Green Horizons: Enabling the Energy Transition through Climate Change Policies

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Abstract

In response to the goals set by the COP21 Summit, the challenges brought about by the COVID-19 pandemic, and the ongoing conflict between Russia and Ukraine, this study aims to develop an effective policy framework to support the transition to sustainable energy. This framework considers key elements such as managing energy risks, leveraging green finance, navigating carbon markets, and evaluating three climate change policy indicators: the impact of climate change summits (CCS), government climate programs (CCGP), and climate change taxation (CCT). Utilizing the Quantile Vector Autoregressive (QVAR) approach and analyzing monthly data from the United States from August 1, 2014, to August 30, 2022, our research examines the influential role of these climate policy indicators. The results show that climate summits, governmental initiatives, and climate taxes are significant influencers, affecting both renewable and conventional energy sectors, carbon market movements, and green finance. The study underscores the importance of government initiatives and climate policies in driving the transition to renewable energy and fostering environmentally sustainable financial activities. Focused on advancing Sustainable Development Goals 7 (Affordable and Clean Energy) and 13 (Climate Action), this research contributes to shaping effective policy frameworks and enriching policy debates on sustainable energy transition.

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1. Introduction

Anthropogenic climate change has the potential to do irreversible harm to the ecosystems that are essential for human well-being. The threat that the international community has acknowledged man-made climate change poses. Since the beginning of the 1990s, and demanded a strict reduction in greenhouse gas emissions to stop "dangerous human interference with the climate system" (UNFCCC, 1994). Nevertheless, the progress made in mitigating global warming has been very limited thus far. One contention posits that addressing climate change constitutes a worldwide public good. Every nation is driven by the desire to benefit from the emission reduction efforts of other nations, while simultaneously reducing its own efforts in order to minimise the costs involved with abatement. Given the absence of a supranational governing body, it is imperative for international agreements to possess effective mechanisms for enforcing collective action. The unequal timing of costs and rewards from emission reduction is another major barrier to climate protection. Considering the inherent physical inertia of the climate system, it is important to note that the positive outcomes resulting from the prevention of climatic damages will likely require a considerable amount of time to become evident. This is particularly relevant as the process of decarbonizing production and consumption patterns may incur economic adjustment costs in the short- and medium-term.

The disparity in the temporal occurrence of costs and benefits elucidates the rationale behind the prevailing trend of climate policy being propelled by contentious deliberations concerning the extent and allocation of expenses linked to the mitigation of emissions. The United Nations Framework Convention on Climate Change (UNFCCC) use the notion of "Common but Differentiated Responsibilities" (CBDR) to delineate the manner in which nations ought to distribute the onus of mitigating the perils posed by climate change. The allocation of responsibilities varies as a result of distinct past contributions to world emissions and divergent capabilities. The Kyoto Protocol demonstrates the notion of Common But Differentiated Responsibilities (CBDR) by directing its efforts towards industrialised nations in terms of reducing greenhouse gas emissions, while providing exemptions for developing nations from legally binding climate commitments. The Kyoto Protocol, which came into effect in 2005, was widely seen as a significant milestone in international climate agreements. However, it was recognised that the protocol needed to serve as a blueprint for a viable climate policy that emphasised collective responsibility. In 2001, the United States withdrew from the Kyoto Protocol, despite its significant historical contribution to greenhouse gas emissions. The United States government has raised concerns regarding the potential financial burdens associated with domestic compliance expenses. Additionally, it has expected that other significant emitters, such as China or India, may derive advantages from the Kyoto Agreement without committing to substantial reductions in emissions. In 2012, Canada ceased its participation in the Kyoto Protocol due to similar concerns, paralleled by Japan and Russia, both large industrialised nations, who expressed their unwillingness to undertake additional responsibilities resembling those outlined in the Kyoto Protocol beyond the first five-year commitment period spanning from 2008 to 2012.

