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Different Regions' Climate Vulnerability and the Success of Transitioning to Renewable Energy

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ABSTRACT

Regional diversity and the transition to renewable energy sources may disproportionately impact the effectiveness of adaptation strategies to the Changes in the environment. The influences of general energy policy on the system for measuring climate sensitivity are still being determined, even though many countries are trying to promote renewable energy to mitigate climate change. To evaluate the effectiveness of climate adaptation strategies along the impact and susceptibility dimensions, we use a variety of renewable energy applications here. Using panel data regression and the Fuzzy Analytic Hierarchy Process, we analyze the temporal and spatial relationship between the worldwide transition to renewable energy and sensitivity to the climate. Although the percentage of renewable energy increases as countries become more aware of and prepared for climate change, the shift to renewables is unique across all countries. Countries with a higher capacity for adaptation are targeted for support of renewable energy, while vulnerable countries are ignored. These findings suggest that the advantages of transitioning to renewable energy sources may be reduced while current policies fail to account for regional differences in climate sensitivity, increasing climate inequality. Inconsistent regional adaption to climate change is a potential outcome of policies favouring renewable energy, which we empirically demonstrate in our study.

Keyword: Climate Resilience; Energy Transition; Changing Climate; Renewable Energy; Climate Vulnerability

1. INTRODUCTION

One definition of resilience is the ability of an individual, family, community, country, or area to resist stressors and shocks, adapt to them, and recover swiftly from them. One of these pressures is climate change, which has implications for infrastructure safety, social security, biodiversity protection, geopolitical stability (climate refugees), and health. One of the most obvious adverse effects of climate change on urban environments is the propensity of buildings to use more energy and produce more waste, raising concerns about the sustainability of structures and residents' comfort (Sharma et al., 2022; Ahmad et al., 2019). Using renewable energy has been emphasized as a critical strategy for reducing and preparing for climate change's consequences. In the battle against climate change and to decrease greenhouse gas emissions, renewable energy has proven to be a powerful weapon (Ibrahim et al., 2022). Many countries have switched from fossil fuels to renewable energy sources, particularly those with high levels of climate risk.

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One hundred twenty-three countries were generating renewable energy as of 2000 (Sonar et al., 2022). Using renewable energy has been emphasized as a critical strategy for reducing and preparing for climate change's consequences. Involvement from the building and transportation industries throughout the planning, creating and operating the country's energy infrastructure produces superior results. The use of non-dispatchable renewable energy technologies will likely expand with the support of these firms, which would significantly improve the flexibility of the power system. When the building and transportation sectors are linked with the energy infrastructure, additional opportunities are created in the energy sector (Geddes et al., 2018; Ferreira et al., 2023). These opportunities include creating employment, expanding technical skills, and rapidly transitioning from fossil fuels. In addition, these opportunities yield more opportunities in the energy sector. The construction and transportation sectors have significant energy needs, which may make it difficult to satisfy those demands throughout the transition to a cleaner energy source (Sebestyén & Abonyi, 2021). Incorporating demand response strategies that use the flexibility of the building and transportation industries will further complicate the ecosystem generated due to integrating energy infrastructure with these other sectors. A change in just one component of an ecosystem might have ramifications for the whole system. In light of this, it is clear that the urban energy ecosystem has to have its stability and flexibility improved throughout this transition period (Rempel & Gupta, 2021).

The change in the energy environment is primarily caused by the severe weather events directly resulting from global warming. The frequency and intensity of severe weather events have progressively increased over the last decade, and this tendency will continue into the foreseeable future. The impacts of these mishaps are being felt across the board in every energy system component. For example, a recent extreme cold event in Texas immediately affected the built environment and produced a massive jump in the demand for heating fuel. This led to an increase in the price of heating fuel. The absence of fuel for heating was instantly noticeable (Mont et al., 2021).

The evolution of the energy ecosystem is significantly impacted by weather extremes brought on by climate change. Extreme weather events have been more frequent and severe over the last ten years, and this tendency is predicted to continue. The impact of these changes on the energy environment is extensive. For instance, the recent very cold occurrence immediately impacted the state's building stock and markedly increased the need for heating energy (Lamichhane et al., 2021; Van de Ven & Fouquet, 2017). Both wind and gas turbines could not function due to the very low temperatures. Due to an imbalance between demand and generation in many places, the transmission and distribution system collapsed, resulting in over 200 fatalities and a loss of over 130 billion dollars for the state. It is challenging to build resilience because of the cumulative effects of catastrophic climatic events on the whole energy environment. This highlights how important it is to promote interdependence and resilience. Consequently, increasing sustainability, interconnectedness, and resilience is necessary to combat and adapt to climate change, a significant issue for human civilization (Bracco et al., 2018).

