that there may be a long-term relationship between the variables.

Table 2. CIPS Unit Root Test Results

Variables	Constant				Constant & Trend			
	Exporter		Importer		Exporter		Importer	
	Level	First Diff.	Level	First Diff.	Level	First Diff.	Level	First Diff.
lny	-1.55	-4.96***	-1.63	-3.89***	-2.12	-5.21***	-1.51	-4.25***
lnk	-1.45	-3.12***	-1.04	-2.17*	-1.59	-3.09***	-1.78	-2.90***
lnl	-1.29	-4.37***	-1.95	-3.79***	-2.10	-4.51***	-1.96	-4.33***
lne	-1.54	-5.29***	-1.89	-5.60***	-2.21	-5.34***	-1.89	-5.60***

Note: Lag selection tstat with maxlag (3), and model specification is trend model. Critical values for the panel unit root test are from Pesaran (2007). The critical values are -2.38 (1%), -2.20 (5%), and -2.11 (10%) for regressions with a constant, and -2.88 (1%), -2.72 (5%), and -2.63 (10%) for regressions including both a constant and a trend. ***, **, and * denote significance at 1%, 5%, and 10% levels, respectively.
Source: Calculated by the authors.

4.2 Cointegration Tests Results

The Westerlund and Edgerton (2008) and Banerjee and Carrion-i-Silvestre (2017) cointegration tests confirm long-term relationships between GDP and key variables, addressing cross-sectional dependence common in macroeconomic data. For a detailed analysis, the Westerlund and Edgerton (2008) test results (Table 3) highlight structural breaks in both energy-exporting and importing countries. Exporters exhibit cointegration under both the level shift and regime shift models, whereas importers do so only under the level shift model. Generally, energy-importing countries' growth is influenced by gradual adjustments in capital, labour, and energy security, as seen during the 2008 financial crisis, while energy-exporting countries experience both gradual adjustments and abrupt regime shifts, driven by geopolitical and economic events like wars and sanctions.

In this context, structural break dates derived from the Westerlund and Edgerton test offer valuable insights. For energy-exporting countries, the breaks align with major events: i) in the level shift model: 1985 (Algeria, Malaysia, Nigeria, Oman, and United Arab Emirates the global oil price collapse), 1990 (Iraq – the Gulf War), 1991 (Kuwait – Iraq's invasion of Kuwait), 1998 (Colombia – the global financial crisis in Asia and conflict with rebel groups), 2001 (Paraguay – political instability and external shocks), 2008 (Canada, Norway – the global financial crisis), 2010 (Indonesia, Saudi Arabia – fluctuating global oil prices and internal economic challenges), 2011 (Iran – sanctions and the Arab Spring), and 2016 (Venezuela – hyperinflation and political instability). ii) Regime shift analysis revises Qatar's break from 2002 to 1999, and Saudi Arabia's from 2010 to 1998. On the other hand, for energy-importing countries, significant break dates include financial crises and political shifts, such as 1985 (France, Italy, and Mexico – the 1980s Debt Crisis), 1989 (Poland – the fall of communism), 1990 (Türkiye – economic liberalisation and the regional impact of the Gulf War), 1996 (Pakistan – adjustment programs with the IMF), 1997 and 1999 (China, Korea, Thailand, and Singapore – the 1997 Asian Financial Crisis), 2005 (Spain – real estate boom), and 2008-2009 (United Kingdom, Germany, United States, India, Taiwan – the 2008 Global Financial Crisis). In this sense, energy-exporting countries' structural breaks are linked to energy-related events such as oil price shifts, wars, and sanctions, emphasising energy's critical role. Energy-importing countries' breaks are more connected to financial crises and broader economic changes, suggesting that energy security is more pressing for exporters, whose economies are more sensitive to energy sector disruptions. Incorporating as dummy variables these break dates into AMG and CCE estimators will refine coefficient estimates, providing a clearer picture of how energy security, capital, and labour shape GDP across both country groups.

