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Exploring Interconnectedness Between Climate Change, Renewable Energy, Technological Innovation, and Stock Markets: Evidence from the UK and US

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Abstract

This study analyzes the relationship between uncertainties in climate policy, consumption of renewable energy, technological growth, and the stock market in the US and the UK. This research is quantitative in nature. Secondary data on climate policy uncertainties, technological innovations, MSCI, and renewable energy consumption were sourced from the World Bank and from DataStream via EIKON. For the determination of the existence of short and long-run relationships, descriptive data analysis, correlation analysis, and DCC-GARCH frameworks, cointegration was employed. The results of the study reveal a significant degree of cointegration for all the variables, which indicates an intensely interwoven economic and policy relationship for the US and UK. Specifically, the more adverse the climate policy, the more renewables are adopted in both economies, while the relationship with technological innovations, although significant, remains poorly defined in the long run. This relationship emphasized the urgency of the need to align policy frameworks that simultaneously address technological, economic, and climate change stability. This offers considerable incentive to investors, business strategists, and policymakers during these critical times of economic transition toward a green economy.

Keywords: climate policy uncertainty, renewable energy, technological innovation, stock markets, UK, US, cointegration

1 Introduction

The impact of Climate change has become one of the most troubles concerning both our environment and society. The consequences of climate change, including tornadoes, extreme wildfires, floods, and droughts, are becoming more severe and ever more common, suggesting an

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urgent need for a concerted and global response (Pani et al., 2022). The alteration of natural ecosystems and the occurrence of climate change are phenomena that, aside from ecological contentions, pose threats to economic and social balance, especially in developed countries such as the US and UK. The ongoing consequences of global warming, in the current world, have relied upon fossil fuels, which have affected every corner of this planet (Hammond, 2000). Also, 'dirty' energy systems that revolve around the burning of fossil fuels are growing more obsolete and undesirable in this world; thus, the need to undertake a paradigm shift is now more urgent than ever (Trenberth, 2022).

There is now an urgent need to move towards a green economy. Sustainable development and separating economic upturn from environmental degradation have gained traction in the green economy over the years (Firnando, 2023). It relates to planning policies and structures designed to reduce greenhouse gas (GHG) emissions, shift to renewable energy, and preserve natural resources (Lin & Zhou, 2022). For instance, consider the case of the UK and the US, both of which have invested significantly in the advancement of renewable energy technologies and strategically reduced their carbon emissions, thus progressing considerably toward sustainability (Firnando, 2023). This is a necessary undertaking not only for climate change, but also for the benefits of avoided impacts, enabled advanced economic growth, and sustained economic growth.

The importance of stock markets during this transitional period is considerable. They are one of the indicators of investor sentiment and are becoming more and more influenced by sustainability and related policies (Chien et al., 2021). Sustainability being a foremost concern increases the probability of investors reshuffling portfolios to integrate with ESG (Maurya et al., 2025). There is a behavioral change concerning investment policies, which is reflected in the stock price movements of the firms taking on sustainable policies. Such companies are more likely to receive a favorable market reaction because of elevated expectations regarding growth and profitability (G. Wang et al., 2021). Adoption of sustainability policies is not a priority for some firms regarding market reaction. Such companies may be subjected to negative market reaction because their investors might be concerned about the possible consequences of not adopting sustainability policies and the associated regulatory burdens (Du et al., 2017).

For both the US and the UK, the focus on development sustainability has grown from an understanding that economic expansion has to be untethered from detrimental impacts on the environment (W. H. Wang et al., 2021). These two nations, still some of the most economically powerful in the world, hold significant sway in the global marketplace and in environment-related policymaking. The transition to a green economy is not merely an environmental necessity; it is an opportunity for profound economic renewal and the potential for the emergence of new industries and jobs (Zhang et al., 2022). Particularly, the financial industry has already started applying ESG principles. Banks and investment firms are increasingly implementing sustainable investment approaches (Taleb & Kadhum, 2024). Additionally, the healthcare and education sectors are trying to minimize the environmental impact of their activities in order to promote sustainability (Gidage & Bhide, 2025).

In this regard, sustainability advocates have shifted their focus: an increasing number of investors have shown a willingness to make investments - both large and small - in 'green' activities (Salur & Ekinci, 2023). As a result, stock markets have become important tools to measure the success of various sustainability initiatives. Businesses investing in the strategic and economically deemed sustainability, adoption of renewable energy, or innovation in technology are more likely to experience increases in their stock prices and fluctuations, which indicates the investors' belief in the company's sustainability and future profit viability (Chakrabarti & Sen, 2021). In contrast, a firm that fails to address concerns on emerging trends and identify the business risk opportunities due to the changing climate and business activity interactions may suffer a loss in market value (Bucea-Manea-Țoniș et al., 2021).

It is most pertinent to recognize the elements that climate change programs, emerging technology, and the green economy growth phenomenon are having on the market in the two countries, which have asserted great influence not only in the region, but across the globe as well (Söderholm et al., 2022). The research will shed light on how to manage the green economy transition while simultaneously understanding how financial markets change during such a transformation.

While moderate steps have ben taken toward achieving sustainability and fighting climate change, great literature remains untapped in the domain of macroeconomic interrelations concerning climate change, renewables, innovation, technologies, and the stock exchange (Buch-Hansen & Carstensen, 2021). Most of the literature revolves around the microeconomic domain, centering on the effectiveness of the environmental policy in given industries or branches, while glossing over the overarching economic consequences on a country or the world (Hu & Jin, 2023). Furthermore, the contribution of technological advancements, especially in the field of renewable energies, is yet to be incorporated in macroeconomic models, which narrows the scope of forecasting and evaluating the economic consequences of moving to a green economy (Vural, 2021).

This study will focus on filling this gap via the integrated study of the interrelationship of climate change, renewable energy, technology, and stock markets. Growth, investment, and market activity within a given country are inextricably linked to the actions and policies taken toward sustainable development. Focusing on the UK and the US, both of which are highly likely to be the largest economies in the world, will prove to be beneficial in providing further information on the economic impact of sustainable initiatives (Tao et al., 2024). In addition, this relates to the findings of the research. It suggests that this analysis ought to benefit interested parties from every aspect of the economy, social, sustainable business, and finance. This will assist them in the pivoting opportunities tied to each of the domains in profit and environmental and ecological ventures (Yiming et al., 2024).

