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Do Geopolitical Risks and Migration Hinder or Stimulate the Renewable Energy Transition? A Wavelet-Based Analysis on the Five Largest Carbon Emitter Countries

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ABSTRACT

This study analyzes the effects of net migration, geopolitical risk, and economic growth on renewable energy supply in the five largest carbon-emitting countries— the United States, China, India, Japan, and Germany—between 1990 and 2022. Using multi-scale and quantile-based methods, it examines whether these factors hinder or promote the energy transition. Renewable energy supply reflects a country's clean energy production capacity. Wavelet Quantile Correlation and Wavelet Quantile Regression techniques capture time-frequency interactions and quantile-based differences. Findings show migration boosts renewable energy adoption in migration-receiving countries like the U.S. and Germany but has weaker short-term effects in migration-sending nations like India and China. Geopolitical risks hinder adoption initially, especially in energy-dependent countries, but strong domestic policies in Germany and the U.S. mitigate these risks. Economic growth supports renewable energy in China and Germany but increases fossil fuel reliance in the U.S. and India initially. These results highlight the need for long-term, strategic policies to enhance energy security and sustainability.

Keywords: Migration, Geopolitical Risk, Economic Growth, Renewable Energy Transition, Wavelet Analysis
JEL Classifications: F22, F50, O47, Q42, Q48, C63

1. INTRODUCTION

The transition from fossil fuels to renewable energy is crucial for sustainability and climate change mitigation, shaped by policy mechanisms (Meckling, 2018). Countries design renewable policies based on economic, environmental, and social contexts (Simbolon and Simbolon, 2024) but face obstacles like fossil fuel resistance and political challenges (Stokes and Breetz, 2018; Gawel et al., 2017). Social factors such as migration, demographic shifts, and urbanization influence renewable transitions. Migration affects energy demand, infrastructure, and labor markets, shaping policy effectiveness. Industrialization, trade, and migration create complex interactions in energy use and carbon emissions (Çelik et al., 2023; Torasa et al., 2020; Wei et al., 2016; Peters et al., 2011; Yeboah, 2016; Adams, 2011). In China, rural-to-urban migration has increased fossil fuel reliance (Zhang et al., 2016; Wang et al., 2022c) while also playing a role in climate adaptation (Grecequet et al., 2017; Gray and Bilsborrow, 2013; Black et al., 2011; Benveniste et al., 2020).

Geopolitical factors shape renewable energy policies through energy security, trade relations, and regional instability. Migration during crises impacts energy consumption through demographic shifts and labor fluctuations. Sanctions may limit energy access, increasing security risks, while effective policies mitigate threats (Wen et al., 2020). Migration, driven by geopolitical tensions and environmental degradation, reshapes energy demand (Bexheti, 2024; Vinogradova et al., 2015) and can destabilize local markets (Vinogradova et al., 2015). Security concerns necessitate stricter border controls and influence urban energy use (Lalić, 2019; Ullah et al., 2020; Lee et al., 2023; Xheladini, 2016). Climate-driven migration further demands new energy infrastructure (Germond and Ha, 2018; Xheladini, 2016). Geopolitical risks and migration significantly influence renewable transitions. While renewables can reduce geopolitical pressures (Cai and Wu, 2021), they also enhance national energy security (Yang et al., 2024). Geopolitical tensions linked to climate change may ease as renewables expand (O'Sullivan et al., 2017; Yang et al., 2024). Criekemans (2023) highlights the role of geography in shaping transitions, while migration has bidirectional effects on energy security (Paravantis and Kontoulis, 2020). However, conflicts and uncertainties can delay investments and complicate net-zero goals (Agaton, 2022; Acheampong et al., 2023), pushing countries to reassess energy security strategies (Alsagr and Almazor, 2021) and fueling geopolitical rivalries (Hache, 2018; Häfner and Tagliapietra, 2020).

The intersection of geopolitical risks and renewable transitions is crucial for energy security. Migration can accelerate shifts, influencing policies and investments (O'Sullivan et al., 2017; Hache, 2018; Paravantis and Kontoulis, 2020). The EU Green Deal and hydrogen economy exemplify strategies for ecological and economic recovery (Peña-Ramos et al., 2021; Scita et al., 2020). While the literature extensively examines renewable transitions and geopolitical risks (Cai and Wu, 2021; Yang et al., 2024; O'Sullivan et al., 2017), the role of migration remains understudied. This study fills this gap by analyzing migration, geopolitical risk, and economic growth in the five highest carbon-emitting countries—the U.S., China, India, Japan, and Germany—between 1990 and 2022. Using multi-scale and quantile-based methods, it assesses how these factors influence renewable adoption, integrating social and political dimensions. The study employs wavelet quantile regression (WQR) and wavelet quantile correlation (WQC) on annual data from 1990 to 2022. Unlike traditional quantile regression, WQR captures interactions across quantiles and time, identifying both linear and nonlinear patterns. This is the first study to apply wavelet-based quantile analysis to migration, geopolitical risk, and renewable transitions, addressing a key gap in the literature.

Following a theoretical and empirical review, the study details datasets, model structure, and econometric methods. The findings are then presented, followed by policy implications and recommendations for future research.

2. LITERATURE REVIEW

2.1. The Role of Renewable Energy Transition in Sustainability and Global Energy Governance

The transition from fossil fuels to renewable energy plays a crucial role in sustainability and combating climate change. This transformation is driven by policy mechanisms shaping global energy governance, yet it faces significant challenges such as resistance from entrenched fossil fuel interests and the necessity of strong political support. While the renewable energy transition is often framed as a technological shift, it also requires a comprehensive approach that balances economic growth and ecological sustainability. However, this transition is not solely influenced by energy policies and technological advancements; social factors such as migration, demographic changes, and geopolitical risks also play a critical role. Migration, in particular, affects energy consumption, infrastructure planning, and labor markets, thereby shaping the effectiveness of renewable energy policies.

2.2. Social Factors: Migration and its Economic and Environmental Impacts

Economic theories on migration have evolved over time, spanning a broad theoretical spectrum. Neoclassical macroeconomic theories argue that individuals migrate in pursuit of higher wages as part of economic development (Harris and Todaro, 1970), while microeconomic approaches emphasize migration as a rational cost-benefit decision (Bauer and Zimmerman, 1998). Sociological perspectives highlight that migration is influenced not only by wage differentials but also by push factors such as natural disasters and conflicts, as well as pull factors like improved living standards (De Haas, 2010). The new economics of migration, meanwhile, views migration as a family-based decision-making process (Stark and Bloom, 1985).

Piore's (2018) dual labor market theory suggests that developed countries rely on migrant labor to meet the demand for low-wage jobs (Gheasi and Nijkamp, 2017), while migration flows are also shaped by postcolonial ties, language, and cultural similarities (Tranos et al., 2015). Established migrant networks further influence return migration and the movement of family members (Massey et al., 1993). Migration systems theory posits that migration flows become stable structures over time, emerging as a natural outcome of cross-border exchanges in goods, capital, people, services, and information (Boyd, 1989; Fawcett, 1989). Additionally, Castles (2010), Portes (2010), and Faist (2010) argue that migration is intertwined with social and cultural transformations beyond economic factors.

Regarding its socio-economic effects, migration generally has neutral or positive impacts on labor markets, regional development, and spatial distributions (Nijkamp et al., 2011). Migrants contribute to economic development by increasing domestic consumption in their home countries through remittances, supporting local investments, and enhancing education levels (Page and Plaza, 2006). Concentrated in urban areas and ethnic settlements, migrants also reduce trade costs, facilitating international trade and foreign direct investment (FDI) (Edin et al., 2003; Gould, 1994; Genc et al., 2012). Furthermore, selective migration policies in developed countries aim to attract highly skilled migrants, reinforcing global capital flows (Docquier and Marfouk, 2005).

Environmental studies on migration use panel data regression models to examine its impact on emissions (Rafiq et al., 2017; Zhang et al., 2016; Zhou et al., 2015). Ahmad et al. (2021) found that rural-to-urban migration fosters sustainable development, whereas Dedeoğlu et al. (2021) argued that migration worsens environmental pollution. Similarly, Bu et al. (2022) linked population migration to increased energy consumption and carbon emissions, while Gao et al. (2021; 2022) emphasized that interregional migration intensifies carbon flows. However, as most studies rely on the "net migration rate" variable, they may not fully capture migration's impact on energy consumption (Qi and Li, 2020; Long et al., 2021). Regression and energy modeling approaches help predict migration's effect on energy use, supporting informed policymaking (Bu et al., 2022; Hu et al., 2019; Wei, 2012).

2.3. Economic Factors: Growth, Energy Consumption, and Renewable Energy Investments

Economic growth plays a key role in increasing energy production, leading to higher energy consumption as economic activity expands. Given the importance of renewable energy for sustainable development, numerous studies have examined its relationship with gross domestic product. Research by Saidi and Omri (2020), Dogan et al. (2020), Wang and Wang (2020), and Shahbaz et al. (2020) found a significant positive relationship between renewable energy consumption and GDP in high-energy-consuming economies, indicating that higher renewable energy use supports economic growth.

Similarly, Ivanovski et al. (2021) reported positive results for both OECD and non-OECD countries, while Gyimah et al. (2022) found that renewable energy consumption had a direct and significant impact on Ghana's GDP between 1990 and 2015. Examining European countries, Dogan et al. (2023) conducted a panel data analysis covering 1995-2019 and found that GDP positively influences renewable energy consumption. A study by Hieu and Mai (2023) on developing economies also confirmed this positive relationship, with similar findings for Asian economies reported by Chen et al. (2022). However, Wang and Lee (2022) noted that this relationship varies across China's provinces.

2.4. Geopolitical Risks and Renewable Energy Transition

In today's global landscape, understanding the impact of geopolitical risks (GPR) on the energy transition is increasingly crucial. Recent studies have explored the complex relationship between GPR and the shift toward renewable energy, highlighting its role in shaping investments and consumption patterns. Flouros et al. (2022) found that GPR significantly influences renewable energy consumption across 171 economies. In the U.S., Sarker et al. (2022) reported that GPR affects renewable energy prices, while Ghosh (2022) emphasized its role in clean energy investments during the pandemic. Dutta and Dutta (2022) noted that price fluctuations heightened geopolitical risks, prompting a shift toward renewables. Sweidan (2021) observed positive effects of GPR on renewable energy consumption in the U.S., with Alsagr and van Hemmen (2021) reporting similar impacts in developing markets.

Cai and Wu (2021) identified a reinforcing relationship between GPR and renewable energy consumption, while Sohag et al. (2022) highlighted its positive spillover effects through green bond investments. Zhang et al. (2023b) found that GPR influences renewable energy consumption volatility more than clean energy. Analyzing U.S. data from 1985 to 2021, Zhang et al. (2023a) concluded that while economic growth and renewable electricity generation support the energy transition, GPR has an insignificant effect. Wang et al. (2023), using data from 39 countries (2003-2019), found that GPR affects energy consumption and production transitions, with variations by region and economic level. Liu et al. (2023) demonstrated that GPR has a bidirectional impact: Rising risks can increase traditional energy costs and encourage renewable investments but may also reduce investor confidence, slowing the transition. Meanwhile, renewable energy development plays a key role in mitigating geopolitical risks. These findings underscore the need for policies that support renewable energy projects to enhance energy security and accelerate the transition.