Table 3. Results of Westerlund and Edgerton (2008) Cointegration Test with Structural Breaks

Model	Test	**Model 1** (Exporting Countries)	**Model 2** (Importing Countries)
None	PD tau	0.199	-3.886***
	PD Phi	1.223	-1.746**
Level Shift	PD tau	-2.289**	-2.221**
	PD Phi	-1.666**	-1.885**
Regime Shift	PD tau	-1.719**	1.517
	PD Phi	-1.426*	-0.343

				Structural breaks periods	
Countries	**Level Shift**	**Regime Shift**	**Countries**	**Level Shift**	**Regime Shift**
Algeria	1985	1985	Austria	2000	1984
Australia	1981	1981	Belgium	1987	1999
Bahrain	1984	1984	China	1997	1983
Canada	2008	2008	France	1985	1985
Colombia	1998	1998	Germany	2008	1990
Ecuador	1992	1992	India	2009	1981
Indonesia	2010	2010	Italy	1985	1983
Iran	2011	2011	Japan	1981	1984
Iraq	1990	1990	Korea	1997	1997
Kuwait	1991	1991	Mexico	1985	1985
Malaysia	1985	1985	Pakistan	1996	1996

Model	Test	Model 1 (Exporting Countries)		Model 2 (Importing Countries)	
Nigeria	1985	1985	Philippines	1984	1984
Norway	2008	2008	Poland	1989	1989
Oman	1985	1985	Singapore	1999	1999
Paraguay	2001	2001	Spain	2005	1982
Qatar	2002	1999	Taiwan	2009	2009
Saudi Arabia	2010	1998	Thailand	1997	1997
Trinidad&Tobago	2002	2002	Türkiye	1990	1993
UEA	1985	1985	UK	2008	2008
Venezuela	2016	2016	United States	2008	1983

Note: ***, **, and * denote significance at 1%, 5%, and 10% levels, respectively.

Source: Calculated by the authors.

In addition to the Westerlund and Edgerton (2008) cointegration test, the panel results of CCE-based cointegration test by Banerjee and Carrion-i-Silvestre (2017) confirms that both energy-exporting and energy-importing countries exhibit long-term relationships among energy security risks, capital, labour, and GDP (Table 4). However, notable disparities emerge upon examining the cross-sectional results. There is a cointegration relationship in all countries except Taiwan, with energy-importing countries showing slightly fewer significant results, particularly in the non-deterministic specification. This suggests that while long-term relationships are present in both groups, their consistency and strength vary. Energy-exporting countries consistently exhibit a higher frequency of significant cointegration, especially in trend models, highlighting the stronger influence of energy revenues and price fluctuations on their economies. In contrast, energy-importing countries display more variability, likely due to diverse economic structures and external factors such as trade policies and technological advancements. The number of significant cointegration results is notably higher for exporting countries, indicating their more consistent long-term relationships.

Table 4. Results of Banerjee and Carrion-i-Silvestre's (2017) Cointegration Test

Countries	Non-det.	Const.	Trend	Countries	Non-det.	Const.	Trend
	Model 1 (Exporting Countries)				**Model 2** (Importing Countries)		
Algeria	-3.15**	-2.75**	-2.97**	Austria	-2.93**	-2.50**	-3.28**
Australia	-3.75**	-4.11**	-3.21**	Belgium	-1.77	-4.32**	-3.42**
Bahrain	-0.32	-0.77	-2.72**	China	-1.71	-2.67**	-2.57**
Canada	-3.45**	-3.15**	-2.84**	France	-1.88	-3.29**	-2.70**
Colombia	-2.38**	-3.56**	-3.59**	Germany	-3.28**	-2.69**	-2.99**
Ecuador	-3.03**	-3.08**	-3.06**	India	-3.07**	-3.52**	-3.20**
Indonesia	-2.53**	-2.56**	-2.40**	Italy	-1.17	-4.56**	-3.89**
Iran	0.41	-2.60**	-3.66**	Japan	-1.34	-2.43**	-4.48**
Iraq	-2.96**	-2.85**	-2.99**	Korea	-3.31**	-2.93**	-4.64**
Kuwait	-4.04**	-3.88**	-5.09**	Mexico	-3.35**	-2.39**	-3.49**
Malaysia	-2.95**	-3.35**	-3.99**	Pakistan	-1.84	-1.01	-2.27*
Nigeria	-1.27	-2.22*	-2.94**	Philippines	-3.58**	-4.53**	-4.97**
Norway	-3.43**	-2.61**	-3.27**	Poland	-2.63**	-2.21	-4.36**
Oman	-3.10**	-2.66**	-4.39**	Singapore	-1.60	-1.71	-5.19**
Paraguay	-4.86**	-5.88**	-6.47**	Spain	-3.10**	-2.76**	-2.00