Despite the apparent connection between renewable energy and environmentally conscious actions, research has shown various explanations for the differences in national renewable energy expenditures. Many variables, such as technical advancement, energy security, power costs, economies reliant on fossil fuels, environmental concerns, a focus on social domination, etc (Phillips et al., 2020), may influence the adoption of renewable energy sources. Determinants of renewable energy deployments include political variables (like tariffs for feed-in tariffs or R&D spending), social and economic variables (such as income and use of energy), and country-specific variables (such as the demand for energy from renewable sources) (Salm et al., 2023). As a result, different countries and areas will experience the consequences of climate change differently, depending on their socioeconomic status. As a result, a sufficient integration of regional, climate-sensitive features is necessary for an efficient renewable energy plan. This is due to the rapid, accelerated transition to renewable energy prioritizing climate mitigation, which may lessen the favourable effects of renewables on climate adaptation if it raises regional disparities in the susceptibility to climate change (Reader et al., 2023).

Despite the relevance of impact and susceptibility factors in environmental research, only several studies investigate the consequences of switching to renewable energy sources on climate change. Most research focuses on adaptive capacity, adjusting social, economic, and environmental structures to climate-related stimuli and implications. However, in the global research of the energy-climate nexus, the idea needs to be adequately put into practice. Exposure to climate change, sensitivity to climate change, and capacity for adaptation are the three interrelated components of climate change vulnerability. This research fills the information vacuum mentioned earlier by thoroughly evaluating how climate adaptation has impacted the adoption of renewable energy sources in 121 countries while accounting for climate influence and vulnerability. We used a panel data analysis technique to examine reliable international datasets from the last three decades. Using the climate vulnerability framework proposed by the IPCC, we chose acceptable indicators that included all aspects of climate adaptation. Our innovative strategy integrates climate vulnerability and adaptation into the transition to renewable energy, offering in-depth insights for implementing that move effectively in the look of climate alteration.

2. LITERATURE REVIEW

The value of renewable energy sources in the fight against climate change has been emphasized worldwide. There is a large body of evidence suggesting that using renewable energy sources improves climate adaptation and the potential to mitigate climate change by lowering carbon emissions. It has been shown, for instance, that if Thailand were to transition to renewable energy, the country could see a reduction in carbon emissions of over 41 per cent compared to a business-as-usual scenario in which the country uses only renewable energy (Rodríguez et al. 2021). By switching to renewable energy, Iran might cut its carbon emissions by 7-41%, according to some estimates. As a result of expanding their usage of renewable energy, the United States, China, seventeen Organization for Economic Cooperation and Development (OECD) countries, Brazil, Russia, India, China, South Africa, and another thirty countries have all reduced their carbon emissions (Alkon et al., 2019).

Regarding climate adaptation, renewable energy's effect on releasing carbon dioxide is crucial. The Intergovernmental Panel on Climate Change, or IPCC, believes that the temperature increase can significantly magnify the effects of changes in the climate, particularly by increasing the frequency and severity of severe weather events (Ranck et al., 2023). Renewable energy sources do not need water for cooling like traditional thermoelectric power production techniques, which is good news for the aquatic environment and water security. Using decentralized renewable energy-producing technologies rather than centralized ones lowers the chance of a catastrophic failure in the energy supply chain. Renewable energy sources may lower elevated temperatures and the ensuing heat island effects, which can lower mortality due to heat in susceptible populations (Kokkinos et al., 2021).

Energy security, social and economic growth, energy availability, and climate change mitigation have all been influenced by the three distinct stages of renewable energy development over the last several decades. The initial wave of renewable energy production was spurred on by the oil price increases that resulted from the geographically limited supply of petroleum (Frantzeskaki, 2019). Clean energy sources improve energy security by reducing reliance on fossil fuels and expanding the range of local energy alternatives. The second phase of the Millennium Growth Goals emphasized expanding access to safe, clean energy and promoting sustainable socioeconomic growth. Since energy generated from renewable sources is grid-free, it has the potential to significantly support economic growth and the reduction of severe poverty, particularly in emerging nations (Lefore et al., 2021). In this third phase, decarbonization via clean energy sources has drawn increased attention in addition to climate variation justification and adaptation energies since it may increase sensitivity to climate risks and consequences by increasing financial and social operational capacity (Orlove, 2022).