2.5. Literature Gap: The Role of International Migration in the Energy Transition

While existing research explores the complex and context-dependent factors shaping the transition from fossil fuels to renewable energy, it largely overlooks the role of international migration. Economic growth provides financial resources for renewable energy investments but can also increase fossil fuel dependence due to rising energy demand. Migration dynamics reshape local energy consumption patterns in both internal and international contexts, indirectly influencing renewable energy investments. Additionally, geopolitical risks introduce uncertainties into the energy transition process.

Heightened geopolitical uncertainty may push countries to invest in domestic renewable energy for energy independence but can also disrupt supply chains and delay policy implementation. Migration increases energy demand in housing, commercial, and transportation sectors, expanding the overall energy footprint (Liu, 2023; Han et al., 2013). Moreover, advanced computing strategies, such as dynamic virtual machine consolidation in cloud computing, offer insights into improving energy efficiency amid population movements (Buchbinder et al., 2011; Dhanoa and Khurmi, 2015; Wang et al., 2022). While numerous studies focus on internal migration (Komatsu et al., 2013; Long et al., 2022; Shi et al., 2023; Acuner and Kayalica, 2018), research on the link between international migration and energy consumption remains scarce. This study fills this gap by integrating international migration into the energy transition analysis. By identifying structural differences and interaction dynamics across countries, it enhances the effectiveness and adaptability of energy policies, offering a strategic roadmap for sustainable development goals on a global scale.

3. DATA AND METHODOLOGY

3.1. Data and Model

This section outlines the data sources, selected methodologies, and quantile approaches utilized in the study. With renewable energy supply (RESS) as the dependent variable, the study incorporates independent variables including net migration (IMG), geopolitical risk (GPR), and economic growth (GDP) to assess their impact on renewable energy transition. The analysis covers five major carbon-emitting countries, USA, China, India, Japan and Germany, over the period from 1990 to 2022. These countries were selected due to their significant contributions to global CO_2 emissions and their crucial roles in shaping international energy policies. The USA and China are the two largest economies and the top carbon emitters, influencing global energy markets and sustainability efforts. India, as one of the fastest-growing economies and a leading migrant-sending country, presents a unique case for evaluating the impact of migration on renewable energy adoption. Japan, with its energy security concerns and post-Fukushima renewable energy shift, represents a different approach to energy transition under external shocks. Germany has been a pioneer in renewable energy policies, particularly through its Energiewende (energy transition) strategy, making it an important case study for policy-driven energy transformation. The study aims to provide a comprehensive understanding of the interplay between net migration, geopolitical risks, economic growth and renewable energy supply, offering valuable insights for policymakers and stakeholders.

Table 1 presents a summary of the variables, including their definitions, sources, and measurement.

This study selects RESS as the dependent variable instead of renewable energy consumption. The primary reasons for this choice include the fact that supply directly reflects a country's capacity to produce and integrate clean energy into the grid, making it a more accurate indicator of technological advancements, policy effectiveness, and infrastructure investments. In contrast, renewable energy consumption is influenced by external factors such as market demand, pricing mechanisms, and fossil fuel dependence, which may not fully capture a country's commitment to renewable energy expansion. Moreover, the fundamental goal of the transition to renewable energy is to increase the share of clean energy in total energy production. In this context, measuring supply directly indicates how much renewable energy is generated, whereas an increase in consumption does not necessarily imply a shift away from fossil fuels. Furthermore, since many countries remain energy importers, consumption figures may not accurately reflect national production capacity, whereas supply provides clearer insights into local renewable energy investments and technological progress. Finally, governments and international organizations prioritize increasing renewable energy supply as a key strategy to ensure energy security, reduce fossil fuel dependency, and achieve climate targets. In contrast, consumption patterns fluctuate due to economic downturns and market dynamics, making supply a more stable and policy-relevant indicator.

Table 1: Selected variables and source

Variable	Description	Data source
RESS	Renewable energy supply, % total energy supply	OECD
IMG	Net migration (The difference between the number of immigrants and the number of emigrants over a specific period)	OECD
GPR	Geopolitical Risk Index (The most widely used source for gpr is Caldara and Iacoviello (2022), which provides a systematic measure of geopolitical tensions based on newspaper coverage of geopolitical events.)	Policy Uncertainty.Com
GDP	Real GDP per capita (2015 constant prices)	OECD

This study considers IMG, GPR, and GDP (GDP also serving as a control variable) as independent variables. IMG can influence renewable energy transition by affecting energy demand and infrastructure development, potentially accelerating the shift to renewable energy or, conversely, hindering investments due to human capital loss. GPR directly impacts energy policies and investment decisions by disrupting energy supply chains and creating policy uncertainty, which may shift the focus toward conventional energy sources such as fossil fuels. However, geopolitical instability can also incentivize countries to invest in renewable energy to reduce reliance on energy imports from politically unstable regions. GDP plays a dual role in renewable energy adoption; while rapid economic expansion increases energy demand and may reinforce dependence on fossil fuels, it also provides financial resources for renewable energy investments. This effect is more pronounced in high-income countries, where technological advancements and policy incentives facilitate renewable energy adoption, whereas in developing economies, the transition process may be slower due to financial constraints.

This study is particularly relevant in the context of global energy transitions, as it provides empirical evidence on how migration trends, geopolitical instability, and economic conditions impact renewable energy expansion in major emitting economies. Policymakers can utilize these insights to design effective energy policies, mitigate risks, and foster sustainable energy investments by understanding the structural influences on renewable energy development. The general model specification is presented in Eq. (1).

$$ress = f\,(img, gpr, gdp) \tag{1}$$

In Figure 1, the methodology framework outlines the steps taken to analyze the relationship between renewable energy supply and its key determinants.

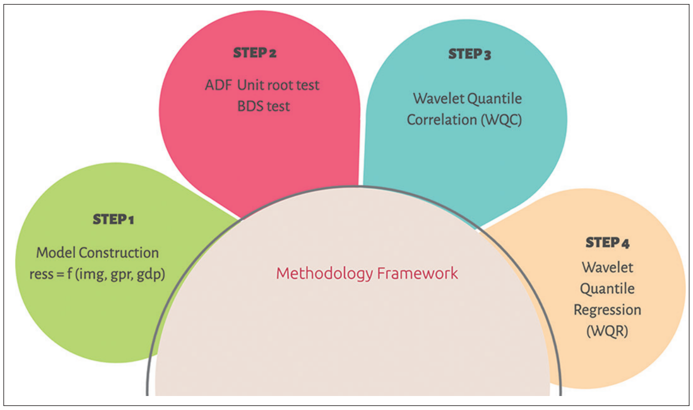
3.2. Augmented Dickey-Fuller (ADF) and Brock-Dechert-Scheinkman (BDS) Test

This study utilizes the Augmented Dickey-Fuller (ADF) test (Schwert, 1989) in Matlab to assess data stationarity, a crucial step for enhancing model accuracy and improving forecasting performance. Additionally, the BDS test (Broock et al., 1996) is employed to examine the independence and nonlinearity of residuals, ensuring that the model captures hidden relationships and dependencies overlooked by linear models. The combined use of these tests strengthens the econometric framework, validating theoretical assumptions and enhancing result reliability.

3.3. Wavelet-Based Approach

This study employs wavelet quantile correlation (WQC) and wavelet quantile regression (WQR) to analyze time-frequency dynamics and quantile-specific variations in the relationships among migration, geopolitical risks, economic growth, and renewable energy supply. By integrating these methods, it

Figure 1: Steps of methodology framework



captures complex, nonlinear, and time-dependent interactions, identifying both short-term fluctuations and long-term trends. This approach provides valuable insights into how economic and geopolitical factors shape renewable energy transitions across different quantiles and time horizons, offering a comprehensive perspective on energy sustainability challenges in major carbon-emitting countries.

3.3.1. Wavelet quantile correlation (WQC)

WQC is particularly useful in this study because it allows for the identification of scale-dependent correlations between variables over time. Unlike conventional correlation methods, which assume a constant relationship across the entire sample period, WQC enables the detection of period-specific and frequency-based dependencies, revealing how the strength and direction of relationships evolve over time. This is particularly important in the context of renewable energy transitions, where external shocks (e.g., geopolitical crises, economic downturns, or policy changes) may alter the dynamics between migration, geopolitical risks, and energy supply. Additionally, WQC evaluates these relationships across different quantiles, ensuring that insights are not limited to average effects but also capture variations in extreme conditions.

Initially, we apply the maximal overlapping discrete wavelet transform (MODWT), introduced by Percival and Walden (2000), to decompose the variable pairs. The MODWT is analogous to the Discrete Wavelet Transform (DWT) that offers several advantages over the traditional DWT. One of the key benefits is that the MODWT can accommodate any sample size T, while the DWT of level J limits the sample size to a multiple of 2^J. Additionally, the MODWT, including its wavelet and scaling coefficients, remains invariant to circular shifts of the time series, a feature not shared by the DWT. The MODWT also provides multiresolution detail and smooth coefficients that are linked to zero-phase filters, another property the DWT lacks. Lastly, the MODWT wavelet variance estimator is asymptotically more efficient than the one based on DWT, which makes it more appropriate for calculating wavelet correlations (Percival and Mofjeld, 1997; Gençay et al., 2002; Percival and Walden, 2000).

A time series, denoted as $f(t)$, can be broken down using wavelet transformation, which can be represented as follows:

$$f(t) = \sum_k s_{J,k}\, \emptyset_{J,k}(t) + \sum_k d_{J,k}\, \delta_{J,k}(t) + \sum_k d_{J-1,k}\, \delta_{J-1,k}(t) + \cdots + \sum_k d_{1,k}\, \delta_{1,k}(t) \quad (2)$$

Where J represents the number of decomposition levels, and k ranges from 1 to the total number of coefficients at each level. The coefficients $s_{J,k}$, $d_{J,k}$,… $d_{1,k}$ are the wavelet transform coefficients and $\emptyset_{J,k}(t)$ and $\delta_{J,k}(t)$ represents the approximating wavelets functions. The wavelets transformations can be expressed as:

$$s_{j,k} = \int \emptyset_{J,k}(t) f(t)\, dt \quad (3)$$

$$d_{j,k} = \int \delta_{J,k}(t) f(t) dt, \text{ for } j = 1,2,\ldots.J \quad (4)$$

Where J is the maximum integer such that 2^J takes value less than the number of observations. The wavelet correlation for the variables x_t and y_t is calculated as:

$$\hat{\rho}_{xy}(\tau_j) = \frac{Cov_{xy}(\tau_j)}{\hat{\sigma}_x^2(\tau_j)\hat{\sigma}_y^2(\tau_j)} \quad (5)$$

The wavelet correlation is similar to the Fourier-based complex coherency (Gençay et al., 2002). It provides a correlation measure across various frequency bands.

In the study for all our wavelet-based analysis, we used the sym4 wavelet, a member of the Daubechies wavelet family. The sym stands for symlet which is a family of wavelets designed to have symmetrical properties, making them especially suitable for capturing details in time series data while maintaining the important features like smoothness. We can better capture the details of the data with the sym4 while avoiding any significant loss of important features, allowing for a more accurate analysis of the relationships between the variables wavelet in our study.