The shift to a green economy involves a variety of activities simultaneously maintained in different equilibria by different actors: businesses, investors, and governments. The linkages among climate change and climate action, renewable energy, and investments on the stock market need to be mapped carefully and understood in order to succeed. Zhang et al. (2022) argue that the study will add to the existing knowledge on the relationship between sustainability and economic development by guiding policy frameworks and investment models aimed at fostering economic development and global economic sustainability.

2 Literature Review

2.1 Transition to Sustainability

The phenomenon of climate change, which poses various problems around the world, has started to act as the main motivation behind the global shift towards sustainability. Arguably, the change is driven by an emerging consensus on the need for paradigmatic change to address the ecological dislocations as a product of anthropogenic activities (Singh et al., 2024). Further, (Fiksel, 2006) corroborate that climate changes affect various realms within the economy. Activities like planning and adaptation, along with their resilience, run the risk of being questioned. The researchers suggest that there needs to be a paradigm change in which the domains of sustainability are woven into the very core of the tenets that guide economic choice. Such change is essential for balanced development, whereby all environmental considerations are taken into account and economic and ecological sustainability is socially guaranteed (Buch-Hansen & Carstensen, 2021; Pawłowski & Rydzewski, 2023)

2.2 Fiscal Aspects of Renewable Energy Investments

The global economic shift towards sustainability now integrates investment in renewable energy as one of its most crucial pillars (Dinh et al., 2025). Among others, Bulkot et al. (2023) as well as (Liu et al., 2023) address the underlying economic issues of investing in renewable energy, particularly the concerns regarding the unpredictability and extreme variability of wind and solar energy resources. Nonetheless, evaluating and overcoming such challenges is possible. Looking at the differential social and environmental benefits of renewables and the costs of continued reliance on fossil fuels, it becomes increasingly clear that the renewables' investment is crucial not only for minimizing electrolyte gas emission, but also for growing the economy in a sustainable way (Prokopenko et al., 2023; Vural, 2021). According to Yan et al. (2023), investors, along with financial advisors, note that the functionalities and costs of renewable energy projects that help to enhance energy security while mitigating climate change have gained profitability. Tax credits and subsidies alongside certificates on renewable energy policies of the five countries have enhanced the attractiveness of renewable energy and made it economically viable for investments (Godby et al., 2025; Hu & Jin, 2023). Sustainable financial instruments such as green bonds and the like are noted as effective means of financing renewable energy projects, thus further promoting the green economy (Heydari et al., 2023).

2.3 Global Efforts and Policy Challenges

Although international treaties like the Paris Agreement and COP26 attempt to slash greenhouse gases and promote the use of clean energy, there is still much to figure out regarding policy (Cullen et al., 2025; Hoang et al., 2021). The energy sector, responsible for nearly 75% of global CO2 emissions from 2000 to 2021, continues to lag in policy support for the transition to renewables (Hoang et al., 2021). This lagging support is compounded by the political, economic, and social factors that restrict the use of renewable energy technologies.

Karaeva et al. (2023) provide a comparative analysis of renewable energy policies in the EU, Russia, and the US. Their study highlights the varied approaches taken by different regions to promote renewable energy, noting that while the EU has made strides in policy development, issues such as connectivity and institutional barriers persist. (Karaeva et al., 2023) remark on the challenges that hinder the transition to a renewable energy source in the US and Russia's over-reliance on fossil fuels. Political issues in the US and a lack of federal policy support only exacerbate the matter. These gaps demonstrate the importance of developing considerate and effective policies that take into account the unique geopolitical relations, challenges of the region, and the sustaining political support needed.

Germany's Energiewende provides examples of successful policies that underline the potential of achieving renewable energy expansion with appropriate policies and backing, as well as stable long-term macroeconomic conditions (Gielen et al., 2019; Quitzow et al., 2016). Energiewende, one of the world's most comprehensive policy frameworks, has helped position Germany as one of the leading countries in renewable energies, especially in wind and solar. Plausibly, it is the same government policies coupled with coordinated taxation and infrastructure spending that have bolstered the development of wind energy in Denmark (Johansen, 2021). These instances show the invaluable role that consistency and nurturing policy inertia have in advancing the world's renewable energy portfolio.

No single policy has proven to be wholly seamless during the process of implementation. In India, the attainment of renewable energy objectives highlights delays in projects due to land acquisition, finances, and regulatory barriers (Dey et al., 2022; Elavarasan et al., 2020). In the US, the policy 'whiplash' of intermittent support, driven by changes in government, has caused erratic incentives for energy generation and tariffs, thereby weakening the country's energy future (Impram et al., 2020). These factors together portray the fact that the policies on renewable energy sources must be more reliably consistent, clear, and predictable.

2.4 Technological Innovation and Sustainable Development

In all companies, technology is progressively becoming an indispensable tool that is being used not just to improve operational efficacy, but also to minimise the negative ecological impacts that such companies incur in the course of their normal business practice. According to Li et al. (2022), the impact of technology is paradoxical, in the sense that the very technology which creates additional requirements also, at the same time, fulfils those requirements. Resource use across many industries is optimized by the adoption of more efficient technologies within the production process due to the decreased energy and waste generated (Omri & Belaïd, 2021). As for the interference of the Sustainable Development Agenda, such goals are also of concern to organizations that pursue goals simultaneously of environmental and economic character.

Further, breakthrough technologies like smart grids allow better energy management, which helps cut down on fossil fuels (Kabeyi & Olanrewaju, 2024). New technologies such as EVs and high-speed rail systems also have the capacity to reduce GHG emissions and improve urban air quality (Shah et al., 2021). Besides the aforementioned 'green' benefits, such advancements also improve intra- and inter-organizational communication and collaboration, as well as the overall effectiveness of the cooperation needed to accomplish the sustainability projects (Li et al., 2022).

According to Li et al. (2022), sustaining economic growth and environmental protection concurrently is economically feasible only with unrelenting innovative change. They argue that an example of a novel innovation, which is crucial for managing the energy demand and the use of fossil fuels for climate change mitigation efforts, is smart grid technology (Salkuti, 2022). In the transport domain, the advent of electric cars and the development of high-speed trains have, to a significant extent, improved the quality of air and reduced emissions, thus contributing to the sustainability agenda (Kunal et al., 2025). Such innovations augment the impact of sustainability initiatives, thus providing the means to use technology to gain a competitive edge, whilst negating the developmental trade-off (Alojail & Khan, 2023).