Climate change sensitivity has increased over the last ten years to consider non-climatic characteristics like adaption capacity. Most recent research gives socioeconomic factors less weight than meteorological ones despite dynamic climate susceptibility because of their close linkages to social systems and spatiotemporal scales. Our study focuses on the literature on this topic since the IPCC's second-generation vulnerability assessment implies that non-climatic variables may directly affect climate impacts and susceptibility (Sovacool & Mukherjee, 2011).

The IPCC classifies each function as a function of exposure, susceptibility, and adaptation ability. Several researchers have discovered traits related to each function. "The concept of climate change exposure," which explains "the nature and degree to which a system is exposed to climatic variations," may be used to characterize extreme weather events, including tropical cyclones, very high temperatures, and unexpected precipitation (Geels, 2014; Orlove, 2022). Sensitivity, or the degree to which climatic stimuli affect a system, is often shown in several physical and social features, including closeness to the shore, height above sea level, urban congestion, and low-income people. The degree to which a civilization can adapt to the disruptive effects of climate change depends on the condition of its infrastructure, institutions, economy, and society. To evaluate this criterion, various metrics are utilized, such as GDP per capita, R&D expenditures, transit accessibility, literacy rates, and access to healthcare and hospital beds. According to the IPCC's conceptual framework, an ecosystem is vulnerable if exposed to and sensitive to the impacts of climate change. Contrarily, exposure and sensitivity work together to influence how a system has an effect (Cucca & Thaler, 2023).

3. METHODOLOGY

The Fuzzy Investigative Hierarchy Process is used to analyze the impact and susceptibility of a switch to energy from renewable sources using data on global renewable power output and estimates of environmental sensitivity. We examine 121 countries whose economies have been driven by renewable energy during the last three decades since the consequences of climate change are widespread and cumulative. An accurate global deployment trend for climate change adaptation is made possible by considering all countries that use renewable energy, regardless of their degree of use. During the study's period, renewable energy was used in 115 different countries (Kremen & Miles, 2012). The other six countries progressively switched to renewable energy at that time. We investigate the heterogeneity in climate influence and susceptibility across geographically distributed transitions to renewable energy using panel data regression.

3.1. Selecting Quantifiable Indicators and Data on Climate Change

Using the exposure, sensitivity, and adaptive capacity framework developed by the IPCC, we evaluate the global implications of changing the climate. Based on the research on assessing vulnerability to climate change Table 1, we use significant worldwide indicators (Ansari & Holz, 2020). We use the following sorts of expert survey methodologies due to the subjective character of indication selection and the relative significance of evaluated indicators: The 21 most-used indicators in the relevant literature were narrowed down to the 18 that, in the opinion of the experts, best-characterised climate vulnerability. Second, we use the AHP method to assign relative importance ratings to the various signals. Third, we use a fuzzy membership function to sidestep problems associated with AHP weighting based on human discretion.

Table 1: Indicators of Climate Change

Aspect	Indicator	Reference
Exposure	Storm occurrences Precipitation Victims of natural disasters Anomaly in Temperature	Curran, (2020)
Sensitivity	Rise in sea levels	
	Proximity to the Coast Elevation Density of the population Population swarming Rise in sea levels	Mathew, & Panchanatham, (2016.
Adaptive	Economy	Bulkeley & Tuts, (2013)
Capacity	Efficiency in Government Patrons of mobile service Electricity Availability Health Coverage Research & Development Economy Education Health care services Infrastructure	Surminski et al., (2016)

We utilize the United Nations Human Growth Index methodology, with its proposed beginning of 0.8, to avoid unfairness caused by the 121 countries' varying levels of development (particularly between wealthy and poor countries). A country's degree of progress has likely changed because we focus on data from the previous three decades. Our results are reliable and free of convergence since we utilize yearly financial growth and status data. However, several developing countries have started organizing massive amounts of renewable energy in the last decade, indicating that analytical findings may be biased if both developed and developing countries are categorized separately (Planas-Carbonell et al., 2023). We include a comparison group with an HDI of 0.7–0.8 to confirm our findings' reliability further. The World Bank and the Global Economy have collated statistics on the quantity and potential of renewable energy generation from 1992 to 2019. Data on the countries affected by each storm or typhoon is collected by the United States.