The signing of the Paris Agreement in 2015 marked a notable change in perspective as it acknowledged the difficulties associated with negotiating obligatory agreements only for developed nations. The Paris Agreement establishes a global framework for mitigating the impacts of climate change, with the objective of constraining the increase in average global temperature to below 2°C, and preferably to 1.5°C, relative to preindustrial levels. The shift in emphasis comprises two components. In contrast to the Kyoto Protocol, the Paris Agreement mandates the participation of all nations in mitigating global warming, rather than solely relying on industrialised nations. By the conclusion of the year 2020, a total of 189 parties, encompassing all 196 members of the United Nations Framework Convention on Climate Change (UNFCCC), will have officially ratified the aforementioned agreement. Consequently, the Paris Pact is the inaugural comprehensive and obligatory agreement addressing the issue of climate change on a global scale. Furthermore, the Paris Agreement represents a transition from a centralised and obligatory framework for reducing emissions to a decentralised one, wherein individual countries autonomously pledge their Nationally Determined Contributions (NDCs) (UNFCCC, 2020). The Paris Agreement is widely seen as a notable global accomplishment in tackling the issue of global warming on a broad scope. However, the provided Nationally Determined Contributions (NDCs) from individual entities do not exhibit complete alignment. Emission mitigation strategies designed to limit global warming to a threshold of 2°C.Two nations are requested to evaluate and amend their Nationally Determined Contributions (NDCs) every five years until the combined commitments are considered satisfactory for achieving the aim. This is done with the expectation that the voluntary approach of NDCs might be enhanced by publicly identifying and criticising countries who fail to meet their obligations. This is due to the acknowledgement that the first voluntary commitments are inadequate in attaining the long-term temperature objective outlined in the Paris Agreement. According to the findings of Vandyck et al. (2016) and Hof et al. (2017), the implementation of more stringent climate policy measures until 2030, which are aligned with the temperature aim set by the Paris Agreement, will lead to much higher economic adjustment costs.

Based on SDGs 7 and 13, it is possible to discuss the requirement of an energy transition for the achievement of the SDG goals. Although energy transition can aid in achieving the goals of economical and clean energy, it can also help in halting environmental deterioration. Based on the latest report on the Sustainable Development Goals (SDGs) in 2022, it is evident that numerous economically advanced nations, including the countries belonging to the Organisation for Economic Co-operation and Development (OECD), require assistance in attaining the objectives outlined by two specific SDGs (United Nations, 2022). This subject came up at the COP26 Summit as well. The discussions of potential mitigation and adaptation measures followed a similar pattern to the OECD study Investing in Climate, Investing in Growth, issued four years earlier (OECD, 2017). The advantages of the energy transition in addressing the concerns of environmental degradation and energy security in these nations were covered in this report. In order to comply with the Paris Accord, the COP26 Energy Transition Council emphasised the importance of embracing the energy transition process (Kumar, 2021). The phase-out of coal-fired power facilities and funding for renewable energy sources may be necessary for this process. It could be necessary to find creative financial strategies to fund these projects. The COP26 Summit strongly emphasised the financing of climate adaptation via the carbon pricing mechanism (Environmental Defence Fund, 2021). By pricing emissions in accordance with the Pigouvian Taxation process, a carbon tax can address the problem of environmental deterioration while also generating tax revenues that can be used to fund energy transition initiatives. Implementing the low-carbon energy transition can help countries become more resilient to the effects of climate change (Saleheen, 2021). These tax proceeds may fund the technological advancements required for the energy transition. The COP26 Summit contained discussions on the significance of environmental technologies in fostering climate resilience. The contribution of environmental technologies to the energy transition was acknowledged by a number of politicians (Liou, 2021). Therefore, for the United States of America to implement the energy transition, it is necessary to redefine the roles of green finance and energy risk management. These two factors should be taken into account in the new energy transition policies as critical motivators. This reasoning strengthens the foundation of the current investigation.

In order to advise the best distribution of money, natural resources, and social resources, an efficient green financial system must be able to coordinate the interaction between ecology and finance (Wang & Zhi, 2016). It effectively eliminates moral hazard and prevents information asymmetry. In order to promote private investment and create sustainable infrastructure, a nation must first create new legislation (Gonzalez Ruiz et al., 2016). It can also examine green finance from a methodical standpoint, according to Hafnera et al. (2020). The direction and support of a top-notch system are inextricably linked to the advancement of theory. Therefore, the development of a green financial system encourages further study. Simultaneously, energy risk management encompasses the process of recognising, evaluating, and alleviating risks linked to activities pertaining to energy. Energy risks can arise from various sources, including market volatility, geopolitical factors, regulatory changes, supply disruptions, and environmental considerations. Effective energy risk management helps organizations optimize energy-related decisions and protect themselves from potential adverse impacts. Some common energy risks are associated with energy prices, supply chains, regulations, and the environment.

The following are the contributions made by this study. First, the main focus of all prior writing on green finance and climate change was its affecting elements. This study closes a gap in the USA's growth of green finance and energy risk management through energy transition and climate change policy indices. Our second approach is to thoroughly and systematically assess the USA energy management system via Quantile Vector Autoregressive (QVAR). This method gets beyond the entry-weight method's restriction that it can only use each index's data as of a particular time point and accurately captures the role of climate change policy indices in green finance, energy transition and energy risk management. Third, this study provides information on the USA's current green finance growth conditions and climate change policies, which is crucial for developing the USA's green finance and energy growth strategy and can help policymakers raise the level of energy transition and green finance growth. Fourth, this study builds an indicator system of the USA's level of energy transition and green financial development from the perspectives of market and policy.