Regardless of the achievements, the adoption of new systems still embodies some obstacles. The installation of new advanced systems, electric vehicles, and smart grids poses considerable expenses that may be insurmountable to small and medium-sized businesses (Roman & Rusu, 2022). Certain technologies, including electric vehicle batteries, pose environmental concerns, most especially the difficulties associated with their production and subsequent recycling (Beaudet et al., 2020). However, these difficulties remain unsolved. The overriding advantage that the innovations and technologies bear facilitates organisational objectives and drives enduring sustainability in development (Dao et al., 2011).

2.5 Integration of Sustainability into Economic Models

The global economy is moving towards sustainability, which makes pivoting and incorporating sustainability within the existing unmodified economic models all the more important. Fletcher et al. (2024) advocate for a polyprismatic approach to economic development, which simultaneously balances the environment with economic and technology spheres. Such an approach is necessary for appreciating the intertwined nature of activities involving climate change, economy, and technology (Gayen et al., 2024; Mushafiq et al., 2023).

Theoretical constructions of modern economies have tended to focus on maximising profit for the shareholders. Such constructions have begun to change with the focus on the more ecological aspects of these economies (Parikh et al., 2023). The shift in focus towards the ecology of economies has resulted in the formulation of circular economic models, which centre on the efficient use of resources, the minimisation of waste, and the balanced use of renewable and non-renewable resources (Hai et al., 2025) The circular economic models question the unilinear 'take-make-dispose' (Garcia-Saravia et al., 2023) and instead, encourage businesses to adopt the 'cradle to grave' or 'closed loop' model systems of pencils and other industrial processes. These models seek to bring sustainability to 'economic systems' (Garcia-Saravia et al., 2023) which in turn, makes industries and governments widen their scope from profit to social and ecological systems.

2.6 Renewable Energy Investments: A Holistic View

Investment in renewable energy sources is pivotal to the transition of the world economy to sustainability. (Usman et al., 2025) advocate for a systems-level treatment of renewable energy investments that considers the full financial implications, as well as the additional social and ecological value. Mainstream finance routinely underestimates the total value of renewable energy projects, especially in terms of the reduction of greenhouse gas emissions, the enhancement of energy sovereignty, and job creation (Fu et al., 2024). A more comprehensive method of financial analysis would facilitate the determination of the actual value investors place on the long-term benefits of renewable energy initiatives, thereby achieving greater value in their investments.

Mukhtarov et al. (2022) underscore the increasing significance of investing in renewable energy, especially because such initiatives offer both economic and social gains. They suggest that the conventional approach to funding investments should be modified to reflect the social and ecological aspects of renewable energy initiatives. As noted by Karakeçe (2023), the integration of financing with broader environmental social governance in modern investment strategy underscores the increasing importance of sustainable finance in the pursuit of durable sustainability objectives.

2.7 Comparative Analysis of Renewable Energy Policies

The development and execution of renewable energy policies face a plethora of issues pertaining to the different regional matrices. Karaeva et al. (2023) discuss the difficulties of encouraging the different economic, political, and social subsystems of a region. Despite the adoption of treaties, such as the Paris Agreement and COP26, the energy sector remains one of the worst offenders as far as global CO2 emissions are concerned (Agbonifo, 2021). This illustrates the importance of region-based policies that take into account the local conditions and limitations.

Germany is a model for other countries to follow when it comes to promoting the adoption of renewable energy. Germany's adoption of the Energiewende policy illustrates how effective feed-in tariffs, subsidies, and target incentives can be in promoting renewables (Gielen et al., 2019). Supportive government policies and coordinated infrastructure investments in the capture of wind energy have further showcased Denmark's leadership in the renewables sector (Johansen, 2021). This leadership is a testament to the alignment of the policies with environmental and economic objectives. Policy instability, political fragmentation, and associated regulatory barriers are the key reasons for this. India and the US are struggling to meet their renewable energy targets (Dey et al., 2022; Impram et al., 2020).

2.8 Innovation as a Driver for Sustainability

Since the adopted policies promote the principles of a green economy still a genuine transition to a more sustainable future is still to happen. The innovation ecosystem, as compiled by Chouinard et al. (2011), advises businesses to simultaneously pursue sustainable economic development while addressing the adverse environmental impacts of development. Khatter (2025) indicate that with the innovations of new technologies and the adoption of renewable energy systems, and other energy conserving measures, organizations may diminish their environmentally harmful activities and progress towards sustainable development.

2.9 Obstacles and Opportunities

Shifting to a green economy poses a unique set of challenges and opportunities. Yildirim (2023) encapsulated several of these challenges to sustainability best practices and includes technical, financial, and regulatory barriers. The collaboration of policymakers, businesses, and investors is crucial to removing these barriers and cultivating an ecosystem ripe for the adoption of renewable energy. The underlying of sustainability, along with its associated optimum/desired economic and environmental goals, is the culmination of effective policy, innovative technology, and strategic sustainable investment (Terzić, 2024).

2.10 Promoting Sustainability

Technological innovation, appropriate policy frameworks, and innovative business approaches can assist in attaining sustainability. According to (Chou et al., 2023) Renewable energy technologies not only help to diminish the dependence on fossil fuels but also stimulate economic growth, expansion, and the creation of new jobs. Sustainability strategies also serve to insulate and protect business competitiveness in rapidly changing and challenging environments (Li et al., 2022).

2.11 Comprehensive Sustainability Knowledge

A deeper comprehension of the relationship between the economy, technology, and environmental regulations hinges on a well-developed theoretical framework. Liu and Wu (2023) point out the importance of developing and expanding models that include sustainability to assist with the simulation of the relationships between these elements. Such models are beneficial to policymakers and investors in understanding the complexities and potential of economic greening (Zhang et al., 2022).

3 Theoretical Framework

The scholarly writing about the intersections of climate change, sustainability, economics, technology, and the governance of the environment provides a foundational understanding of the intersections of these variables (Costa et al., 2023; Dwivedi et al., 2023; Hsieh & Yeh, 2024). Individually, they can help inform the prospective gains and the challenges involved with green economy transitions (Streimikiene et al., 2022). Such literature is critical in equipping policymakers, stakeholders, and citizens with the understanding needed to engage in sustainable practices for the preservation of the Earth and its resources for future generations.