According to the World Meteorological Organization, a tropical cyclone is a low-pressure system with more than 34 knots of sustained surface winds.

3.2. Environment Change Assessment Indicators

We create custom climate impact and vulnerability indices that account for various climate vulnerability factors to evaluate the longitudinal connection between renewable energy uptake and environmental change indicators. The data must be normalized, and each component must be given its due weight since different indicators use different scales.

$$\Upsilon_{ijt} = \frac{\chi_{ijt} - \rho_{ijt}}{\varphi_{ijt} - \rho_{ijt}} \quad (1)$$

For meteorological measurer I in country j in year t, the normalized Yijt ranges from 0 to 1, with 0 being the minimum and 1 the maximum value. The F-AHP method is extensively used to assess the severity and vulnerability of climate change. This method has seen extensive use in assessing climate sensitivity, and it includes comparing data that indicate each other to get a mean of the expected results.

Given the relative importance of various environmental indications, it is essential to establish suitable weight numbers between and within the climate susceptibility aspects (climate exposure, susceptibility, and adaptive capability). The significance of variables like storm velocity and temperature anomaly may shift depending on who is looking. We looked for experts in climate change, disaster preparation, public administration, and resilience-building techniques who had been appointed to their positions of authority by respectable organizations to ensure the accuracy of the responses. There was also a minimum amount of time spent working in the industry, usually about 20 years. Since 23 of the invited experts did not reply, we use the results of the expert screening approaches to determine the relative importance of the indicators we use to estimate climate vulnerability.

Considering that bias may influence human judgment, this limitation still stands even if the consistency ratio values in the AHP matrix are all 0.1. This would suggest that the experts' AHP weights are consistent. There is a connection between Saaty's linguistic ideas and the fuzzy triangle scale shown in Table 5. Using Equations (2) and (3), we can calculate the F-AHP matrix. We get the following results if the equation =1ij ij =1 is written for each i and j in the intervals.

$$A_i = \sum_{j=1}^{n} 1 \left(l_{ij}, m_{ij}, u_{ij}\right)\left[\sum_{i=1}^{n} 1 \cdot \sum_{j=1}^{n} 1 \left(l_{ij}, m_{ij}, u_{ij}\right)\right]^{-1} \quad (2)$$

$$\zeta_i = \frac{\min \eta\left(A_i \geq A_j\right)}{\sum_{k=1}^{n} \min \eta\left(A_k \geq A_j\right)} \quad (3)$$

The ordinates mi and mj depict the most significant intersection of the triangle membership function, and the probability degree is

$$\left(u_i - l_j\right)/\left[\left(u_i - m_i\right) + \left(m_j - l_j\right)\right] \quad (3)$$

The capital letter i represents the indication of its weight in the F-AHP. It equals one if mi > mj and ui = lj, and it equals 0 if mi = mj. In the corresponding supplementary tables (Tables 6 and 7), you will find the complete AHP and F-AHP matrices. Using the formula shown below,

$$W_t = \left(\sum_{f=1}^{n} \omega_{e,t} \times \zeta_{f,t}\right) + \left(\sum_{g=1}^{n} \omega_{s,t} \times \zeta_{g,t}\right) - \left(\sum_{h=1}^{n} \omega_{c,t} \times \zeta_{h,t}\right) (4)$$

We can get a complete set of F-AHP weights. The sections on exposure, sensitivity, and adaptive capacity are represented by the letters e, s, and c, respectively, to indicate their relative importance. The markers of fish climatic exposure (f), sensitivity to climate change (g), and adaptation ability (h) are denoted by the letters f, g, and h, respectively. It denotes the overall weighted F-AHP value for Country t.