Countries	Non-det.	Const.	Trend	Countries	Non-det.	Const.	Trend
	Model 1 (Exporting Countries)				**Model 2** (Importing Countries)		
Qatar	-4.04**	-3.53**	-3.54**	Taiwan	-1.52	-2.19	-2.10
S.Arabia	-1.25	-1.70	-3.52**	Thailand	-3.45**	-2.43**	-3.78**
T&T	-2.43**	-2.90**	-1.96	Türkiye	-0.90	-2.69**	-2.78**
UAE	-2.76**	-2.70**	-3.59**	UK	-4.23**	-1.93	-0.48
Venezuela	-2.71**	-1.70	-1.06	US	-2.07	-3.40**	-4.97**
Panel	-2.70**	-2.93**	-3.36**	Panel	-2.44**	-2.81**	-3.38**

Note: **, and * denote significance at 5%, and 10% levels. T&T (Trinidad and Tobago), UAE (United Arab Emirates), UK (United Kingdom), US (United States).

Source: Calculated by the authors.

4.3 Long-Run Estimation Results

The AMG and CCE estimators reveal the long-term effects of energy security risk on GDP, along with capital and labour variables, by integrating structural breaks obtained from the Westerlund and Edgerton (2008) test into the model as dummy variables to enhance result precision. According to the findings, the negative impact of energy security risk on GDP is more significant in energy-exporting countries (Table 5), where a 1% increase in risk leads to a 0.461% (AMG) to 0.381% (CCE) decrease in GDP. In comparison, energy-importing countries (Table 6) experience a smaller, but substantial reduction of 0.240% (AMG) and 0.163% (CCE). These results underline the asymmetrical exposure of exporters, whose economies are tightly bound to volatile energy revenues. In contrast, it can be argued that energy-importing countries demonstrate greater resilience by utilising a mix of energy sources, such as solar and wind power, and diversifying the number of countries from which they import energy.

Cross-sectional results reveal a stark asymmetry in energy security risk's impact on energy-exporting and importing countries. In this context, energy-exporting countries demonstrates a higher incidence of severe negative AMG or CCE coefficients (13 countries worse than -0.5 vs. 7 importers), underscoring their heightened vulnerability to energy market disruptions. Notably, Nigeria (-2.167), Iraq (-1.23), Oman (-1.46), and Saudi Arabia (-0.89) demonstrate the steepest declines, reflecting their heavy reliance on energy revenues. In contrast, only 7 importers exceed this threshold, with the Philippines (-1.269 – the only country with a coefficient worse than -1%) most affected. While Japan (-0.79), South Korea (-0.64), and Italy (-0.5) also demonstrate sizable negative impacts, many importers report milder, positive, or statistically insignificant coefficients – suggesting that diversification strategies and policy frameworks have partially insulated them from external shocks. Venezuela's erratic and often implausible coefficients likely stem from its severe political and economic instability, undermining estimate reliability. Collectively, these patterns highlight the structural fragility of exporters, rooted in revenue concentration, versus the relatively adaptive capacity of many importers.