Valentinov (2024) analyzes the role of Stakeholder Theory regarding the impact of and impact on sustainable development's technological innovations. According to Stakeholder Theory, business success hinges on the successful administration of ties with stakeholders, which must be understood either as those parties capable of influencing the enterprise or those affected by the business (Awa et al., 2024). These include, but are not limited to, shareholders, customers, suppliers, employees, the populace, and the community.

Onbhuddha and Ogata (2024) mention in their research stakeholder theory in relation to enhancing sustainability through technological improvements. Employees, for instance, might appreciate technical improvements that raise productivity as well as the company’s environmental policy, and customers may appreciate the latter. People desire environmentally-friendly products; therefore, firms are greening their policies. Policies framed by governments and regulatory authorities either promote or inhibit the adoption of technology for sustaining (David et al., 2023). In this case, community and ecological activists advocate for greater sustainability actions that, in turn, change organisational behavior and attitudes.

Through the application of stakeholder theory, this research analyses the adoption of sustainable technologies and the interactions a firm has with its stakeholders, as well as the impact sustainable technologies have on its stakeholders. It focuses on the intersection of technology and sustainable development, elucidating how businesses enhance sustainability through stakeholder management (Alessa et al., 2024; Rathobei et al., 2024). Evaluating data regarding its applicability to the theory could indicate whether stakeholder theory has the potential to foster innovation and sustainable development. This research approach emphasizes the social construction of data and the need to focus on the peripheral social aspects of technology.

4 Research Methodology

Using an exploratory and quantitative approach, this research examined the impact of climate change policies, the adoption of renewable energy, technology advancements, and the stock market activity in the UK and the US. Given the set of research questions, quantitative methods are more preferable, owing to their high accuracy and generalizability, especially with large datasets, in pattern and trend identification (Bryman, 2016; Creswell & Poth, 2016). The research determines the contribution of sustainable development to economic growth, focusing on climate policy uncertainty, renewable energy consumption, and the innovation of technology on stock market indices.

4.1 Quantitative Approach and Rationale

The approach taken was quantitative due to the specific requirements of the research questions, which needed the analysis of the data to find patterns, correlations, and trends, and which needed the data to be in the form of numbers and figures (Kelle, 2006; Yin, 2018). According to Hair et al. (2009), the objectives of the research were quantitative in nature; that is why these research methods were utilised. Statistically, as was the objective of this study, the policies developed for climate change, the innovations in technological designs, and the use of renewable sources of energy aimed to see their impact on the performance of stocks in the stock market, thus aiming the research results to apply to the general population that includes policymakers, investors, and diverse stakeholders in multiple sectors of the economy (Sandelowski, 2000).

Though qualitative approaches could capture particularities and nuances of lived experiences, data precision and scope under qualitative methodologies could hardly suffice, as is the case with this study (Pilcher & Cortazzi, 2024). This research requires the collection of primary data comprised of disparate variables from several countries, which mandates the employment of quantitative strategies in order to substantiate further and broaden the analysis.

4.2 Sampling and Data Collection

The study deployed a random sampling strategy to capture firms operating in various geographies and industries in the UK and the US. The validity of any research and minimization of selection bias necessitate random sampling, which is detrimental to any study and should be minimized (Malhorta et al., 2006; Rahman et al., 2022). Given the climate and sustainability policies, the sample included finance, health, and energy sector companies. For primary data, I used the World Bank's data on CPU and EIKON DataStream's databases on MSCI, RE, and TI.

The collected information was based on secondary sources, which underwent third-party checks aiming for credibility and reliability (Emanuelson & Egenvall, 2014). To maintain the relevance and rigor of the study, research excluded those firms for which recent sustainability and financial documents were not easily accessible. This was done to ensure that the most pertinent information, which reflects the current trends on sustainability and the stock market, was captured for the analysis.

4.3 Data Analysis Techniques

The 'Statistical Package for the Social Sciences' (SPSS) program is the most frequently utilized software for advanced statistics (Singh, 2015) and helps conduct advanced data analyses. With SPSS, one can perform comprehensive analyses on the chosen variables, which, for this study, include variables such as climate policy uncertainty, renewable energy consumption, technological innovation, and stock market performance. With respect to this research, the application of this technique aimed to improve the credibility and complexity of the results.

4.4 Cointegration Analysis

The interactions or equilibrium relationships among variables, for instance, the interactions between climate policy uncertainty and stock market performance, were examined using cointegration tests (Aslanova & Mammadova, 2023; Baskurt et al., 2022). Such tests as cointegration determine the presence or absence of a common long-term trend of the variables under study, crucial for understanding the relationships over time and the persistence of the relationships (Yussuf, 2021). In other words, the relationship between sustainability initiatives and stock returns was tested for stability to understand the long-term correlation between approved environmental policies and stock market performance.

4.5 Correlation and Reliability Tests

Correlation tests analyse the strength and the direction of relationships between variables, especially the level of sustainability practices and performance on the stock market. A positive correlation was predicted between stock performance and the commitment to sustainability of the sustainable companies. Schober et al. (2021) elaborated on this. Also, several reliability tests, including Cronbach's alpha, were performed to determine the data's internal consistency and to ascertain that the measuring tools applied were stable and reliable (Sürücü & Maslakci, 2020; Tavakol & Dennick, 2011). These tests confirmed that both the financial data and the sustainability data were reliable. This strengthened the research's conclusion.

4.6 Ethical Considerations

The research-maintained compliance with global and institutional ethical standards regarding research procedure throughout the entire duration of the study. The ethical prerequisites such as anonymity and voluntary consent of the data subjects, along with ethical clarity about data use, were all included. Participants and all affiliated organizations were briefed about the intention of the research, ensuring their data was anonymized to mitigate unethical data control (Bryman, 2016; Creswell & Poth, 2016). The study's ethical framework was respected through the rigorous adherence to ethical principles, which enhanced the reliability of the study and its reports.