3.3. Renewable energy and global warming.

To assess how switching to renewable energy sources could affect the characteristics of climate susceptibility,

$$ln\mathrm{Y}_{it} = \alpha_0 + \alpha_1 \mathrm{E}_{it} + \alpha_2 \mathrm{S}_{it} + \alpha_3 \mathrm{X}_{it} + c_i + \varepsilon_{it} \quad (5)$$

Vectors include things like Eit (climate exposure), Sit (climate vulnerability), and Xit (climate adaptation capabilities). The Ci dummy variable represents recession. An indicator of a country's potential for and rate of exponential growth in renewable energy production in year t. indeed, there is a more appropriate way to put that. We choose a random impact model slightly more than a fixed impact model since Prob>chi2 in the Hausman specification test is more than 0.05 across all models and periods.

4. RESULTS AND ANALYSIS

Throughout our examined periods, most adaptability indices reacted to national renewable energy policy Table 2. GDP per capita, governmental effectiveness and access to electricity, R&D, human development index, and the switch to renewable energy all have beneficial relationships. At the 5% significance level, education and healthcare do not affect the production of renewable energy (columns 1-3) (Dafermos et al., 2021). Precipitation, temperature anomalies, sea level rise, urban density, and sensitive populations are examples of climate impact (exposure and sensitivity) indicators. These indicators typically decline as renewable energy output and capacity grow. The coefficients of adaptation indicators have increased over the last 14 years (2006-2019). However, the results from 1992-2005 are still substantially consistent with those from after 2005.

Table 2: Regression Analysis

		(1) RPG	(2) RPG	(3) RPG	(4) RPC	(5) RPC	(6) RPC
Exposure	Storm	1.005	1.002	.006	.008	.004	.008
	Casualty	−1.002	−1.002	.002	−.002	.003	−.005
	Precipitation	1.284	1.215	.291	.235	.197	.214
	Temperature	−1.005	1.011	.013	.021	−.022	.024
Sensitivity	Sea level rise	1.338	1.335	.219	.242	.228	.188
	Coastal prox.	−1.079	−1.033	−.327	−.225	−.156	−.364
	Elevation	−1.031	−1.028	−.038	−.095	−.158	−.028
	Pop density	−1.056	1.018	.034	−.005	−.012	.075
	Urban density	1.047	1.084	.102	.074	.108	.153
	Vulnerable	1.104	1.097	.167	.072	.115	.142
Adaptive	GDPPC	1.066	1.024	.078	.153	.107	.092

		(1) RPG	(2) RPG	(3) RPG	(4) RPC	(5) RPC	(6) RPC
Capacity	Gov effect	1.081	1.103	.044	.074	−.012	.048
	Elec access	1.128	1.127	.282	.145	.095	.258
	R&D	1.213	1.021	.257	.27	.114	.263
	HDI	1.546	1.422	.369	.349	.271	.377
	Road	1.033	−1.024	.078	.015	−.045	.064
	Education	−1.014	−1.005	.039	.073	.045	.094
	Hospital	−1.004	1.004	−.025	−.008	.004	−.038
	Recess	1.005	−1.007	−.003	.011	.006	.004
	Observation	3298	1636	1663	3295	51618	1678
	R^2	1.469	1.255	.347	.462	.268	.378

Notes: Dependent variables are logged renewable power generation (columns 1–3) and logged renewable power capacity (columns 4–6). The main entries in each column report the standardized beta coefficients estimated by the random effect model.

Table 3 shows that high-adaptive capability countries to low-income countries, which would be less prepared to adjust to climate change, have actively pushed for renewable energy. More trustworthy findings for the recent age (2006-2019) show that affluent nations strive for more renewable energy while impoverished countries install less renewable energy. This paradox may worsen as a consequence of recent developments in renewable technology. This would lead to an inequity in deploying renewable energy sources across different regions. This trend may become more noticeable when combined with other endogenous factors like political and economic issues. In low-income rural areas, where renewable sources are either unavailable or too expensive, conventional biomass and fossil fuels are increasingly used for cooking and heating. Another potential factor is insufficient funds for renewable energy and infrastructure maintenance initiatives. Factors like widespread ignorance about renewable energy's problems and a decision-making approach that demands unanimous consent are to blame. Several of the elements mentioned above affect the possibility of regional differences in developing nations' investments in renewable energy (Roberts & O'Donoghue, 2013).

The starting point for each metric was standardized. We used a 5-point scale, with 1 being the most negligible change in renewables and five being the most, to visualize the variation in renewable energy deployment across climate change impact and vulnerability dimensions. Two indices, one measuring the influence of renewables on the climate and the other measuring their susceptibility to climate change, may be generated using this clustering method.