3.3.2. Wavelet quantile regression (WQR)

While WQC provides a preliminary understanding of the correlation structures, WQR extends the analysis by estimating the causal impacts of independent variables (migration, geopolitical risks, and economic growth) on renewable energy supply across different quantiles and time scales. This approach is crucial because the effects of these variables are unlikely to be uniform across the entire distribution of renewable energy supply. For instance, the impact of migration on renewable energy investments may differ in low quantiles (where renewable energy supply is limited) compared to high quantiles (where renewable energy supply is abundant and well-developed). Similarly, geopolitical risks may have a stronger effect during specific periods of economic uncertainty or policy shifts. WQR helps uncover these asymmetric effects, enabling policy interpretation.

MODWT decomposes the variables into distinct scales, capturing both the low-frequency (smooth trends) and high-frequency (short-term fluctuations) components of the data. Subsequently, WQR uses these decomposed components to assess how the relationships between variables evolve at different time scales and across quantiles. Taking into account of quantiles, WQR provides insights into how the relationship between variables varies across different segments of the distribution and across distinct time frames (short, medium and long term). WQR improves upon the traditional Quantile-on-Quantile Regression (Sim and Zhou, 2015) by accounting for time-varying relationships between variables, allowing for a more flexible and accurate analysis of how the influence of factors like migration, geopolitical risk, and economic growth evolves over time and across different quantiles. In our analysis, we decompose the variables into four distinct time scales (D1, D2, D3, and D4) using wavelet type sym4. Using an s4 wavelet with annual or quarterly data will still capture the appropriate periodicities, while allowing the researcher to break down the data into higher-order scales (Crowley, 2007). The choice of quantiles (0.1-0.9) is made to capture a broad range of the distribution of renewable energy supply, from low to high levels, ensuring that the analysis reflects the full spectrum of data variability. The four distinct time scales, ranging from 2-4 years to 16-32 years, were chosen to capture both short-term fluctuations and long-term trends that might influence renewable energy supply.

WQR attempts to find the regression coefficients for each quantile, and this formulation can be expressed as:

$$Y_t = \beta_\tau X_\tau + \varepsilon_{\tau,t}\ \tau \epsilon\ (0,1) \tag{6}$$

X^τ represents the vector of independent variables (migration, geopolitical risk, economic growth, etc.), β_τ is the vector of regression coefficients for the τ -quantile.

The key advantage of WQR is its ability to reveal asymmetric effects, such as how migration impacts renewable energy investment differently at low quantiles (where renewable energy supply is limited) versus high quantiles (where renewable energy supply is abundant). This differential impact helps policymakers design more targeted interventions.

4. EMPIRICAL RESULTS

The descriptive statistics in Table 2 highlight the distributional properties of variables across countries. The Jarque-Bera (JB) test rejects normality in several cases, notably for India and Japan, where multiple variables show significant deviations. The USA and Germany exhibit mixed results, while China and Germany display relatively stable distributions. Skewness and kurtosis values confirm these patterns, with notable deviations in GPR and GDP for the USA, India, and Japan, indicating asymmetries and heavy tails. High standard deviation and variance, particularly in India, suggest greater fluctuations in renewable energy shares and geopolitical risks. These findings emphasize the need for advanced modeling techniques like WQR.

Before conducting the analysis, the data undergoes a stationarity test using the Augmented Dickey-Fuller test. The results, presented in Table 3, indicate that the time series of all countries, when expressed in natural logarithms, are non-stationary at the level. However, all these series become stationary when the returns are calculated by taking the first difference of their natural logarithms.

According to the BDS test results in Table 4, all variables for the USA, China, and Japan are significant at the 1% level across all dimensions (from M2 to M6). This strongly rejects the null hypothesis of independence and identical distribution for each variable. In other words, each variable exhibits nonlinear dependencies, indicating that these relationships form complex patterns that cannot be explained by linear structures alone.

However, for Germany, all variables except for geopolitical risk are significant at the 1% level. In India, all variables except for migration and geopolitical risk are also significant at the 1% level. The BDS test results reveal that the strength of all variables increases with higher embedding dimensions (M2-M6), making nonlinear dependencies more evident at higher dimensions. This confirms that each variable has significant and strong effects on structural dynamics in the long run. In particular, geopolitical risk and economic growth exhibit strong influences across all dimensions, while migration dynamics display evolving and complex structures over time. Migration tends to diminish its impact in the long run for some countries, whereas in others, it interacts with complex structures, driving structural transformations. These findings suggest that each variable is not only linked through linear relationships but also exhibits strong nonlinear dependencies, playing a crucial role in shaping the long-term structural evolution of each country.

4.1. WQC Results

This study analyzes the dynamic relationships between migration, geopolitical risk, economic growth, and renewable energy supply using WQC. WQC captures time- and frequency-dependent correlations across quantiles, revealing variations at different distribution points (low, medium, high). Unlike traditional wavelet methods, it examines asymmetric relationships by assessing interactions beyond averages. In the graphs, red and yellow indicate strong correlations, while blue represents weak or negligible ones. Color changes over time reflect fluctuations in relationship strength. This approach enables a comparative analysis of how these factors influence renewable energy supply across time scales and countries, emphasizing quantile-based differences (see Figure 2).

4.1.1. USA

An analysis of U.S. data shows that the correlation between IMG, GPR, GDP, and RESS remained low from 1995 to 2005, indicating limited renewable energy investments and development. During this period, economic growth and migration had no significant effect on renewable energy supply. However, between 2006 and 2015, the correlation between GPR and RESS increased significantly, particularly in mid-quantiles (0.4-0.6), reflecting the impact of the 2008 financial crisis and subsequent geopolitical

Table 2: Descriptive statistics

Variable	USA	CHINA	INDIA	JAPAN	GERMANY
ress					
Quartile (0.10)	1.48	2.10	3.14	1.12	0.49
Mean	1.72	2.57	3.36	1.35	1.67
Median	1.64	2.38	3.37	1.22	1.87
Quartile (0.90)	2.07	3.15	3.64	1.84	2.70
Variance	0.05	0.18	0.04	0.08	0.76
Standard deviation	0.22	0.43	0.19	0.29	0.87
Skewness	0.43	0.26	0.27	0.98	−0.19
Kurtosis	1.87	1.41	1.76	2.64	1.42
JB	3.07	1.59	20.10***	15.50***	1.71
img					
Quartile (0.10)	6.01	−5.80	−5.83	4.59	4.78
Mean	6.11	−5.52	−3.63	4.97	5.34
Median	6.12	−5.64	−5.33	5.08	5.47
Quartile (0.90)	6.26	−5.17	3.91	5.21	5.64
Variance	0.01	0.09	14.37	0.07	0.10
Standard deviation	0.12	0.30	3.79	0.26	0.32
Skewness	−0.97	1.23	1.64	−0.73	−0.85
Kurtosis	4.52	4.89	3.81	2.08	2.42
JB	37.98***	66.09***	4.03	366.03***	3.06
gpr					
Quartile (0.10)	0.42	−1.41	−1.98	−1.91	−1.51
Mean	0.78	−0.91	−1.65	−1.52	−1.03
Median	0.77	−0.95	−1.63	−1.55	−1.04
Quartile (0.90)	1.29	−0.21	−1.24	−0.96	−0.54
Variance	0.11	0.21	0.12	0.15	0.19
Standard deviation	0.34	0.46	0.35	0.39	0.44
Skewness	0.23	0.50	−0.21	0.34	0.22
Kurtosis	2.88	2.62	3.61	2.09	3.83
JB	61.98***	0.70	40.98***	5.82*	6.01**
gdp					
Quartile (0.10)	29.56	28.90	29.80	33.84	28.19
Mean	30.17	30.68	31.40	33.89	28.51
Median	30.26	30.72	31.38	33.90	28.50
Quartile (0.90)	30.69	32.22	32.92	33.95	28.86
Variance	0.18	1.56	1.37	0.00	0.06
Standard deviation	0.42	1.25	1.17	0.04	0.25
Skewness	−0.22	−0.28	−0.07	−0.81	0.04
Kurtosis	1.93	1.93	1.75	3.69	2.15
JB	7.27**	5.07*	22.78***	9.12***	4.67

Table 3: ADF unit root test results

Countries	Variables	Level		First difference	
		ADF	P-value	ADF	P-value
USA	RESS	2.494	0.639	8.517	0.021
	IMG	4.007	0.316	7.412	0.039
	GPR	4.731	0.181	20.536	0.000
	GDP	2.535	0.995	8.129	0.027
China	RESS	−2.984	0.176	−1.850	0.061
	IMG	−0.104	0.605	−7.501	0.000
	GPR	−1.342	0.162	−7.854	0.000
	GDP	10.640	0.999	−2.459	0.015
India	RESS	3.726	0.125	−3.526	0.000
	IMG	−1.241	0.191	−9.927	0.000
	GPR	−0.705	0.386	−8.228	0.000
	GDP	17.306	0.999	−2.934	0.053
Japan	RESS	2.109	0.989	−6.164	0.000
	IMG	1.323	0.949	−4.269	0.000
	GPR	−0.649	0.406	−6.088	0.000
	GDP	1.519	0.965	−5.078	0.000
Germany	RESS	4.303	0.999	−2.177	0.030
	IMG	−0.936	0.302	−6.976	0.058
	GPR	1.059	0.257	−6.527	0.000
	GDP	7.168	0.999	−2.565	0.012

events on the energy sector. Post-2015, correlations strengthened further, linking economic growth directly to renewable energy supply. The red and yellow tones in the graphs suggest rising investments and sector expansion. However, at lower quantiles (where renewable energy supply is low), independent variables had minimal impact, likely due to infrastructure limitations. In mid-quantiles, GPR's influence on RESS became more pronounced, highlighting the growing role of geopolitical risks. At higher quantiles, the strong positive correlation between GDP and RESS indicates that as the renewable energy sector expands, economic growth plays an increasingly significant role. Frequency analysis reveals no significant short-term (1-5 years) correlations, except for a weak GDP-RESS relationship. In the medium term (6-15 years), economic and political factors had a stronger impact on renewable energy supply, with GPR-RESS correlations becoming particularly evident in mid-quantiles. In the long term, the sector reached maturity, and GDP-RESS correlations remained strong, emphasizing the crucial role of long-term planning, sustainable policies, and economic support in renewable energy development.