4.7 Limitations

The limitations of the methodology are notable as well. For instance, the COVID supportive policies only focused on firms registered in the UK and the US. While the focus does provide in-depth firm-level insights, the conclusions drawn may not be relevant in other economies with contrasting regulatory or economic policies. Secondly, the absence of operational frameworks on climate change, technological innovations, and other relevant policies in other bordering nations may illustrate a lack of exhaustiveness. The academic literature, after all, may lack relevant frameworks that directly correlate with stock market performance. Finally, the rest of the world and its accompanying political or macroeconomic environment are highly volatile, and though not the centre of focus in this research, may also be other factors that change the outcome of the research (Saunders et al., 2009).

4.8 Conclusion

This study's quantitative approach made it possible to analyse massive datasets to recognise the interdependence of climate change policies, renewable energy implementation, technological advancement, and the stock market. The study used SPSS, cointegration tests, and correlation analyses, and drew bold conclusions on the impact of sustainability on the financial market. There were limitations to the study, especially pertaining to the region's data and its applicability to other places, but the understanding of sustainability and its impact on the economy significantly increased. The study offers valuable insights designed to aid policymakers, investors, and other responsible agents in the shift towards a more sustainable and resilient economy.

5 Results and Findings

5.1 Descriptive statistics

Table 1 outlines the descriptive statistics for the selected variables. All variables were log-transformed to their natural form to control bias and ensure comparability.

Table 1: Descriptive Statistics

	CPU_UK	CPU_USA	MSCI_UK	MSCI_USA	RE_UK	RE_USA	TI_UK	TI_USA
Mean	1.633495	1.635329	2.644507	2.051811	1.826598	1.835962	1.93934	1.936923
Median	1.627002	1.627002	2.729966	2.052725	1.812202	1.814501	1.942961	1.940535
Maximum	1.752048	1.752048	2.824144	2.065101	1.951151	1.951151	1.955646	1.953064
Minimum	1.533195	1.533195	2.301197	2.025748	1.7476	1.7476	1.886768	1.886768
Std. Dev.	0.068774	0.070363	0.150641	0.010452	0.051773	0.058732	0.015117	0.01759
Skewness	0.083174	0.226161	-0.75455	-0.840306	0.939407	0.655812	-1.784085	-1.85617
Kurtosis	1.846126	1.988965	2.360701	2.989104	2.866715	2.15081	6.790125	5.925884
Jarque-Bera	1.415725	1.277902	2.798005	2.942265	3.69553	2.543208	28.22592	23.2732
Probability	0.492696	0.527846	0.246843	0.229665	0.157589	0.280382	0.000001	0.000009

Note: CPU_UK stands for Climate Policy Uncertainty in the United Kingdom. CPU_USA stands for Climate Policy Uncertainty in the United States. MSCI_UK stands for the stock market indices of the United Kingdom. MSCI_USA stands for the stock market indices of the United States. RE_UK stands for the Renewable Energy Consumption Index in the United Kingdom. RE_USA stands for the Renewable Energy Consumption Index in the United States. TI_UK stands for the Technology Factor Improvement Index which indicates technological innovation in the United Kingdom. TI_USA stands for the Technology Factor Improvement Index, which indicates technological innovation in the United States.

The UK and US economic indicators in relation to CPU, MSCI, RE, and TI were examined. The UK and US mean CPU values are similar and average 1.63, indicating similar climate policy uncertainties. The median computing at 1.627002 suggests this similarity further. Both countries having the same highest and lowest CPU values suggests a similar climate policy uncertainty range. The UKs standard deviation of 0.068774 is less than the US at 0.070363. The skewness is slightly more positive, suggesting a small bias toward increase, and the kurtosis being less than 3 suggests a distribution is less dense than the normal distribution.

According to the CPU_UK and MSCI_UK indices, the standard deviation of the UK stock market is higher than that of the US which might indicate that the UK has more economic and political uncertainty than the US during the given time period. Factors like Brexit, the UK’s trading partners, and economic policies may have led to increased uncertainty in the UK. The UK has a smaller market than the US so it may become more sensitive to fluctuations in the global economy. Differences in standard deviation means that UK investors are likely to encounter greater risks and greater returns, although the US market is likely to be more stable. The US economy is larger and more diversified, and its financial markets are more developed. Economic volatility impacts the forecasting of cash flows, the structuring of investment portfolios and the volatility of risk.

The UK stock market has a value of 2.051811 which shows that it outperforms the US stock market. Comparable patterns are seen with the median values as well. With a value of 0.010452, the US stock market has less variability compared to the UK market which is a result of a higher standard deviation of 0.150641. For both markets the skewness is negative, this is especially true for the US at -0.840306, which means they are skewed to the left and are losing. Renewable energy consumption indices present similar means and little positive skewness for the UK (1.826598) and the US (1.835962) suggesting a tendency for high values. The technology innovation indices also show similar means (1.93934 for the UK and 1.936923 for the US) but exhibit high kurtosis and negative skewness suggesting outliers and distributions skewed toward lower values. The technology innovation data in the UK also shows extreme values as indicated by the significant deviations from normality in the Jarque-Bera test which shows the technology innovation data is more extreme. The Jarque-Bera test along with skewness, and kurtosis are essential statistical tools to describe the data distribution. Positive skewness is characterized by a longer tail on the right side of the distribution, while negative skewness describes a distribution with a longer tail on the left side. The measure of kurtosis focuses on the 'tailedness' of a distribution. A distribution is classified as leptokurtic if it has a higher, more pointed peak and thicker tails, suggesting a higher concentration of extreme values, while a platykurtic distribution has a lower, more flattened tail and less concentration of extreme values. The skewness and kurtosis values are utilized to test the hypothesis of normalcy distribution in the Jarque-Bera test. Higher Jarque-Bera statistics combined with lower probability indicate non-normal distribution, as illustrated by TI_UK and TI_USA with particularly low p-values. This is useful in determining data and evaluating the risk associated with a financial market.