Table 3: Demographic trend results

	Expected population (Thousands of people)			**Expected population variation (Thousands of people)**	
	2020	2050	2080	2050–2020	2080–2020
Coastal prox.	37.23	45.31	47.16	9.09	8.94
Elevation	37.23	44.42	46.01	8.18	9.79
Pop density	37.23	34.06	27.65	–	–
Urban density	37.23	41.98	39.89	5.78	3.67
Vulnerable	37.23	55.43	67.52	19.21	31.28
GDPPC	48.49	51.88	45.99	2.43	–
Gov effect	48.49	48.27	44.65	–	–
Elec access	48.49	42.85	28.94	–	–
R&D	48.49	48.03	39.39	–	–
HDI	48.49	57.91	59.44	8.43	9.96

Table 4 indicates that the renewables-climate vulnerability index is our dependent variable of interest since there is a strong relationship between climate sensitivity indicators and the volatility of renewable energy. We utilize the estimated F-AHP weighted renewables-climate vulnerability index as our primary dependent variable to test the hypothesis that the increased usage of renewable energy sources would increase spatial inequality due to differences in provision along the dimensions of climate effect and vulnerability (Stadelmann et al., 2013). Here, we show that increased renewable energy generation is not associated with decreased climate vulnerability over various adaptive capacity characteristics. These findings demonstrate a wider gap between renewable energy and climate sensitivity in low-income developing countries compared to high-income industrialized nations. Independently estimating high-, middle-, and low-income countries is a robustness check for assessing the effects of developing nations like China and India, which have deployed significant volumes of renewable energy over the last decade.

All factors reflecting adaptation capacity have negative coefficients in low-income nations (Abrams et al., 2021). The gap between climate vulnerability and renewable energy is, nevertheless, being closed by the majority of climate sensitivity and exposure attributes. Recent times have shown the most consistent and robust effects (Column 3) of climate change indicators on the gap. Table 4 separates sensitivity factors (proximity to coast, elevation, population density, and urban density) from adaptive capabilities (GDP per capita, government influence, research and development, education, and hospitals) in separate columns.

Table 4: Development of total built surfaces

	(1)	(2)	(3)	(4)	(5)	(6)
	2050			2080	2050	2080
Coastal prox.	169.28	207.88	4.65E+5	5.48E+5	3.92E+5	4.59E+5
Elevation	148.82	183.88	4.25E+5	4.96E+5	3.58E5	4.17E+5
Pop density	–	–	–	–	–	–
Urban density	98.36	56.53	3.15E+05	1.20E+05	1.72E+05	9.59E+04
Vulnerable	378.13	632.06	9.19E+05	1.36E+06	6.55E+05	1.09E+06
GDPPC	471.66	–	9.47E+05	–	7.46E+05	−2.37E+06
Gov effect	–	–	–	–	–	–
Elec access	–	–	–	–	–	–
R&D	–	–	–	–	–	–
HDI	2468.44	2977.79	5.4E+06	5.36E+06	3.91E+06	4.72E+06

Table 5 shows the variations in producing renewable energy sources and vulnerability to climate change, which are also essential factors. Most of the information in each column comprises coefficients obtained from a random effect model. An indentation is used to differentiate between common errors. The research concludes that recent developments in renewable energy technologies have worsened the issue when adaptive capacity elements are not considered when creating policies (Goodwin et al., 2022). We do an extra robustness check by eliminating 27 nations from the dataset whose average renewable power generation is less than one billion kilowatt-hours since, in certain countries, the use of renewables is much less than the total energy consumption. Though the findings are comparable across columns, rows 2 and 3 have the most excellent R-squared values. Due to the disparity between the usage of renewable energy and climate adaptation, some people are concerned that the current renewable energy plan may worsen climate inequality. Most of the world's poorest people have the least advanced economies, governments, research and development, roadways, populations, and healthcare systems.

Renewable energy has been encouraged as a response to climate change. However, our results show that less effort has been made to promote the use of renewable energy in nations with weak adaptive capacities. However, more developed countries are embracing renewable energy sources more and more due to their increased capability for adaptation.