Table 4: Results of BDS test

Variable	Embedding dimension	USA	China	India	Japan	Germany
RESS	M2	30.558***	60.165***	33.857***	17.034***	47.869***
	M3	33.351***	67.975***	35.275***	18.578***	53.097***
	M4	36.677***	78.792***	37.743***	20.113***	60.556***
	M5	40.900***	95.208***	42.014***	22.291***	71.305***
	M6	46.659***	118.424***	48.353***	25.106***	86.725***
IMG	M2	7.798***	5.594***	0.024*	15.587***	13.657***
	M3	9.110***	5.026***	1.360	15.026***	13.808***
	M4	9.053***	5.842***	0.585	14.451***	13.703***
	M5	9.047***	7.020***	-0.984	15.172***	13.859***
	M6	9.044***	8.268***	-4.010***	15.358***	14.832***
GPR	M2	6.693***	9.019***	3.627*	6.115***	3.485*
	M3	5.689***	9.156***	2.869*	4.264***	2.511*
	M4	6.134***	9.521***	1.988*	7.036***	2.683*
	M5	6.698***	10.107***	1.755*	8.343***	2.565*
	M6	6.873***	11.146***	1.903*	8.386***	2.829*
GDP	M2	33.353***	38.021***	43.607***	6.541***	27.657***
	M3	34.959***	40.283***	46.831***	5.543***	29.754***
	M4	37.532***	43.532***	51.494***	5.578***	32.627***
	M5	41.252***	49.169***	58.853***	5.931***	37.175***
	M6	46.415***	57.424***	69.481***	6.930***	43.308***

4.1.2. China

Before 2010, China exhibited a strong positive correlation between geopolitical risk (GPR), international migration (IMG), and renewable energy supply (RESS), particularly at higher quantiles (0.7-0.9) in the 1990s and early 2000s. This suggests that migration and geopolitical risks significantly shaped renewable energy infrastructure, with energy expansion influencing migration patterns and geopolitical strategies. High energy demand, evolving policies, and increased regional political activity further reinforced this relationship. However, after 2010, the correlation between RESS and GPR/IMG weakened or reversed, as indicated by the transition to blue tones in the data. This shift likely reflects China's sustained renewable energy investments, which reduced the sector's sensitivity to migration and geopolitical risks. Strengthened energy infrastructure may have mitigated the influence of these external factors. Additionally, post-2010 global and regional economic dynamics contributed to this transformation. The 2010s marked a turning point in China's energy transition, where renewable energy development became less reliant on migration and geopolitical risks. Investments increasingly prioritized long-term sustainability, weakening the earlier link between energy supply and economic growth. Geopolitical tensions, including territorial disputes in the South China Sea and trade conflicts with the U.S., also influenced energy strategies. As the post-2008 economic boom stabilized, slower growth and reduced energy demand may have moderated renewable energy investments. Consequently, the once-strong correlation between economic growth and renewable energy supply weakened, reflecting China's shift toward a more stable and self-sufficient energy model.

4.1.3. India

Between 1990 and 2005, IMG and RESS exhibited a strong correlation at higher quantiles, reflecting migration's labor-driven nature. However, after 2010, this correlation shifted to lower quantiles. Initially, India's priority was economic growth over renewable energy due to limited infrastructure. Between 2000 and 2010, migration had little impact on renewable energy, as it was primarily driven by labor demand and education rather than energy investments. While skilled migrants contributed to knowledge transfer, significant advancements in the renewable sector were lacking. After 2010, migration gained importance, supporting renewable energy investments through knowledge exchange and foreign capital. By 2020, migration and renewable energy became more integrated, aligning with labor market demands and foreign investments. A similar pattern is observed in the relationship between GPR and RESS. Until the early 2000s, India's energy dependence was shaped by external geopolitical risks, but renewable energy adoption remained limited. From the mid-2000s onward, rising geopolitical tensions—particularly competition with China and border disputes with Pakistan—pushed India toward energy security and renewables. After 2010, the shift to renewable energy accelerated as geopolitical risks played a more decisive role in shaping energy policies. In the 1990s, GDP and RESS had a weak correlation, as economic expansion took precedence over renewables. Between 2000 and 2010, this relationship strengthened as economic growth spurred renewable energy investments. Post-2010, India's renewable energy sector, particularly solar projects, grew alongside economic expansion. However, in recent years, the GDP-RESS correlation has weakened, as indicated by blue tones in the data. Despite increasing renewable energy investments, the sector has struggled to keep pace with India's rapid economic growth. The continued reliance on coal and oil further weakens the connection between economic growth and renewable energy supply, underscoring the challenge of achieving a full transition to renewables in a fast-growing economy.

4.1.4. Japan

Between 1990 and 2000, IMG and RESS exhibited a moderate positive correlation at higher quantiles (0.8-0.9). After 2000, this relationship strengthened, as reflected in the increasing color intensity of the correlation structure. Post-2010, while the correlation remained weak at lower quantiles (0.1-0.3), a strong positive relationship emerged at mid-to-upper quantiles, aligning with Japan's rising migration rates and expanding renewable energy sector. Migration policies aimed at addressing an aging population coincided with renewable energy growth, particularly after the 2011 Fukushima disaster, which accelerated the shift to renewables, especially solar energy. Migration responded to labor market needs, while renewable energy investments aimed to enhance energy security. Between 1990 and 2010, GPR and RESS maintained a strong positive correlation at higher quantiles (0.7–0.9), indicating Japan's reliance on renewables during geopolitical uncertainty. After 2010, mid-level quantiles saw a shift to a negative correlation, while higher quantiles maintained a significantly positive relationship. Over the full 1990-2022 period, rising geopolitical risks consistently drove Japan's renewable energy expansion, particularly in recent years. The relationship between GDP and RESS showed no clear trend between 1990-2000 and 2005-2015. However, after 2015, a strong positive correlation emerged at mid-to-upper quantiles, reflecting deeper integration between economic growth and renewable energy supply. Japan's structural energy shift gained momentum post-2010, particularly after Fukushima, marking a decisive shift from fossil and nuclear dependence. Empirical findings suggest that renewable energy investments were largely policy-driven rather than market-led. Post-2015, Japan prioritized green energy to support economic growth, focusing on high-tech and efficiency-driven investments, strengthening the GDP-RESS link. This transition underscores Japan's move toward a more sustainable energy strategy aligned with broader economic objectives.

4.1.5. Germany

Germany, the EU's leading migration destination, experienced major migration waves from Eastern Europe in the 1990s, EU enlargement in the 2000s, and the refugee influx after 2015. Parallel to this, Germany entered the renewable energy sector in the 1990s, expanded capacity in the 2000s, and accelerated its transition after phasing out nuclear energy in 2011. Between 1990 and 2005, IMG and RESS showed a weak or negative correlation in lower quantiles (0.1-0.5) but turned positive above 0.6, particularly in the early 2000s. From 2005 to 2015, correlation strengthened in mid-to-high quantiles, aligning with the Energiewende (Energy Transition) policies that drove renewable energy adoption. Post-2015, correlation remained negative at lower quantiles but strong and positive at higher quantiles, suggesting that migration and renewable energy supply moved in parallel at certain levels. Germany's energy policies were also shaped by geopolitical risks. From 1990 to 2005, GPR and RESS showed weak or negative correlations at lower quantiles but turned positive above 0.6. Between 2005 and 2015, geopolitical risks played a more significant role, with events such as the 2009 natural gas crisis and the 2014 Ukraine-Russia conflict accelerating Germany's shift to renewables. Post-2015, correlation remained high but fluctuated, reflecting Germany's gradual move away from fossil fuels. While geopolitical risks were already elevated between 1990 and 2000, the renewable energy transition had not yet gained momentum. However, from 2005 onward, rising geopolitical risks pushed Germany toward energy independence, with peak uncertainty between 2015 and 2022 further accelerating this shift. Germany maintained economic growth while expanding its renewable energy supply between 2005 and 2022. Despite economic slowdowns after 2020, renewable energy investments continued. Before 2000, GDP and RESS had a weak or negative correlation across all quantiles, but post-2005, this correlation steadily increased, becoming strongly positive. This shift coincided with Germany's renewable energy incentive programs, with a strong correlation persisting beyond 2015. The stable link between economic growth and renewable energy supply highlights Germany's commitment to its energy transition, viewing it as essential despite economic fluctuations.

4.2. WQR Results

When interpreting the WQR results, the graph should be analyzed by examining the quantile distribution along the x-axis (ranging from 0 to 1) and the time scale level (TSL) on the y-axis, which represents different time periods (2-4 years, 4-8 years, 8-16 years, and 16-32 years). The 3D surface plot visualizes how regression coefficients vary across these time scales and quantiles. The color gradient is key to understanding relationship strength: brighter colors (e.g., yellow) indicate stronger positive relationships, while cooler colors (e.g., blue) represent weaker or negative relationships. This visualization highlights how the impact of IMG, GPR, and GDP on RESS changes over different time horizons and quantile levels, providing deeper insights into the dynamic and asymmetric nature of these relationships.

4.2.1. USA

In Figure 3, the relationship between RESS and IMG, GPR, and GDP is examined for USA. The impact of IMG on RESS in the USA is generally negative but varies across time scales and quantiles. In the short term (2-4 years), the effect is weak in the middle and lower quantiles, while a significant positive relationship appears in the higher quantiles (0.75 and above). This suggests that in regions receiving IMG, renewable energy investments may have limited short-term effects but could increase as the migrant population grows. In the medium term, IMG's impact on RESS becomes consistently positive across all quantiles, with a particularly strong effect in the higher quantiles (0.75 and above). This indicates that policies integrating the energy demand of migrant populations into sustainable sources may play a crucial role in the USA's long-term energy strategy. However, in the long term, negative trends emerge in higher quantiles, suggesting that as saturation levels are reached, IMG may put pressure on infrastructure, potentially limiting renewable energy investments. While migration drives the transition to renewable energy in the medium term, it may pose challenges for infrastructure and resource management over time. Therefore, supporting migrant populations with policies that promote sustainable energy consumption is essential.

GPR negatively impacts RESS in the short term, particularly in lower and middle quantiles, by creating uncertainty that discourages clean energy investments. However, at higher quantiles (0.75 and above), this effect weakens, indicating that U.S. energy policies help mitigate these risks over time. In the long run, geopolitical risk has minimal influence on renewable energy, suggesting that long-term policies have strengthened sector resilience. While geopolitical risks initially hinder the clean energy transition, sustained U.S. policies and incentives ensure continued investment, highlighting the country's ability