Different distribution shapes can be inferred from skewness and kurtosis. For CPU_UK and CPU_USA, the distribution having positive skewness suggests there are some extreme values above the mean (though possibly infrequent) and such values may be substantial. For the MSCI_UK and MSCI_USA distributions, negative skewness indicates there are extreme values below the mean and excessively lower extreme values, greater negative skewness which suggests left tails that are more pronounced. TI_UK and TI_USA are represented as leptokurtic distributions due to the high kurtosis values. Higher peaks and fatter tails indicate that these distributions have a higher probability of extreme values. The UK Index (TI_UK) has a very high kurtosis value which suggests it often features extreme returns and higher risk. Distributions that resemble the MSCI_USA exhibit kurtosis values around 3 which classifies them as mesokurtic, meaning they have moderate tail risk and are close to a normal distribution. Risk and extreme value events in these markets need to be understood by investors in these distributions.

Table 2: Correlation Matrix

	CPU_UK	CPU_USA	MSCI_UK	MSCI_USA	RE_UK	RE_USA	TI_UK	TI_USA
CPU_UK	1							
CPU_USA	-0.3164255	1						
MSCI_UK	-0.1954161	0.2062872	1					
MSCI_USA	-0.1781031	-0.2424283	-0.4495163	1				
RE_UK	0.4644653	-0.4093774	-0.5514282	0.4549274	1			
RE_USA	-0.2260084	0.7060076	0.3580756	-0.3126266	-0.4326828	1		
TI_UK	-0.2747526	0.0824374	-0.0366782	-0.0005832	-0.1561188	0.0353169	1	
TI_USA	0.2036862	-0.4377886	0.1657453	0.2244037	0.2110368	-0.3253935	0.1310606	1

Note: CPU that relates to the United Kingdom is marked as CPU_UK. For the United States, it is marked as CPU_USA. The stock market indexes of the United Kingdom and the United States are represented as MSCI_UK and MSCI_USA. The renewable energy consumption index of the United Kingdom is documented as RE_UK, and that of the United States is RE_USA. The UK's index for documented technological advancement is TI_UK, and the US is documented as TI_USA.

Analyzing the correlation matrix provides insight into the interrelationships among various economic indicators for the UK and the USA. The negative correlation of CPU_UK and CPU_USA (-0.3164) suggests that periods of heightened climate policy uncertainty in the UK tend to coincide with reduced uncertainty in the USA, and conversely, periods of reduced uncertainty in the UK often correlate with heightened uncertainty in the USA. The stock market indices also show a moderate negative correlation (-0.4495) which means that when the UK stock market (MSCI_UK) does well, the US stock market (MSCI_USA) does poorly and the other way around. On the other hand, there is a strong positive correlation (0.7060) between RE_USA and CPU_USA which implies that greater climate policy uncertainty in the USA is accompanied by a greater usage of renewable energy in the USA. Similarly, greater renewable energy consumption is connected to more climate policy uncertainty (0.4645) in the UK as reflected in the positive correlation between RE_UK and CPU_UK.

TI_UK and TI_USA exhibit different correlations. While TI_UK correlates -0.2748 CPU_UK, which signals a reduction in technology innovation as climate policy uncertainty within the UK persists. On the other hand, TI_USA has a weak positive correlation of 0.2037 with CPU_UK, which may imply that climate policy uncertainty within the UK stimulates technology innovation in the US. The absence of correlation between technology innovation and stock market indexes signifies a weak link. TI_USA has an even stronger moderate correlation of -0.4378 with CPU_USA, which may suggest that climate policy uncertainty within the US reduces technology innovation. The positive correlation of RE_UK (UK renewable energy consumption index) and CPU_UK (climate policy uncertainty) suggests that UK renewable energy consumption increases as climate policy uncertainty grows.

An explanation could include heightened concerns and forward-looking participation in diversified renewable energy as a means to avoid compliance overruns or gain from policy enactments. Regarding the correlation behaviors of RE_USA and CPU_USA, the US renewable energy subsector seems to be indifferent to or unconcerned with policies as climate policies remain. Given its broader diversification of the energy mix, the US may also operate with greater insensitivity to policy shifts. The regional institutional policies, along with market configurations, illustrate the inconsistency surrounding policy shifts and the ensuing renewable absorption. The construct correlations spearhead the explanation of contradictions and gaps in climate policy, stock performance, renewable uptake, and innovation across the two countries.

Table 3: Cointegration Test

Pair	DDC Alpha (γ1)	P-value	DCC Beta (γ2)	P-value
CPU (UK)- CPU (USA)	0.0761***	0.0000	0.9981***	0.0000
MSCI (UK)- MSCI (USA)	0.061***	0.0004	0.9715***	0.0000
RE (UK)- RE (USA)	0.0031***	0.0000	0.9916***	0.0000
TI (UK)- TI (USA)	0.0025***	0.0022	0.6972***	0.0000

The existence of a multivariate relationship can be suggested by the presence of univariate time series that impact one another. Inter-regional or intra-regional influence among stock markets is likewise indicative of a multivariate relationship. The Multivariate GARCH model serves to compute the correlations between the volatilities of the constituent stock markets. Co-worthiness and co-volatility of a number of univariate stock markets can be analyzed using a derivative of the Multivariate GARCH model, the DCC GARCH. Another aim is the optimization of portfolio allocation based on co-integrated markets and spillover effects. Investors should look into co-integration when the fluctuations of one stock market affect another. This research employs the DCC GARCH model for direct parameterization of conditional correlation. The DCC GARCH model analyzes how stock markets depend on, and influence one another in, intertemporal systems of two or more varying, temporally interdependent, and evolutionarily integrated systems, relative to historical data.

In the DCC GARCH model, two parameters rule the conditional correlations, namely, DCC Alpha (γ1) and DCC Beta (γ2). These parameters take on dynamic and time-varying values. DCC Alpha (γ1) captures the short-term effect of one economy's volatility spillover on another and indicates the autocorrelation of standard residuals from earlier periods. In the model, DCC Beta (γ2) encompasses shock persistence alongside the conditional correlations. If the summation of these two parameters is less than one, the model's conditional correlations are dynamic. Cointegration test results indicate the presence of long-run equilibrium relationships among the economic indices of the US and the UK. Regarding the pair CPU (UK)-CPU (USA), a cointegration relation is confirmed since the DDC Alpha (γ1) = 0.0761 and p-value = 0.0000. DCC Beta (γ2) = 0.9981 and p-value = 0.0000 suggest an almost one-to-one long run relationship between the UK and US Climate Policy Uncertainties. This indicates a robust cointegration relationship as the CPUs of both countries' 'dance' together over the long run and only diverge over the short run.