Table 5: Demonstrates how switching to renewable energy sources might mitigate climate change

		(1)		(2)		(3)	
		1992–2019		**1992–2005**		**2006–2019**	
Exposure	Storm	.014	(.006)	−.008	(.017)	.013	(.008)
	Casualty	.028	(.007)	.018	(.014)	.096	(.087)
	Precipitation	.037	(.004)	.028	(.009)	.024	(.003)
	Temperature	.021	(.002)	.006	(.005)	.022	(.003)
Sensitivity	Sea level rise	.031	(.008)	.025	(.018)	.028	(.005)
	Coastal prox.	.014	(.008)	−.038	(.019)	.022	(.005)
	Elevation	.006	(.008)	−.005	(.017)	.018	(.005)
	Pop density	.003	(.008)	−.028	(.021)	.021	(.006)
	Urban density	.009	(.004)	−.003	(.008)	.023	(.003)
	Vulnerable	.021	(.002)	.019	(.004)	.024	(.002)
Adaptive	GDPPC	−.013	(.004)	.094	(.012)	−.024	(.005)
Capacity	Gov effect	−.028	(.003)	.005	(.009)	−.029	(.004)
	Elec access	−.031	(.003)	−.055	(.007)	−.024	(.003)
	R&D	.019	(.003)	.015	(.008)	−.017	(.003)
	HDI	−.024	(.003)	−.018	(.011)	−.027	(.004)
	Road	−.021	(.002)	−.016	(.005)	−.018	(.002)
	Education	−.024	(.002)	.023	(.004)	−.024	(.002)
	Hospital	−.017	(.002)	.006	(.003)	−.018	(.002)
	Recess	−.003	(.002)	−.002	(.005)	−.004	(.003)
	Constant	.534	(.013)	.331	(.045)	.602	(.016)
	Observation	3388		856		856	
	R^2	.777		.301		.551	

4.3 DISCUSSION

This action might lessen renewable energy's advantages and worsen climate justice problems. Building resilience to climate change requires addressing socioeconomic factors that significantly impact a system's capacity to respond to climate stimuli because vulnerability to climate change is a function of a system's exposure to, sensitivity to, and capacity for adapting to environmental changes. If this aspect is disregarded in nations with little ability for adaptation, climate inequality (Elmqvist et al., 2019), which renders already fragile countries even more susceptible, may occur. Nations and cultures all over the globe should think about developing policies that encourage the use of renewable energy and nurture the development of adaptive capabilities to decrease the adverse consequences of climate change. Our results provide fresh viewpoints and actual information for discussions on climate inequalities associated with the switch to renewable energy sources. We employ a combination of F-AHP and panel data regression to take advantage of variability in renewables across climatic exposure, sensitivity, and adaptive capacity on a global scale since the effects of the deployment of renewable energy on climate change adaptation are not well understood (Keenan et al., 2018).

This study is unique in four ways. It is the first to examine renewable energy legislation's effects on various geographical areas and climatic conditions. We start by examining the effects and vulnerability of climate change before moving on to an overview of the different renewable energy sources. Second, to evaluate the space-time similarities between the key elements of renewable energy policy and climate change, our study develops two unique indices: the renewables-climate impact index and the renewables-climate vulnerability index (Shokry et al., 2022). Third, by precisely recording the values of the crucial factors that influence climate change, we use F-AHP approaches to lessen the influence of subjective assessment. Fourth, we conduct adequate robustness testing with middle-income nations like China and India, who, over the last ten years, have accepted a significant portion of renewable energy sources and nations where the share of renewable energy sources in total energy usage is far smaller (Noort et al., 2022).

5. CONCLUSION AND POLICY IMPLICATIONS

The empirical findings show that the spatial disconnect between policy frameworks and reality makes the current use of renewable energy insufficient to halt climate change. Because it makes adaptation easier and lessens the adverse effects of climate change, renewable energy is favoured by many nations. Low-income developing countries have received less attention in this field, even though they rely more heavily on renewable energy sources due to a lack of flexible capacity. The disparity between developed and poor countries' use of renewable energy sources might widen. When switching to renewable energy in the face of climate change, it is crucial to consider adaptive capabilities (Shokry et al., 2020). The transition to renewable energy is being driven, in addition to politics, by the oil crisis, energy independence, social issues, and environmental issues. Thus, local political and economic circumstances might result in different temporal and geographical effects. The effects of the renewable energy and climate change nexus may differ at the micro-regional level. Therefore, we support independent, regional-scale research on potential climate risk.

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