Table 5. Long-Term Coefficient Prediction Results (Energy-Exporting Countries)

Country	AMG					CCE				
	K	L	E	TB	c	K	L	E	TB	c
Algeria	0.50**	0.10	-0.50*	-0.07	9.18***	-0.21	1.03**	-0.45	-0.02	-9.00
Australia	1.12***	0.16	-0.41***	-0.01	-0.92	2.95***	0.05	-0.11	0.00	-25.66***
Bahrain	0.30*	0.95***	-0.88***	-0.08*	14.06***	-0.52	0.87***	-0.94***	0.05	-2.78
Canada	0.44***	1.13***	0.07	-0.11***	3.76**	1.74***	1.04***	0.18	-0.06**	-15.98**
Colombia	1.58***	-0.64***	0.06	-0.20***	-7.72***	1.42***	-0.41	-0.02	-0.20***	-16.04***
Ecuador	1.69***	-0.32***	-0.35***	-0.06**	-7.97***	2.10***	-0.41	-0.38**	-0.06**	-8.19**
Indonesia	0.49***	0.49	-0.62***	0.44***	8.24***	0.14	0.84	-0.68***	0.34***	3.14
Iran	0.27	2.00***	0.28**	-0.19**	1.55	-0.34	1.95***	0.28	-0.20	6.58
Iraq	-0.48**	2.41***	-0.94***	-0.29*	21.42***	-2.01***	0.55	-1.23***	0.16	-92.20***
Kuwait	1.30***	-1.16***	0.29	0.00	-6.45	0.62	-1.02	0.24	-0.08	-14.51
Malaysia	0.54***	0.91***	-0.45***	-0.08***	6.47***	0.59***	-0.09	-0.80***	-0.14***	8.31**
Nigeria	-3.41	3.28***	-2.17***	-0.22	64.98**	-2.38	0.13	-1.57***	-0.01	-93.47*
Norway	0.93***	1.03***	-0.05	-0.13***	-1.14	0.65	1.20***	0.12	-0.11***	10.39
Oman	1.53***	-0.01	-1.46***	0.01	2.32	0.66	-0.04	-0.93*	0.11	-5.92
Paraguay	-0.18	2.23***	-0.78***	0.01	16.43***	-0.20	0.29	-0.40**	0.03	6.51
Qatar	0.75***	0.12	-0.15	0.20**	2.95	0.77***	-0.22*	-0.55***	0.05	-6.13
S.Arabia	0.45***	0.65***	-0.89***	0.24***	12.01***	2.43***	0.90***	-0.68***	0.08	29.91***
T&Tobago	0.88***	-0.15	-1.05***	0.02	8.73***	1.09***	0.12	-0.46*	0.07	4.65
UEA	1.06***	-0.06	-0.54***	-0.10	1.43	-1.06	-0.47**	-0.09	-0.19*	28.70***
Venezuela	1.58	-0.50	1.23	-2.55***	-13.55	14.04***	-5.57***	0.91	-1.12***	93.47***
Panel	0.79***	0.51*	-0.46***	-0.06*	3.73*	0.48	0.32*	-0.38***	-0.02	-3.68

Notes: ***, **, and * denote significance at 1%, 5%, and 10% levels. The AMG estimator was employed following the methodology proposed by Bond and Eberhardt (2009) and Eberhardt and Teal (2010), while the CCE estimator was applied as outlined by Pesaran (2006). Both estimators compute coefficients as averages across groups using outlier-robust means (rreg). The analysis includes 780 observations across 20 groups, with a minimum, average, and maximum of 39 observations per group. For AMG, the Wald chi^2 statistic is 43.05 ($p = 0.0000$), and RMSE is 0.1263. For CCE, the Wald chi^2 statistic is 13.46 ($p = 0.0093$), and RMSE is 0.0943. RMSE values are derived from group-specific residuals and are unaffected by robustness adjustments.

Source: Calculated by the authors.