Figure 2: Results of wavelet coherence tests

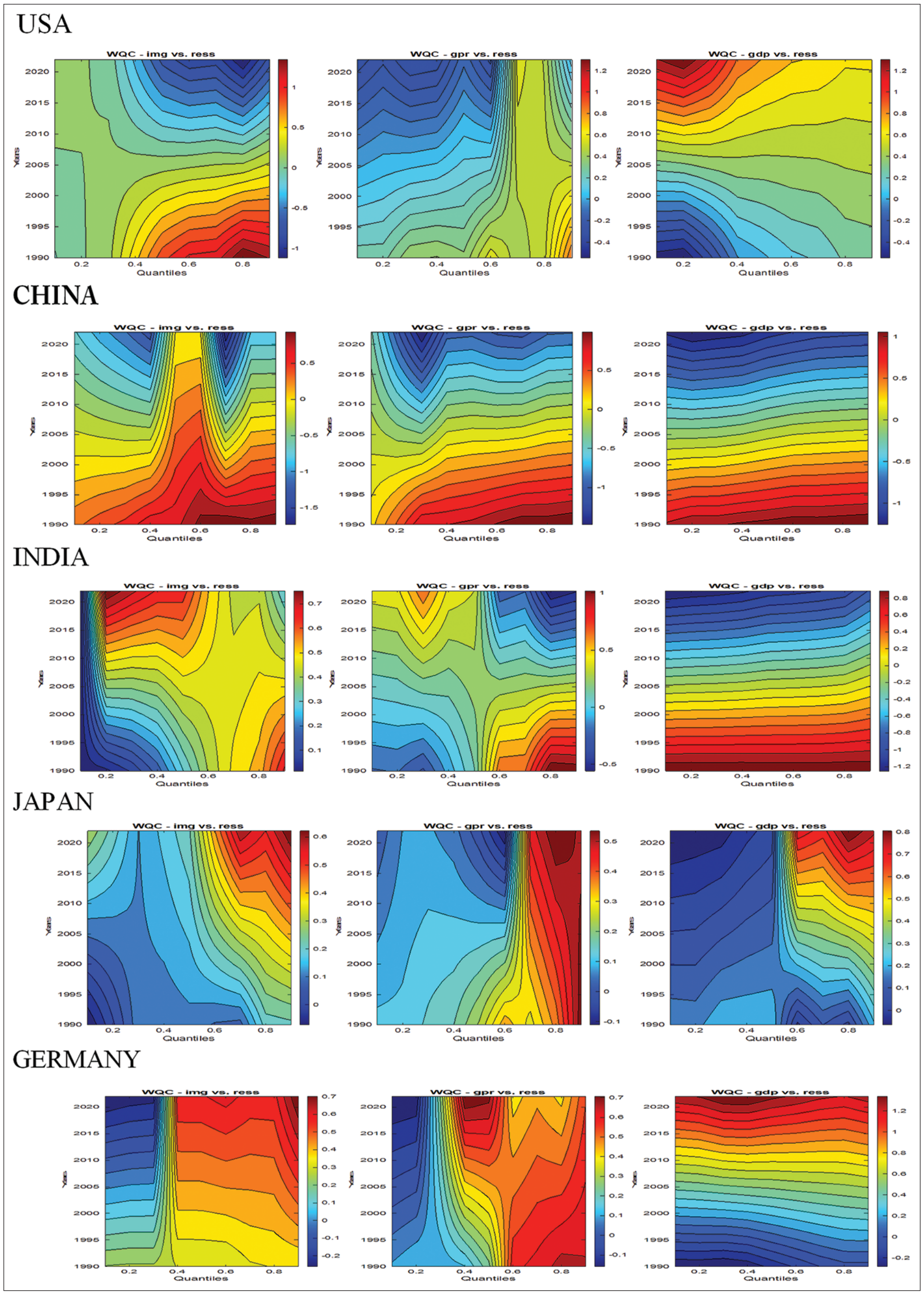
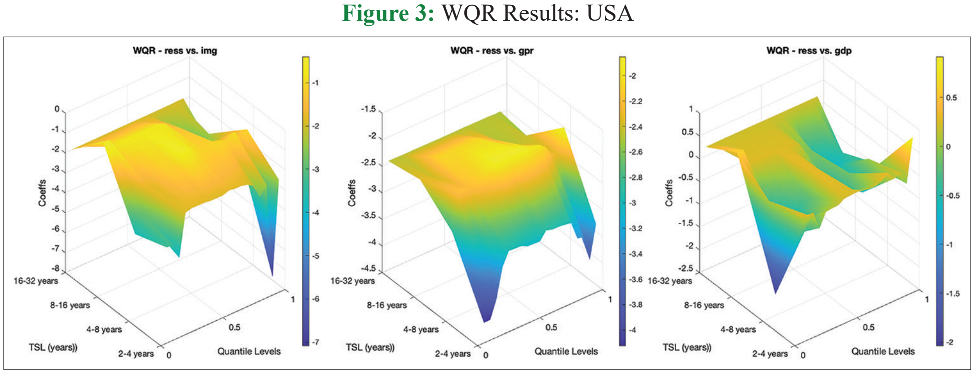


Figure 3: WQR Results: USA



to shield the sector from global uncertainties. In the short term, GDP negatively affects the renewable energy transition, especially in lower and middle quantiles, as economic expansion often favors fossil fuels. However, in the medium term, at higher quantiles, GDP begins to positively influence renewable energy investments. In the long run, at the highest quantiles (0.90 and above), GDP becomes a strong driver of the clean energy transition, underscoring the importance of aligning economic growth with sustainable energy policies. The WQR analysis reveals that multiple factors shape the U.S. renewable energy transition. IMG supports clean energy investments in the medium term but may strain infrastructure over time. GPR slows the transition in the short term but has minimal long-term effects due to adaptive policies. GDP initially favors fossil fuels but evolves into a key driver of renewable energy. To accelerate the transition, U.S. policies should emphasize long-term investment strategies, sustainable economic growth, and risk reduction measures. Strengthening these policies will ensure a stable and resilient clean energy future.

4.2.2. China

In Figure 4, the relationship between RESS and IMG, GPR, and GDP is examined for China.

In the short term, IMG negatively affects RESS in China, particularly at lower quantiles (0–0.25), as increased migration pressures energy infrastructure and slows renewable investments. As a migrant-sending country, China's emigrants contribute to energy demand abroad, limiting domestic renewable growth. In the medium term, this effect stabilizes, with migration having a neutral impact at mid-quantiles (0.5) but turning positive at higher quantiles (0.75+), suggesting that migrant-driven energy demand gradually shifts toward renewables. Returning migrants may further strengthen China's renewable market by enhancing energy

Figure 4: WQR results: Chına

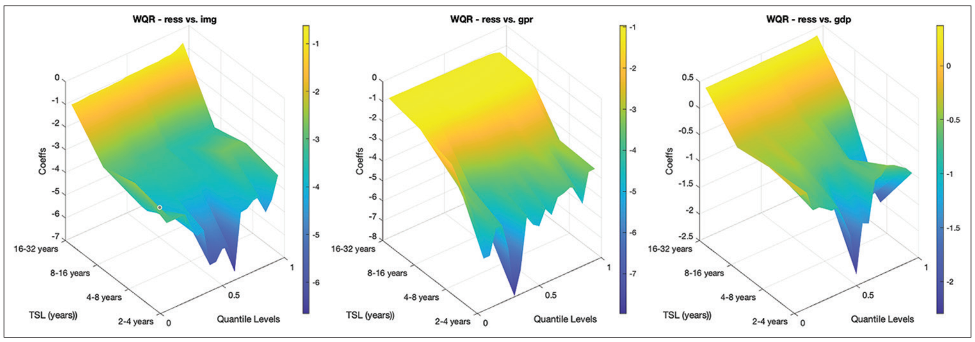


Figure 5: WQR results: Indıa

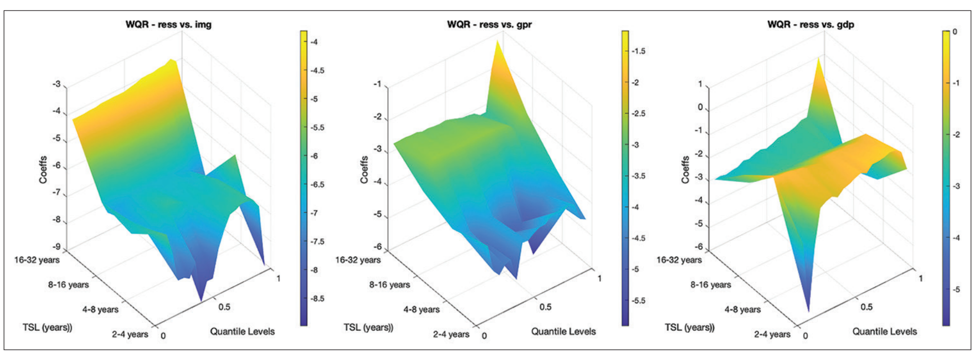
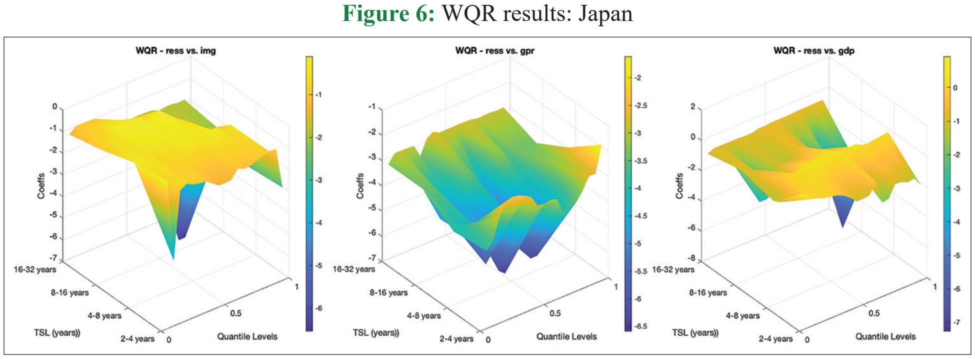


Figure 6: WQR results: Japan



infrastructure. In the long term, migration's influence becomes strongly positive at high quantiles (0.75+), indicating sustained demand for renewables. A growing migrant population supports long-term renewable energy expansion, reinforcing China's energy transition. GPR initially hampers renewable investments by increasing uncertainty and delaying projects. However, in the medium term, its impact weakens, stabilizing investments. At high quantiles (0.75+), long-term resilience suggests that China's policies effectively mitigate geopolitical risks, ensuring a more sustainable transition to renewables. GDP initially suppresses renewable investments, particularly at low quantiles, as economic expansion prioritizes fossil fuels. However, in the medium term, renewable investments increase with industrialization. In the long run, a strong positive correlation at high quantiles (0.75+) indicates that sustained economic growth channels resources into renewable energy, reinforcing China's long-term transition strategy.

4.2.3. India

In Figure 5, the relationship between RESS and IMG, GPR, and GDP is examined for India. India's rapidly growing population and economy have led to a sharp rise in energy demand. Similar to China, the short-term impact of IMG on RESS is largely negative, reflecting the initial strain migration places on infrastructure and energy investments. In the medium term, this effect stabilizes, but no significant positive trend emerges in the long run. This suggests that the integration of the migrant population into India's energy system does not directly support sustainable energy expansion over time. GPR negatively affects renewable energy supply in both the short and medium term, with a particularly strong impact at low and middle quantiles. In the long term, while GPR no longer has a significant effect, it also does not contribute positively, indicating that India has developed resilience to geopolitical uncertainties and stabilized its energy policies. The impact of GDP on RESS remains negative in both the short and long term, suggesting that economic growth continues to favor fossil fuel consumption, making the transition to renewables more challenging. While a positive effect of economic growth is expected at higher quantiles, the data does not show sustained momentum in the long run. This underscores the need for India to align economic growth with renewable energy investments and highlights the importance of strengthening incentives for clean energy development.