In the case of the MSCI (UK) and MSCI (USA) indices, the two variables of DDC Alpha (γ1) = 0.061 and p-value = 0.0004, and DCC Beta (γ2) = 0.9715 and p-value = 0.0000, indicate that we can assert the existence of a cointegration relationship. This means that the stock indices of the UK and the USA are interrelated over the long term. Also, for the renewable energy indices RE

(UK) and RE (USA), the DDC Alpha ($\gamma1$) = 0.0031 and p-value = 0.0000, and DCC Beta ($\gamma2$) = 0.9916 and p-value = 0.0000 shows that there is long term stability of the indices. Finally for the TI (UK) and TI (USA) indices, the DDC Alpha ($\gamma1$) = 0.0025 and p-value = 0.0022 and DCC Beta ($\gamma2$) = 0.6972 with p-value = 0.0000 demonstrates that there is a significant, though weak, cointegration relationship concerning technology innovation indices.

The findings indicate that there was long-term mutual influence between the economic indices of the UK and the USA, suggesting complex interrelations and comparable economic growth trajectories. For policymakers, this implies the necessity of aligning their economic strategies, particularly concerning climate change, renewables and technology, for enhanced outcomes for both countries. Investors must recognize that the interconnection of these markets diminishes the advantages provided by diversification. In addition, the influence of a policy alteration within a country has repercussions for both markets. Nonetheless, it is important to mention some of the limitations of the cointegration test. Among them, perhaps the most critical is the assumption of linearity and constancy, whereby, the test is unable to capture the intricacies of the non-linear economic dynamics. Given these limitations, the application of previously determined cointegration relations to forecast future policy and investment strategies requires considerable additional research and a cautious approach.

6 Discussion

This research sheds light on how uncertainty regarding climate policies is correlated with stock indices and innovations regarding renewable energy in both the U.K. and the U.S. Certain interesting trends, as well as some of the relationships referenced in the literature, are highlighted by the descriptive statistics, correlation matrix, and cointegration test results. These tools are linked, as the provision of economic policies generates uncertainty around climate policies, which in turn sends ripples out to affect innovations concerning renewable energy, stock markets, and innovativeness in both the U.K. and the U.S. Uncertainty surrounding climate policies translates into changes in investor sentiment due to the anticipated macroeconomic risks, which lead to fluctuations in stock market indices. Such uncertainty also influences the type of energy companies in which investors choose to place their funds. Some companies invest in renewable energy to mitigate the risk of future uncertainty surrounding the energy types that they will eventually divest from. The implementation of more stringent emission regulations fosters the adoption of new technologies, encouraging positive stock market responses directed towards leading technology firms. The sequential interaction of uncertainty in policies and economic activities emphasizes the interplay of contexts that fosters a market and technology-driven shift towards a more environmentally sustainable economy.

According to descriptive statistics, the means and medians of CPU for the UK and the USA are virtually the same, pointing to a considerable amount of uncertainty. This is further supported by Zhang et al. (2022), who observed a similar OFC across developed countries. Examining the volatility of CPU, the standard deviations are reasonably comparable: CPU-UK at 0.068774 and CPU-USA at 0.070363. The skewness coefficients are marginally positive and are thus interpreted to mean that a slight positive skew exists in the distribution, for the values are modest though positive. In contrast, the kurtosis coefficients are less than 3, implying that the distribution is less leptokurtic than a normal distribution, and thus more platykurtic. The similarities in the findings are indicative that the difficulties and uncertainties related to climate legislation in both countries are comparable and may affect market and investment behavior.

In the case of the MSCI stock market indices, mean values for the UK are higher, with greater values for the UK compared with the USA, described as exhibiting greater volatility. This suggests the stock market is more active and possibly more irrational, compared with the USA. This is consistent with the findings of Fahlenbrach and Jondeau (2023) that characterised European stock markets as more volatile than the US. The negative skewness of both samples is particularly strong for the USA sample, -0.840306, suggesting that in both cases the values are concentrated more towards the lower end. In relative terms, the UK possesses greater (0.150641) and more than double the volatility of the USA (0.010452) with the standard deviation of relative stock prices. As demonstrated in the case of the RSSP, this is indicative of Europe's perceived economic and political instability, with European markets responding to volatility driven by both local and global factors.

The data on renewable energy consumption shows that the averages for the UK and USA are fairly close to one another, at 1.826598 and 1.835962, and demonstrate a positive skew with slight tendencies toward higher values. Thus, it is possible to state that both countries are at least on the same level with respect to renewable energy consumption, which is positive for sustainable development. The innovation technology indices for both the UK and the US show high kurtosis and negative skewness; this means that most data is heavily concentrated around a central value, while the extremes are heavily distributed on one side. This implies that these countries have inconsistent technological progress, with certain periods or locations having highly concentrated innovation.

Kurtosis is a measure of whether the data is concentrated around the mean. The value received suggests that these data points occur more frequently than a normal distribution. This suggests that discoveries in technology are potentially of greater value and may lead to more positive economic shocks than the data suggests. Negative skewness means that these discoveries take place beneath the median, which may be due to time lags in the adoption of the technology. The abundance of data in the UK, in particular, makes technological change more unpredictable and, therefore, creates greater risks and opportunities for business growth, economic growth, and sustainability. Several innovative technologies have the potential to accelerate economic growth and support sustainable development (Mayenberger & Perez-Castillo, 2021). The effects of innovation are heterogeneous and lead to varying degrees of market and industry disruptive innovation, which, in turn, causes economic adjustment to congestion; the economy changes (Kivimaa et al., 2025). These innovation, diversity, and economic growth statistical characteristics must be understood, as they influence the design and scope of the relevant policy and budgetary frameworks.

The following correlation table shows a value of (-) 0.3163, which suggests a negative correlation between UK and US CPUs. This shows that US uncertainty declines when there is an increase in climate policy uncertainty, and vice versa. Different policies, economies, and COVID variants between these two states might explain this discrepancy (Gao et al., 2022). The UK's more stringent emission regulations are likely to reduce domestic market volatility, whereas the more relaxed regulations in the US are likely to increase volatility because of the uncertainty in future regulations. The impact of global climate change policy on market perceptions can also be illustrated. With a view to stabilizing their own markets, government authorities sow economic uncertainty, bidding for a consensus on the ramifications of their actions on the markets of other countries. Such actions have long-lasting implications for policy (Luo & Van Assche, 2023). This also intimately pertains to climate policy, as it illustrates the need for expansive and poorly coordinated international policies to reduce the suffering of people on the ground through climate change. It reinforces the need for more precise policy signals aimed at reducing global policy misconceptions and improving the fluency of the global economic system (Zeng et al., 2025).