Table 6. Long-Term Coefficient Prediction Results (Energy-Importing Countries)

Country	AMG					CCE				
	K	L	E	TB	c	K	L	E	TB	c
Austria	0.90***	0.90***	-0.34***	-0.02**	0.68	1.23***	0.93***	-0.42***	-0.03*	-5.31**
Belgium	0.32***	1.89***	-0.40***	-0.02	8.29***	1.10*	1.64***	0.07	0.03	0.95
China	0.52***	0.66***	0.14	0.00	1.69	0.39*	1.78**	-0.31*	-0.04	-11.48**
France	0.12	2.29***	-0.19***	0.00	6.34***	-0.45	2.09***	-0.13	-0.02	10.06***
Germany	0.70***	0.91***	-0.45***	0.06*	3.02	1.44	0.98***	-0.04	0.04	-8.22
India	0.78***	0.15	0.06	-0.01	0.67	0.93***	0.31	-0.05	-0.04	-5.84***
Italy	0.56***	0.64**	-0.50***	-0.02	6.77***	-0.06	0.51	0.53*	-0.04	16.18***
Japan	0.35***	0.24	-0.79***	0.00	13.81***	0.73***	-0.16	0.04	0.02	7.75***
Korea	0.93***	-0.11	-0.62***	-0.11***	4.57***	1.41***	0.37	-0.64**	-0.11***	7.14***
Mexico	1.15***	-0.40	-0.03	-0.15***	-2.10	0.75	0.29	-0.25*	-0.10*	-4.90
Pakistan	0.84***	0.61***	-0.08	-0.13***	-0.14	1.56***	0.13	-0.56***	-0.03	-3.73
Philippines	0.39**	0.98***	-1.27***	-0.15**	12.99***	1.28***	-0.10	-0.95***	-0.05	10.12**
Poland	0.88***	0.84***	-0.43***	-0.03	1.62	-0.08	0.54**	0.55**	-0.16***	-3.07
Singapore	0.53***	0.67**	-0.31*	0.16***	6.46**	-0.39	0.21	-0.09	0.16***	-19.53**
Spain	0.50***	0.85***	-0.26***	-0.07***	5.38***	-0.40*	1.08***	-0.12	0.02	5.88***
Taiwan	0.58***	0.80***	-0.50***	-0.01	6.70***	0.73***	1.13***	-0.15	0.01	8.45***
Thailand	0.65***	0.52***	0.26**	-0.23***	0.01	0.23	0.75***	-0.09	-0.16***	-11.95***
Türkiye	0.34***	0.88***	0.30	-0.08*	3.96**	0.64**	0.94***	-0.02	0.03	4.22
U. Kingdom	0.79***	0.83***	0.07	-0.11***	-1.44	-0.14	1.01***	-0.52***	-0.07**	-3.67
USA	0.78***	0.84***	-0.01	-0.03**	-1.42	0.98***	1.15***	-0.13	-0.03**	-7.32***
Panel	0.63***	0.72***	-0.24***	-0.05**	3.61***	0.60***	0.75***	-0.16**	-0.03*	-0.69

Notes: ***, **, and * denote significance at 1%, 5%, and 10% levels. The AMG estimator was employed following the methodology proposed by Bond and Eberhardt (2009) and Eberhardt and Teal (2010), while the CCE estimator was applied as outlined by Pesaran (2006). Both estimators compute coefficients as averages across groups using outlier-robust means (rreg). The analysis includes 780 observations across 20 groups, with a minimum, average, and maximum of 39 observations per group. For AMG, the Wald chi^2 statistic is 282.33 (p-value = 0.0000), and RMSE is 0.0368. For CCE, the Wald chi^2 statistic is 48.60 (p-value = 0.0000), and RMSE is 0.0258. RMSE values are derived from group-specific residuals and are unaffected by robustness adjustments.

Source: Calculated by the authors.