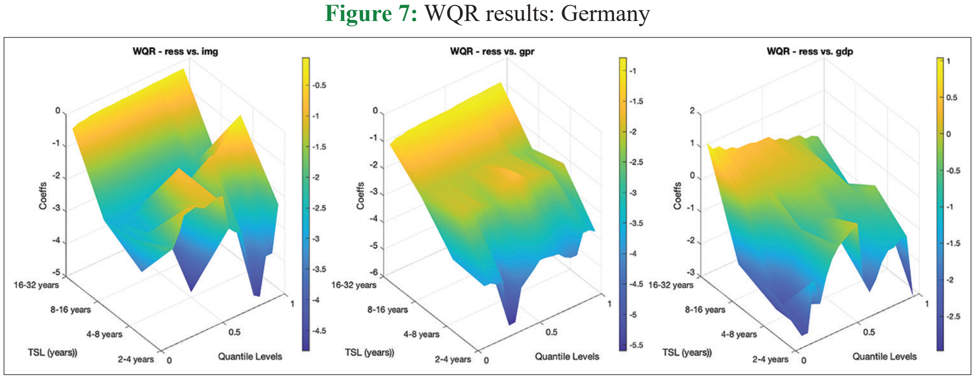
4.2.4. Japan

In Figure 6, the relationship between RESS and IMG, GPR, and GDP is examined for Japan. The relationship between RESS and IMG, GPR, and GDP in Japan varies across time scales and quantiles. IMG generally has a negative impact on RESS, with a significant short-term effect in the lower and middle quantiles. This suggests that rising migration pressures energy infrastructure, making it difficult to implement renewable energy projects quickly. While this negative effect weakens in the medium term, no significant positive shift occurs, and even in the long run, migration does not appear to directly contribute to renewable energy expansion. GPR has a strong negative short-term impact, primarily due to Japan's reliance on external energy sources, which makes it vulnerable to global uncertainties. Although the effect weakens in the medium term, volatility persists. In the long run, however, government policies and strategic energy investments help neutralize these risks. GDP negatively affects RESS in the short term, as fossil fuel consumption dominates in the lower and middle quantiles. While this trend stabilizes in the medium term, in the long run, GDP supports RESS only in certain quantiles. However, the overall impact remains neutral or slightly negative, indicating that despite rising renewable energy investments, fossil fuels still play a dominant role in Japan's energy mix. Overall, while IMG and GPR negatively affect RESS in the short term, these effects diminish over time. However, the expected positive influence of GDP on RESS is not fully realized, underscoring the need for stronger incentives and long-term strategies to accelerate Japan's transition to sustainable energy.

4.2.5. Germany

In Figure 7, the relationship between RESS and IMG, GPR, and GDP is examined for Germany. In Germany, IMG positively impacts RESS, with effects evolving over time. In the short term (2-4 years), its influence is limited or neutral in lower and middle quantiles but significantly positive in higher quantiles, particularly in high-demand regions. By the medium term (4-8 years), the positive impact becomes more widespread, and in the long term (16-32 years), it stabilizes, indicating a sustained role in energy infrastructure development. GPR negatively affects RESS, especially in the short term, due to Germany's reliance on energy imports and geopolitical instability, such as the Russia-Ukraine war. In the medium term, its influence fluctuates, while in the long term, it nearly disappears, reflecting Germany's strengthened energy resilience. GDP initially hinders RESS in the short term (2-4 years), as economic expansion increases fossil fuel dependence. By the medium term (4-8 years), its impact becomes neutral with emerging positive trends. In the long term (16-32 years), GDP strongly

Figure 7: WQR results: Germany



supports RESS, aligning economic growth with renewable energy investments. Overall, IMG drives RESS, while GPR poses short-term challenges. GDP transitions from a barrier to a long-term enabler of clean energy. Germany's energy policies reinforce a resilient and sustainable shift to renewables.

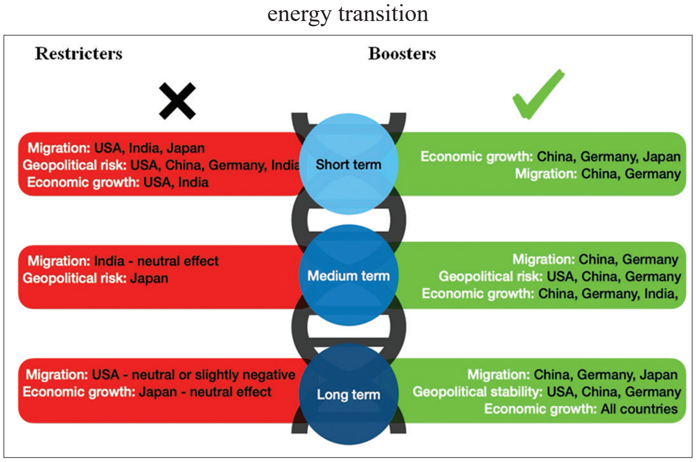
Figure 8 illustrates how the transition to renewable energy has been influenced by various factors over time. It is particularly evident that the effects of IMG, GPR, and GDP vary over time.

In the short term, IMG negatively impacts RESS in the U.S., India, and Japan, as growing migrant populations hinder rapid renewable energy deployment. However, in Germany and China, IMG supports RESS by driving energy demand management and infrastructure expansion. Japan shows neutral to positive effects, while India's infrastructure and policies lag behind migration trends. In the long term, IMG stimulates RESS in Germany, China, and Japan, fostering gradual energy infrastructure development. GPR negatively affects RESS in all countries except Japan in the short term, delaying investments. However, in the medium term, China, Germany, and the U.S. become more resilient, turning GPR into a driver for renewable energy investment, while Japan remains vulnerable. Over time, GPR's impact diminishes in China, Germany, and the U.S., while Japan maintains stability. GDP initially increases fossil fuel reliance in the U.S. and India, slowing renewable energy progress. In contrast, China, Germany, and Japan use GDP to promote renewable investments. By the medium term, GDP accelerates RESS expansion in China, Germany, and India. In the long term, GDP positively influences RESS across all countries, with China, Germany, and Japan transitioning faster, while India remains slower due to fossil fuel dependence. Overall, Germany and China lead the renewable transition through IMG and GDP, while India faces challenges due to GPR and fossil fuel reliance. Japan effectively manages GPR but experiences a more limited impact of migration on renewable energy compared to other nations.

5. DISCUSSION

IMG, GPR, and GDP can either promote or hinder the transition to renewable energy; however, these effects vary from country to country. These differences are determined by factors such as national energy policies, economic structures, migration dynamics, and geopolitical positioning. The impact of migration on the transition to renewable energy varies across countries. Our findings indicate that in countries that receive migrants (e.g., the United States and Germany), an increase in the migrant population promotes the transition to renewable energy in the medium and long term. This is linked to the rising energy demand due to migration and the tendency of governments to expand investments in sustainable energy. In contrast, in countries that send migrants (e.g., India and China), the short-term effects of migration are generally negative or weak. While the outflow of migrant labor does not directly encourage renewable energy investments in the domestic market, it can support financial resources and knowledge transfer, which may accelerate energy transformation in the long run.

Figure 8: Time-based comparison restrictors vs. boosters on renewable energy transition



Source: Author's construction

These findings align with previous studies emphasizing the role of migration in energy policies. For example, Germany's Energiewende policy promotes a comprehensive transition to renewable energy in line with its goal of reducing CO_2 emissions (McCarthy, 2018). Additionally, there is evidence that an increase in migrant density strengthens government initiatives toward renewable energy (Price and Feldmeyer, 2011). In migrant-sending countries, migration may not directly boost energy investments, but remittances and acquired skills from abroad are suggested to encourage sustainable energy investments (Khan and Ming-Yi, 2018). In the European context, migration movements have been noted to alter demographic structures and exert significant long-term effects on energy policies (Bagavos, 2019; Otero et al., 2022).

The impact of geopolitical risk on the transition to renewable energy depends on a country's energy dependence. Our findings indicate that countries highly dependent on external energy sources, such as Germany and Japan, are the most affected by geopolitical risks in the short term. However, as geopolitical risks increase, countries like Germany have shifted more toward renewable energy, enhancing their energy independence in the long run. In contrast, countries with strong domestic energy resources, such as the United States and China, have managed the effects of geopolitical risks over time, developing more resilient energy policies in the long term. In India, concerns over fossil fuel supply security have generally hindered the transition to renewable energy.

These results are consistent with previous studies that reveal the dual impact of geopolitical risks on renewable energy (Liu et al., 2023). Rising geopolitical tensions can increase the cost of conventional energy sources, thereby encouraging investments in renewable energy (Acheampong et al., 2023; Husnain et al., 2022). On the other hand, geopolitical instability can negatively affect the financing and feasibility of renewable energy projects (Fen et al., 2021; Alsagr and Almazor, 2021). Countries like Germany and Japan experience energy vulnerabilities due to geopolitical risks, prompting them to accelerate their transition to renewable energy (Flouros et al., 2022; Konovalova and Abuzov, 2023). In contrast, the United States and China mitigate the negative impacts of geopolitical risks by developing strong energy policies

(Zhao et al., 2023; Gupta et al., 2018). Studies suggest that an increase in geopolitical risks may drive up global fossil fuel prices, making the transition to renewable energy more complex, especially in developing countries (Gupta et al., 2018; Gözgör et al., 2021; Cai and Wu, 2021).

The impact of economic growth on the transition to renewable energy depends on energy policies. Our findings indicate that in China and Germany, economic growth has a positive relationship with renewable energy investments, and as growth increases, policies supporting energy supply are implemented. In contrast, in the United States and India, economic growth increases dependence on fossil fuels in the short term, limiting the transition to renewable energy. However, in the long term, economic growth becomes a supporting factor for energy transformation. In Japan, the relationship between economic growth and the transition to renewable energy is weaker and more inconsistent. Particularly after the Fukushima nuclear disaster, state interventions and incentives have played a crucial role in shaping energy policies.

These findings align with previous studies demonstrating the positive and statistically significant impact of renewable energy production on economic growth. In Germany and China, a strong link between the renewable energy sector and economic growth is highlighted (Lu et al., 2021; Singh et al., 2019). In contrast, in the United States and India, economic growth has been found to increase fossil fuel consumption in the short term and restrict renewable energy investments (El-Karimi, 2021). In Japan, energy policies appear to be shaped more by government interventions rather than economic growth (Vivoda, 2012; Eweade et al., 2022). Previous research also suggests that investments in renewable energy technologies support economic growth, reinforcing the symbiotic relationship between energy infrastructure development and economic stability (Huh et al., 2018; Mohlin et al., 2019; Sadorsky, 2009).

Our findings indicate that net migration, geopolitical risk, and economic growth can play either a supportive or restrictive role in the transition to renewable energy, depending on a country's economic, political, and energy structures. While Germany and China have leveraged geopolitical risks and economic growth as opportunities to expand renewable energy, countries such as India and the United States have, at times, increased their reliance on fossil fuels due to these factors. These results align with the extensive literature emphasizing that renewable energy policies should be tailored to each country's unique socio-economic and political context.

6. CONCLUSION

This study examines the dynamic effects of net IMG, GPR, and GDP on RESS across different countries. Using WQC and WQR analyses, it highlights the changing impacts of these three key determinants over time. In the short term, migration has had a negative effect on renewable energy supply in the U.S., China, and India, mainly due to infrastructure constraints and increased energy demand. In contrast, in countries such as Germany and Japan, more integrated energy policies have resulted in a neutral or positive impact of migration. Geopolitical risks have hindered the transition to renewable energy in Germany, China, and the U.S., while their impact has been more manageable in Japan. Economic growth has limited renewable energy investments in the short term by increasing dependence on fossil fuels.

In the medium term, migration has become a supportive factor for renewable energy supply in Germany and China. Geopolitical risks have encouraged some countries (e.g., the U.S., China, and Germany) to enhance their energy policies' resilience to external shocks. Economic growth has also started to align more closely with renewable energy investments. In the long term, economic growth positively influences renewable energy supply in all countries, although the intensity of this effect varies. Germany and China have transitioned more rapidly to renewable energy, while India has experienced a slower transition. Migration has contributed positively in Germany, China, and Japan, while its impact has remained neutral or limited in the U.S. and India. Over time, geopolitical risks have either diminished or stabilized.