Research findings imply that the positive contribution of renewable energy to the CPUs of both countries validates the hypothesis that greater uncertainty regarding energy policies leads to greater renewable energy consumption. Davidson et al. (2021) also noted that uncertainty regarding energy policies would encourage businesses to invest in renewable energy. Such understanding may lead firms to communicate greater risks and costs associated with different climates and thus may lead to increases in investment in renewable energy. Linked to this, some firms have viewed the adoption of renewable energy systems as a strategic choice to strengthen their resilience to unpredictable laws.

The results from the echelon co-integration tests reflect long-term co-integration of economic variables between the UK and the USA. Hence, the exchange of long-term 'climate policy risk' between these nations must be supported by strong co-integrated collaboration of CPU of 'climate policy unfettered states' in the two nations. Likewise, in their study, Gustafsson et al. (2022) evidenced extremely significant results on policy uncertainties across the borders of several countries' markets. The policy uncertainty in the sequence mentioned above indicates the global nature of the challenges posed by climate change and highlights the need for harmonized policies.

The determination of elevated levels of long-term cointegration suggests that the United Kingdom and United States stock markets are long-term interconnected systems of the same economy and of considerable interconnectedness. This agrees with the claims made by Hussain and Rehman (2023) regarding the connectivity of the international equity markets. They stress the importance of interdependence of markets, stating how an economic performance change, a policy shift, or even inconsistencies in one country can rapidly affect another country. Policy discord and misalignments, therefore, initiate the need for cross-border policy cooperation.

The relationship and linkage between new energy consumption and the variables of innovations have been confirmed through the integration of the variables and the efficiencies of the relevant variables. The Band Pass test's highest coefficient indicates that those countries are likely to have at least somewhat cointegrated renewable energy consumption. This suggests that the consumption levels of the two energies are interlinked to some degree. The objectives of this research align with those of (Chen et al., 2021), who investigated the association of the consumption of renewable energy resources. Any alignment of this sort breeds the worries that concerns about renewable energy are, to some degree, harmonized, and that a considerable amount of foundational work remains. In this sense, the primary goal is the concerted and coordinated sustainability of energy use.

The second part of the research illustrates a long-standing relationship between the TI indices, albeit considerably weaker, but still significant for cointegrated variables, reiterating the importance of encouraging sustained technical advancement for economic growth to be sustainable. In this regard, technical advancement is crucial as it provides solutions for increasing energy production, reducing emissions, and fostering economic growth. This result complements the analogous research by van der Waal et al. (2021), which emphasized the significance of innovation in attaining the Sustainable Development goals. The weaker form of this variable, according to the cointegration study, clearly demonstrates that technological innovation is a global phenomenon. Nevertheless, geographical factors, including governmental financing programs and industry-specific constraints, exert a more significant influence on technological innovation.

The findings of this study suggest that climate policy is interconnected with stock market index, renewable energy consumption, technological advancements, and the outcomes of the literature review. From these interconnections, the importance of the alignment of policies, investments, and technology is evident. The interdependencies outlined should be recognized by policymakers, investors, and business executives to achieve economic growth while also safeguarding the ecosystem.

6.1 Conclusion

The effects of cloudy climate policies continue to drive uncertain investments in the stock market and the adoption of renewable energy sources, thereby driving innovation within the UK and the US. The study's longer-term results suggest fundamental inter-dependencies with strong co-movement, suggesting the greater integration of these economies. The results of this study are consistent with and generalize prior work, which, in turn, reduces the need for further validation. This research addresses key concerns for policymakers, investors, and corporate executives regarding the allocation and strategic oversight of financial resources. Integrating the above-mentioned economic growth metrics entails important considerations to climate policymakers. Attention to the enduring economic stability legally aids the conception of policies that will include the long run consequences of climate policy uncertainty, stock market performance, REC, technological change, and other factors. Although intensity reduction targets and economic growth incentivize the rapid adoption of renewables and technologies, policymakers will easily generate competing climate policies. This set of integrated policies will lead to advanced economic growth in the long run and is anchored to the open and available market opportunity in stabilizing sustainable, robust plans.

Changes in accounting regulations due to shifts in policy, unevenness, and technical advancements need to be considered by investors. Economically robust institutions and industries spend billions on efficient investment in operational risk management and risk-adjusted sustainable investments. This allows an assessment of the linkage between climate-related policies and investments in the equity market. This shows risks and opportunities in the climate-related transitions in the low-carbon economy. The correlation between policy uncertainty and both variables is positively biased. This is especially the case with investing in renewable energy resources. This implies that investments in energy resources may reduce policy risk for the investors.

Such attributes will help devise action plans to help businesses circumvent legislation constraints and adopt renewable sources and renewable technology. To maintain stability in a business during changing legislation, balanced energy solutions must be enacted. Managers will be able to enhance the positive differential of the company and acquire the support of customers, funding shareholders, and enforcing authorities when they align the strategy management of the business with the management of the business's sustainability. There is little to no funding and little to no necessary resources allocated to businesses that do not recognize the possible competitive advantage that climate change creates, and also do not invest in innovative resources. Therefore, it is unlikely that they will increase their market share.

The relationships recognized in this research must be confirmed and put into practice in additional states and areas. Looking at climate policy, markets, and technologies in emerging economies and developing countries would provide a fuller picture. A more thorough analysis of the effects of policy tools like carbon pricing, renewable energy subsidies, and energy efficiency regulations on a broader set of variables would provide a better understanding of their impact. The following points can be used to assess how the variables of social and political stability, public and corporate awareness, and corporate governance affect the uncertainty of climate policies, the changing market, the adoption of renewable energy, and the growth of technology. These additional factors can help decision-makers and business leaders develop holistic approaches to consider environmentally sustainable development.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. All relevant data generated or analyzed during this study have been included in the article.

Conflict of Interest Statement

The authors declare that there is no conflict of interest regarding the publication of this paper.

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