Finally, although the primary focus of this study lies in examining how changes in energy security risk affect economic growth, the enduring centrality of capital (K) and labour (L) as the fundamental drivers of growth across global economies necessitates a parallel evaluation of their effects. Despite structural shifts, capital and labour remain key growth drivers in both exporter and importer contexts, warranting focused analysis. In this context, across panels, capital and labour consistently exhibit positive coefficients, reaffirming their foundational role in economic development, while also revealing distinct across panels asymmetries in their magnitude and significance. Accordingly, in energy-exporting countries, the AMG model highlights a stronger influence of capital (0.787) compared to labour (0.511), while in energy-importing countries, labour exerts a more pronounced effect on GDP (0.720 AMG, 0.754 CCE) relative to capital (0.631 AMG). These findings suggest that energy-exporting economies rely more on capital-intensive growth, whereas energy-importing economies benefit significantly from workforce-driven economic activity. In energy-exporting countries, robust capital accumulation emerges as a critical driver of GDP, particularly in countries such as Norway, Saudi Arabia, and the United Arab Emirates, where coefficients consistently exceed 1% in either AMG or CCE estimators. However, the statistically insignificant capital coefficient in the CCE model for exporters points to potential model sensitivities or structural variations in capital's productivity. Similarly, labour plays a significant role in these economies, with countries like Nigeria, Iraq, and Algeria exhibiting strong positive labour coefficients. However, exceptions such as Ecuador and Colombia, where labour indicates negative coefficients, likely reflect structural inefficiencies or mismatches in labour-market dynamics. In contrast, for energy-importing countries, both capital and labour maintain their critical roles. Countries like Germany, Belgium, and Pakistan demonstrate particularly strong positive capital effects, while labour coefficients are notably significant in the United States, the United Kingdom, and China, highlighting the importance of workforce efficiency and human capital development in these economies. Negative labour coefficients are statistically insignificant and rare among importers, suggesting relatively stable labour market conditions compared to exporters.

The finding that capital exerts a stronger influence on economic growth in energy-exporting countries than in importers warrants contextual interpretation rather than being seen as paradoxical. Energy-exporting economies are typically shaped by capital-intensive sectors – such as oil and gas extraction, refining, and export infrastructure – where sustained output depends heavily on physical investment. Revenues from these sectors often finance further infrastructure and industrial expansion, reinforcing capital’s centrality. Moreover, weak institutional structures and labour market inefficiencies in many exporter economies limit the productivity of labour, increasing dependence on capital for growth. In contrast, some energy-importing countries – especially those with diversified and mature economies – may experience diminishing marginal returns to capital and rely more on innovation and human capital to sustain growth. Additionally, heightened energy security risks in exporting countries – through price volatility and geopolitical exposure – intensify the need for capital-driven stabilisation strategies. Collectively, these structural and contextual factors explain why capital plays a more prominent role in the growth dynamics of energy-exporting economies.

5. Conclusions

This study, which extends the production function by adding the energy security risk variable, empirically proves that rising energy security risks adversely affect economic growth in both energy-exporting and importing countries, albeit with differing intensities. Based on the results obtained, it can be argued that energy-exporting economies, heavily reliant on volatile hydrocarbon revenues, exhibit greater macroeconomic fragility to increases in energy security risk levels, whereas energy-importing economies, though vulnerable, benefit from strategic flexibility through diversification and resilience mechanisms. The core of this asymmetry lies in structural dependence. Exporters' fiscal balances are tightly coupled with global energy prices, making them highly susceptible to external shocks – be it price volatility, geopolitical tensions, or sanctions. Such reliance amplifies exposure to boom-bust cycles and Dutch Disease effects, where non-energy sectors remain underdeveloped. Supporting this case, structural breaks identified in the Westerlund and Edgerton (2008) test align closely with major oil price shocks, regional conflicts, and sanctions, underscoring the direct link between energy security and macroeconomic stability. In contrast, energy-importing countries, though burdened by high import costs, are relatively less exposed to geopolitical disruptions tied to production. Their vulnerability arises more from supply reliability and price spikes. Nevertheless, these countries often deploy proactive tools – such as renewable energy investments, efficiency improvements, and diversified sourcing – that buffer their economies and reduce long-term exposure to energy insecurity.