The findings indicate that country-specific strategies are necessary for the renewable energy transition rather than a fixed model. Policy recommendations include strengthening renewable energy infrastructure in migration-receiving countries in the short term and integrating migrants into the energy sector in the medium and long term. To mitigate the negative impact of geopolitical risks, energy supply security should be prioritized. Economic growth should be leveraged to support renewable energy investments through subsidies, R&D funding, and industry-integrated energy policies. Germany and China's successful energy policies could serve as models for other nations, while countries like India should implement stronger incentives to accelerate the transition. The study's focus on a specific time period and five major carbon-emitting countries may limit its generalizability. Future research should employ broader datasets, alternative methodologies such as artificial intelligence and machine learning, and deeper analyses of the relationship between sustainable development and the energy transition.

REFERENCES

Acheampong, A., Opoku, E., Aluko, O. (2023), The roadmap to net-zero emission: Do geopolitical risk and energy transition matter? Journal of Public Affairs, 23(4), 2882.

Acuner, E., Kayalica, M.Ö. (2018), A review on household energy consumption behavior: How about migrated consumers? Environmental Economics, 9(4), 8.

Adams, R. (2011), Evaluating the economic impact of international remittances on developing countries using household surveys: A literature review. The Journal of Development Studies, 47(6), 809-828.

Agaton, C. (2022), Will a geopolitical conflict accelerate energy transition in oil-importing countries? A case study of the Philippines from a real options perspective. Resources, 11(6), 59.

Ahmad, M., Khan, Z., Anser, M.K., Jabeen, G. (2021), Do rural-urban migration and industrial agglomeration mitigate the environmental degradation across China's regional development levels? Sustainable Production and Consumption, 27, 679-697.

Alsagr, N., Almazor, E. (2021), The impact of financial development and geopolitical risk on renewable energy consumption: Evidence from emerging markets. Environmental Science and Pollution Research, 28(20), 25906-25919.

Alsagr, N., Van Hemmen, S. (2021), The impact of financial development and geopolitical risk on renewable energy consumption: Evidence from emerging markets. Environmental Science and Pollution Research, 28, 25906-25919.

Bagavos, C. (2019), On the multifaceted impact of migration on the fertility of receiving countries: Methodological insights and contemporary evidence for Europe, the United States, and Australia. Demographic Research, 41, 1-36.

Bauer, T.Z., Zimmerman, K. (2000), Causes of international migration: A survey. In: Gorter, P., Nijkamp, P., Poot, J., editors. Crossing Borders: Regional and Urban Perspectives on International Migration. London: Routledge. p95-127.

Benveniste, H., Oppenheimer, M., Fleurbaey, M. (2020), Effect of border policy on exposure and vulnerability to climate change. Proceedings of the National Academy of Sciences, 117(43), 26692-26702.

Bexheti, M. (2024), Impact of migration on global politics and security. European Journal of Law and Political Science, 3(2), 28-33.

Black, R., Adger, W., Arnell, N., Dercon, S., Geddes, A., Thomas, D. (2011), The effect of environmental change on human migration. Global Environmental Change, 21, S3-S11.

Boyd, M. (1989), Family and personal networks in international migration: Recent developments and new agendas. International Migration Review, 23(3), 638-670.

Broock, W.A., Scheinkman, J.A., Dechert, W.D., LeBaron, B. (1996), A test for independence based on the correlation dimension. Econometric Reviews, 15(3), 197-235.

Bu, Y., Wang, E., Qiu, Y., Möst, D. (2022), Impact assessment of population migration on energy consumption and carbon emissions in China: A spatial econometric investigation. Environmental Impact Assessment Review, 93, 106744.

Buchbinder, N., Jain, N., Menache, I. (2011), Online Job-Migration for Reducing the Electricity Bill in the Cloud. Berlin: Springer. p172-185.

Cai, Y., Wu, Y. (2021), Time-varying interactions between geopolitical risks and renewable energy consumption. International Review of Economics and Finance, 74, 116-137.

Caldara, D., Iacoviello, M. (2022), Measuring geopolitical risk. American Economic Review, 112(4), 1194-1225.

Castles, S. (2010), Understanding global migration: A social transformation perspective. Journal of Ethnic and Migration Studies, 36(10), 1565-1586.

Çelik, O., Çetiner, S., Abdallah, I., Udemba, E. (2023), Environmental implication of international migration on high- and middle-income countries: A comparative analysis. Energy and Environment, 35(7), 3399-3417.

Chen, J., Su, F., Jain, V., Salman, A., Tabash, M.I., Haddad, A.M., & Shabbir, M.S. (2022), Does renewable energy matter to achieve sustainable development goals? The impact of renewable energy strategies on sustainable economic growth. Frontiers in Energy Research, 10, 829252.

Criekemans, D. (2023), Geopolitics, Geoeconomics, and Energy Security in an Age of Transition Towards Renewables. In Handbook on the geopolitics of the energy transition Cheltenham, UK: Edward Elgar Publishing. p20-43.

Crowley, P.M. (2007), A guide to wavelets for economists. Journal of Economic Surveys, 21(2), 207-267.

De Haas, H. (2010), Migration and development: A theoretical perspective. International Migration Review, 44(1), 227-264.

Dedeoğlu, M., Koçak, E., Uucak, Z.Ş. (2021), The impact of immigration on human capital and carbon dioxide emissions in the USA: An empirical investigation. Air Quality, Atmosphere and Health, 14, 705-714.

Dhanoa, I., Khurmi, S. (2015), Analyzing Energy Consumption During VM Live Migration. In Proceedings of the International Conference on Computing, Communication & Automation. p584-588.

Docquier, F., Marfouk, A. (2006), International migration by education attainment, 1990-2000. In: International Migration, Remittances and the Brain Drain. London: Palgrave Macmillan. p151-199.

Dogan, E., Altinoz, B., Madaleno, M., Taskin, D. (2020), The impact of renewable energy consumption to economic growth: A replication and extension of. Energy Economics, 90, 104866.

Dogan, E., Hodžić, S., Šikić, T.F. (2023), Do energy and environmental taxes stimulate or inhibit renewable energy deployment in the European Union? Renewable Energy, 202, 1138-1145.

Dutta, A., Dutta, P. (2022), Geopolitical risk and renewable energy asset prices: Implications for sustainable development. Renewable Energy, 196, 518-525.

Edin, P.A., Fredriksson, P., Åslund, O. (2003), Ethnic enclaves and the economic success of immigrants-evidence from a natural experiment. The Quarterly Journal of Economics, 118(1), 329-357.

El-Karimi, M. (2021), Investigating the causal linkage among economic growth and renewable and non-renewable energy consumption: Cases of Germany, the UK, and France. OPEC Energy Review, 45(4), 414-437.

Ewеade, B., Uzuner, G., Akadiri, A., Lasisi, T. (2022), Japan energy mix and economic growth nexus: Focus on natural gas consumption. Energy and Environment, 35(2), 692-724.

Faist, T. (2010), Towards transnational studies: World theories, transnationalisation and changing institutions. Journal of Ethnic and Migration Studies, 36(10), 1665-1687.

Fawcett, J.T. (1989), Networks, linkages, and migration systems. International Migration Review, 23(3), 671-680.

Fen, L., Yang, C., Li, Z., Failler, P. (2021), Does geopolitics have an impact on energy trade? Empirical research on emerging countries. Sustainability, 13(9), 5199.

Flouros, F., Pistikou, V., Plakandaras, V. (2022), Geopolitical risk as a determinant of renewable energy investments. Energies, 15(4), 1498.

Gao, C., Tao, S., He, Y., Su, B., Sun, M., Mensah, I.A. (2021), Effect of population migration on spatial carbon emission transfers in China. Energy Policy, 156, 112450.

Gao, C., Zhong, Y., Mensah, I.A., Tao, S., He, Y. (2022), Spatio-temporal impact of global migration on carbon transfers based on complex network and stepwise regression analysis. Sustainability, 14(2), 844.

Gawel, E., Strunz, S., Lehmann, P. (2017), Support Policies for Renewables: Instrument Choice and Instrument Change from a Public Choice Perspective. Oxford: Oxford Academic. p80-100.

Genc, M., Gheasi, M., Nijkamp, P., Poot, J. (2012), The impact of immigration on international trade: A meta-analysis. In Migration Impact Assessment. United Kingdom: Edward Elgar Publishing. p301-337.

Gençay, R., Selçuk, F., Whitcher, B. (2002), Robustness of Systematic Risk Across Time Scales. Informal University of Windsor Working Paper.

Germond, B., Ha, F. (2018), Climate change and maritime security narrative: The case of the international maritime organisation. Journal of Environmental Studies and Sciences, 9(1), 1-12.

Gheasi, M., Nijkamp, P. (2017), A brief overview of international migration motives and impacts, with specific reference to FDI. Economies, 5(3), 31.

Ghosh, S. (2022), COVID-19, clean energy stock market, interest rate, oil prices, volatility index, geopolitical risk nexus: Evidence from quantile regression. Journal of Economics and Development, 24(4), 329-344.

Gould, D.M. (1994), Immigrant links to the home country: Empirical implications for US bilateral trade flows. The Review of Economics and Statistics, 76, 302-316.

Gözgör, G., Lau, C., Zeng, Y., Yan, C., Lin, Z. (2021), The impact of geopolitical risks on tourism supply in developing economies: The moderating role of social globalization. Journal of Travel Research, 61(4), 872-886.

Gray, C., Bilsborrow, R. (2013), Environmental influences on human migration in rural Ecuador. Demography, 50(4), 1217-1241.

Grecequet, M., DeWaard, J., Hellmann, J., Abel, G. (2017), Climate vulnerability and human migration in global perspective. Sustainability, 9(5), 720.

Gupta, R., Gözgör, G., Kaya, H., Demir, E. (2018), Effects of geopolitical risks on trade flows: Evidence from the gravity model. Eurasian Economic Review, 9(4), 515-530.

Gyimah, J., Yao, X., Tachega, M.A., Hayford, I. S., Opoku-Mensah, E. (2022), Renewable energy consumption and economic growth: New evidence from Ghana. Energy, 248, 123559.

Hache, E. (2018), Do renewable energies improve energy security in the long run? International Economics, 156, 127-135.

Häfner, M., Tagliapietra, S. (2020), The Global Energy Transition: A Review of the Existing Literature. Berlin: Springer. p1-24.

Han, J., Jeong, Y., Lee, I. (2013), Analysis of electric energy consumption patterns: A case study of a real-life office building. Applied Mechanics and Materials, 330, 158-162.

Harris, J.R., Todaro, M.P. (1970), Migration, unemployment and development: A two-sector analysis. The American Economic Review, 60(1), 126-142.

Hieu, V.M., Mai, N.H. (2023), Impact of renewable energy on economic growth? Novel evidence from developing countries through MMQR estimations. Environmental Science and Pollution Research, 30(1), 578-593.

Hu, J., Wang, G., Xu, X., Lu, Y. (2019), Study on dynamic service migration strategy with energy optimization in mobile edge computing. Mobile Information Systems, 2019, 5794870.

Huh, T., Choi, Y., Kim, J. (2018), The time-series of energy mix and transition: A comparative study of OECD countries through the fuzzy-set analysis. Energies, 11(11), 2992.

Husnain, M., Syed, Q., Bashir, A., Khan, M. (2022), Do geopolitical risk and energy consumption contribute to environmental degradation? Evidence from E7 countries. Environmental Science and Pollution Research, 29(27), 41640-41652.

Ivanovski, K., Hailemariam, A., Smyth, R. (2021), The effect of renewable and non-renewable energy consumption on economic growth: Non-parametric evidence. Journal of Cleaner Production, 286, 124956.

Khan, Y., Ming-yi, W. (2018), How the GCC economic crises effect labor migration: Evidence from Pakistan. Asian Journal of Economics and Empirical Research, 5(2), 139-146.

Komatsu, S., Ha, H.D., Kaneko, S. (2013), The effects of internal migration on residential energy consumption and CO_2 emissions: A case study in Hanoi. Energy for Sustainable Development, 17(6), 572-580.

Konovalova, M., Abuzov, A. (2023), Geopolitical crises, the energy sector, and the financial capital market. E3S Web of Conferences, 381, 01042.

Lalić, V. (2019), Securitization of migration in the European Union and the role of private security firms. Security Dialogues/Безбедносни Дијалози, 1, 47-61.

Lee, C., Xing, W., Wang, C. (2023), Impacts of energy security on economic development: Evidence from China. Energy Research Letters, 4(3), 33897.

Liu, F., Su, C.W., Qin, M., Lobonţ, O.R. (2023), Winner or loser? The bidirectional impact between geopolitical risk and energy transition from the renewable energy perspective. Energy, 283, 129174.

Liu, K. (2023), Research on the migration algorithm of mobile cloud computing. Advances in Computer Signals and Systems, 7(6), 070615.

Long, H., Li, J., Liu, H. (2022), Internal migration and associated carbon emission changes: Evidence from cities in China. Energy Economics, 110, 106010.

Lu, Z., Zhu, L., Lau, C., Isah, A., Zhu, X. (2021), The role of economic policy uncertainty in the renewable energy-growth nexus: Evidence from the Rossi-Wang causality test. Frontiers in Energy Research, 9, 750652.

Massey, D.S., Arango, J., Hugo, G., Kouaouci, A., Pellegrino, A., Taylor, J.E. (1993), Theories of international migration: A review and appraisal. Population and Development Review, 19(3), 431-466.

McCarthy, K. (2018), Surviving regulation: How European energy industries are adapting to new rules. Journal of Business Strategy, 39(4), 28-33.

Meckling, J. (2018), Governing renewables: Policy feedback in a global energy transition. Environment and Planning C: Politics and Space, 37(2), 317-338.

Mohlin, K., Bi, A., Brooks, S., Camuzeaux, J., Stoerk, T. (2019), Turning the corner on U.S. power sector CO_2 emissions: A 1990-2015 state-level analysis. Environmental Research Letters, 14(8), 084049.

Nijkamp, P., Gheasi, M., Rietveld, P. (2011), Migrants and international economic linkages: A meta-overview. Spatial Economic Analysis, 6(4), 359-376.

O'Sullivan, M., Øverland, I., Sandalow, D. (2017), The geopolitics of renewable energy. SSRN Electronic Journal, Harvard Kennedy School, Massachusetts.

Otero, N., Martius, O., Allen, S., Bloomfield, H., Schaefli, B. (2022), Characterizing renewable energy compound events across Europe using a logistic regression-based approach. Meteorological Applications, 29(5), 2089.

Page, J., Plaza, S. (2006), Migration remittances and development: A review of global evidence. Journal of African Economies, 15(suppl 2), 245-336.

Paravantis, J., Kontoulis, N. (2020), Energy Security and Renewable Energy: A Geopolitical Perspective. London: IntechOpen.

Peña-Ramos, J., Pino-García, M., Sánchez-Bayón, A. (2021), The Spanish energy transition into the EU Green Deal: Alignments and paradoxes. Energies, 14(9), 2535.

Percival, D.B., Mofjeld, H.O. (1997), Analysis of subtidal coastal sea level fluctuations using wavelets. Journal of the American Statistical Association, 92(439), 868-880.

Percival, D.B., Walden, A.T. (2000), Wavelet Methods for Time Series Analysis. Vol. 4. Cambridge: Cambridge University Press.

Peters, G., Minx, J., Weber, C., Edenhofer, O. (2011), Growth in emission transfers via international trade from 1990 to 2008. Proceedings of the National Academy of Sciences, 108(21), 8903-8908.

Piore, M.J. (2018), The dual labor market: theory and implications. In Social stratification. Routledge; pp. 629-640.

Portes, A. (2010), Migration and social change: Some conceptual reflections. Journal of Ethnic and Migration Studies, 36(10), 1537-1563.

Price, C., Feldmeyer, B. (2011), The environmental impact of immigration: An analysis of the effects of immigrant concentration on air pollution levels. Population Research and Policy Review, 31(1), 119-140.

Qi, W., Li, G. (2020), Residential carbon emission embedded in China's inter-provincial population migration. Energy Policy, 136, 111065.

Rafiq, S., Nielsen, I., Smyth, R. (2017), Effect of internal migration on the environment in China. Energy Economics, 64, 31–44.

Sadorsky, P. (2009), Renewable energy consumption and income in emerging economies. Energy Policy, 37(10), 4021-4028.

Saidi, K., Omri, A. (2020), The impact of renewable energy on carbon emissions and economic growth in 15 major renewable energy-consuming countries. Environmental Research, 186, 109567.

Sarker, P.K., Bouri, E., Marco, C.K.L. (2023), Asymmetric effects of climate policy uncertainty, geopolitical risk, and crude oil prices on clean energy prices. Environmental Science and Pollution Research, 30(6), 15797-15807.

Schwert, W. (1989), Tests for unit roots: A Monte Carlo investigation. Journal of Business and Economic Statistics, 7, 147-159.

Scita, R., Raimondi, P., Noussan, M. (2020), Green hydrogen: The holy grail of decarbonisation? An analysis of the technical and geopolitical implications of the future hydrogen economy. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3709789

Shahbaz, M., Raghutla, C., Chittedi, K.R., Jiao, Z., Vo, X.V. (2020), The effect of renewable energy consumption on economic growth: Evidence from the renewable energy country attractive index. Energy, 207, 118162.

Shi, X., Cui, L., Huang, Z., Zeng, P., Qiu, T., Fu, L., Jiang, Q. (2023), Impact of internal migration on household energy poverty: Empirical evidence from rural China. Applied Energy, 350, 121780.

Sim, N., Zhou, H. (2015), Oil prices, US stock return, and the dependence between their quantiles. Journal of Banking and Finance, 55, 1-8.

Simbolon, S., Simbolon, D. (2024), Sustainable workforce in a green era: Indonesia's energy sector transition. International Journal of Energy Economics and Policy, 14(3), 702-710.

Singh, N., Nyuur, R., Richmond, B. (2019), Renewable energy development as a driver of economic growth: Evidence from multivariate panel data analysis. Sustainability, 11(8), 2418.

Sohag, K., Hammoudeh, S., Elsayed, A.H., Mariev, O., Safonova, Y. (2022), Do geopolitical events transmit opportunity or threat to green markets? Decomposed measures of geopolitical risks. Energy Economics, 111, 106068.

Stark, O., Bloom, D.E. (1985), The new economics of labor migration. The American Economic Review, 75(2), 173-178.

Stokes, L., Breetz, H. (2018), Politics in the U.S. energy transition: Case studies of solar, wind, biofuels and electric vehicles policy. Energy Policy, 113, 76-86.

Sweidan, O.D. (2021), The geopolitical risk effect on the US renewable energy deployment. Journal of Cleaner Production, 293, 126189.

Torasa, C., Sittisom, W., Mekhum, W. (2020), What difference urban sprawl, industrialization and migration can make in energy consumption? A time-series analysis of Thailand. International Journal of Energy Economics and Policy, 10(5), 577-583.

Tranos, E., Gheasi, M., Nijkamp, P. (2015), International migration: A global complex network. Environment and Planning B: Planning and Design, 42(1), 4-22.

Ullah, A., Hasan, N., Mohamad, S., Chattoraj, D. (2020), Migration and security: Implications for minority migrant groups. India Quarterly: A Journal of International Affairs, 76(1), 136-153.

Vinogradova, M., Kulyamina, O., Koroleva, V., Larionova, A. (2015), The impact of migration processes on the national security system of Russia. Mediterranean Journal of Social Sciences, 6(3), 161.

Vivoda, V. (2012), Japan's energy security predicament post-Fukushima. Energy Policy, 46, 135-143.

Wang, E.Z., Lee, C.C. (2022), The impact of clean energy consumption on economic growth in China: Is environmental regulation a curse or a blessing? International Review of Economics and Finance, 77, 39-58.

Wang, J., Gu, H., Yu, J., Song, Y., He, X., Song, Y. (2022), Research on virtual machine consolidation strategy based on combined prediction and energy-aware in cloud computing platform. Journal of Cloud Computing: Advances, Systems and Applications, 11(1), 50.

Wang, Q., Wang, L. (2020), Renewable energy consumption and economic growth in OECD countries: A nonlinear panel data analysis. Energy, 207, 118200.

Wang, R., Chen, G., Feng, J. (2022c), Carbon footprint patterns of domestic migrants in China and 1.5 °C mitigation pathways. Environmental Research Letters, 17(12), 124023.

Wang, S., Wang, J., Wang, W. (2023), Do geopolitical risks facilitate the global energy transition? Evidence from 39 countries in the world. Resources Policy, 85, 103952.

Wei, B. (2012), A novel energy optimized and workload adaptive modeling for live migration. International Journal of Machine Learning and Computing, 2, 162-167.

Wei, T., Dong, W., Moore, J., Yan, Q., Song, Y., Yang, Z.,… & Chen, D. (2016), Quantitative estimation of the climatic effects of carbon transferred by international trade. Scientific Reports, 6(1), 28046.

Wen, J., Zhao, X., Wang, Q., Chang, C. (2020), The impact of international sanctions on energy security. Energy and Environment, 32(3), 458-480.

Xheladini, F. (2016), Security implications of forced migration and the refugee flows. European Journal of Interdisciplinary Studies, 2(2), 104.

Yang, Z., Yuan, X., Hu, J., Liu, D., Tang, W. (2024), The impact of the proportion of renewable energy consumption on geopolitical risks in the United States and the United Kingdom. Energy Exploration and Exploitation, 42(6), 1958-1986.

Yeboah, C. (2016), Internal migration, remittances and welfare impacts: A case study in Dormaa Municipality, Ghana. African Human Mobility Review, 2(3), 773.

Zhang, C., Cao, X., Ramaswami, A. (2016), A novel analysis of consumption-based carbon footprints in China: Unpacking the effects of urban settlement and rural-to-urban migration. Global Environmental Change, 39, 285-293.

Zhang, D., Chen, X.H., Lau, C.K.M., Cai, Y. (2023b), The causal relationship between green finance and geopolitical risk: Implications for environmental management. Journal of Environmental Management, 327, 116949.

Zhang, S., Shinwari, R., Zhao, S. (2023a), Energy transition, geopolitical risk, and natural resources extraction: A novel perspective of energy transition and resources extraction. Resources Policy, 83, 1-9.

Zhao, Y., Chen, L., Zhang, Y. (2023), Spillover effects of geopolitical risks on global energy markets: Evidence from the COVAR and CAVIAR-EGARCH model. Energy Exploration & Exploitation, 42(2), 772-788.

Zhou, Y., Liu, Y., Wu, W., Li, Y. (2015), Effects of rural–urban development transformation on energy consumption and CO_2 emissions: A regional analysis in China. Renewable and Sustainable Energy Reviews, 52, 863-875.