Geopolitical exposure further widens this divide. Exporters often operate in politically unstable regions, where conflicts, sanctions, or embargoes disrupt production and trade, directly impairing economic performance. Conversely, importers face such risks indirectly through global price transmissions. These distinct threat profiles necessitate differentiated policy responses: while exporters must reduce overdependence through structural transformation, importers should prioritise energy security via technological innovation and strategic reserves.

The structural breaks identified by Westerlund and Edgerton's (2008) test reflect the distinct economic structures of the two country groups: exporters' breaks often align with events that heighten energy security risks, such as oil price crashes, internal and external conflicts, and sanctions, highlighting their direct vulnerability to these factors. In contrast, importers' breaks correlate with broader macroeconomic crises rather than solely energy security risks. Therefore, while multiple policy strategies can enhance energy security, the urgency and effectiveness of these measures depend on country-specific circumstances. For energy-exporting countries, the immediate priority should be economic diversification to reduce reliance on volatile energy revenues. In contrast, energy-importing countries should focus on accelerating the transition to renewable energy sources and improving energy efficiency to minimise external dependencies. These findings call for targeted policy strategies aligned with each group's specific vulnerabilities and institutional capacities. Energy-exporting countries should prioritise economic diversification by investing in manufacturing, agriculture, and services, which can enhance resilience against price fluctuations. Strategic capital allocation is also essential, with energy revenues redirected towards infrastructure, technological innovation, and renewable energy projects to mitigate long-term vulnerabilities and align with global sustainability goals. Additionally, expanding renewable energy capacity and investing in energy storage technologies can stabilise domestic markets and reduce exposure to external shocks. On the other hand, for energy-importing countries, enhancing energy security requires a focus on supply diversification and sustainability. Expanding investments in renewable energy sources such as solar, wind, and hydropower, alongside diversifying import routes through regional cooperation, can strengthen resilience against supply disruptions. Infrastructure development is also crucial, as strengthening transport and storage capabilities can improve energy accessibility and reduce vulnerability to supply chain risks. Moreover, implementing energy efficiency policies across industries and households can lower overall energy demand, reducing exposure to security challenges.

Beyond these specific strategies, both energy-exporting and importing countries must adopt cross-cutting approaches to enhance energy security. Establishing comprehensive national energy security frameworks that integrate infrastructure investment, renewable energy adoption, and emergency preparedness measures will be crucial for long-term stability. Strengthening international cooperation in energy markets, including cross-border energy trade, technology transfer, and coordinated crisis response, can further enhance market stability and resilience on a global scale.

The observed differences between these two groups have far-reaching policy implications beyond this study's scope. In today's interconnected global energy market, energy-exporting countries' vulnerabilities underscore the urgent need for diversification strategies – both nationally and for global supply stability. For energy-importing countries, mitigating energy security risks through infrastructure investments and renewable energy integration is vital for national and global resilience. As climate change and geopolitical tensions reshape the energy landscape, nations must adopt adaptive strategies that align energy security needs with broader international sustainability goals. These insights offer valuable guidance for policymakers and international organisations seeking to foster collaboration in energy security. By addressing the distinct vulnerabilities of both energy-exporting and importing countries, a coordinated global response promoting resilient energy systems and sustainable economic growth amid increasing uncertainty can be laid.

While empirically robust, this study faces limitations primarily rooted in data availability. The temporal and country coverage are constrained by the lack of comprehensive, regularly updated, and internationally comparable energy security indices. In particular, the widely ESRI offers data only until 2018 and for a limited set of countries, impeding the analysis of recent developments such as the COVID-19 pandemic or the Russia–Ukraine conflict. This reflects a broader gap in the literature: the absence of open-access, multidimensional indices limits timely empirical inquiry and weakens the policy relevance of findings. Addressing this data deficiency is essential not only for advancing empirical energy security research but also for equipping policymakers with accurate, forward-looking insights in an increasingly volatile global energy landscape.

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