The remainder of the paper is structured as follows. Section 2 discusses the available literature related to research constructs extensively. Section 3 reports the data, methods and materials used to conduct this study and develop a theoretical and practical frameworks. Section 4 provides an estimation and description of the empirical findings and results. The final section of this study serves as a conclusion, providing recommendations for both theoretical and policy consequences.

2. Literature Review

Without a constant supply of energy, modern society suffers. The global economy is fueled by energy. However, using unsustainable methods to meet energy needs has caused the environment to suffer irreparable harm to the planet. The growth in greenhouse gas emissions, the temperature increase, and the presence of harmful substances in the air and water all threaten future generations' survival. The general public has been much more aware of climate change since the turn of the twenty-first century. Many parties, including the general public, call for risk-reduction measures related to climate change (Tiba & Belaid, 2020). One of the primary items on the global political agenda right now is the switch from conventional to more sustainable energy sources. Due to recent disruptive geopolitical events, the energy transition has become a significant problem. On a global scale, nations require assistance in attaining the Sustainable Development Goals (SDGs). One of the primary obstacles encountered by nations is the transition towards utilising more environmentally sustainable energy sources (Chishti et al., 2023). In order to effectively address the challenges posed by environmental pollution and climate change and make progress towards the Sustainable Development Goals (SDGs), it is imperative to undertake a shift towards the development and utilisation of renewable energy sources (Awijen et al., 2022; Belaïd et al., 2021; Belaïd & Zrelli, 2019). The proposition that energy transition has the potential to enhance environmental quality and energy efficiency is irrefutable. According to Olson and Lenzmann (2016), recent anecdotal evidence suggests that an overreliance on fossil energy sources has adverse implications for the socio-economic development of nations, primarily attributable to supply chain challenges. The attainment of sustainable socio-economic progress can be realised by a nation through the transition towards sustainable energy generation. Nevertheless, the process of transitioning to more sustainable energy resources is not a simple task.

The utilisation of fossil fuels for energy generation gives rise to numerous environmental challenges. This promotes the utilisation of sustainable resources as a source of fuel for the generation of energy. Energy storage is a significant technological challenge that arises in the context of renewable resource utilisation for energy production and the endeavour to enhance the share of renewable energy in the worldwide energy composition (Gallo et al., 2016). To embrace the shift to renewable energy, every country must innovate and create effective energy systems (Kittner et al., 2017). The creation of environmentally friendly technologies is essential to the creation of effective energy systems. Infrastructure in a country can be made more efficient for producing and using renewable energy thanks to environmental technologies. In keeping with this, Bayulgen (2020) has investigated the socio-economic factors influencing the transition of different form of energy and contends that the advancement of green technologies is a key factor in the orderly transfer of energy sources. Traditional and renewable energy sources. The idea that environmental technology is one of the key factors influencing the energy transition is also supported by other existing work (see, for example, Aklin & Urpelainen (2013, 2018); Baker et al. (2014); Chien et al. (2021). In a more recent development, the European Environment Agency has underscored the importance of innovation in environmental technology as a means to enhance environmental quality and promote the effective and responsible utilisation of natural resources (European Commission, 2011). According to anecdotal evidence and well-known research on the factors affecting the energy transition, it is possible to hypothesise that a nation's technological development will significantly benefit the energy transition.

The function of both formal and informal institutions in effecting change has been well acknowledged in the field of literature. Formal institutions serve the purpose of providing a legal framework that facilitates the implementation of specific strategies. In addition, formal entities provide clients with financial help in the form of subsidies, with the aim of promoting the adoption of socially beneficial products. The aforementioned subsidies represent a constituent element of fiscal expenditure, which is financed by the collection of taxes. In recent times, governmental bodies have been employing environmental (carbon) taxes as a strategic tool within their fiscal policies, with the aim of diminishing the utilisation of energy sources derived from fossil fuels, while concurrently promoting the adoption of sustainable energy alternatives. Corporations globally are identified as the primary users of resources, particularly those pertaining to the environment (Hussain et al., 2018). Therefore, industrial companies that undermine the environment must be held accountable. Bringing about business change will hasten the energy transition process simultaneously. Environmental taxes also encourage governments to fund programmes that benefit the environment. Drawing upon the empirical evidence presented in the existing body of literature, it is plausible to posit that the implementation of environmental taxes has the potential to exert a substantial influence on a country's energy transition.

Globalisation poses both advantages and disadvantages for sustainable development in any given economy. On one hand, it provides opportunities for socio-economic advancement. However, it has major environmental consequences. Due to rising productivity and population, there has been degradation (He et al., 2021). Despite the pressure that globalisation placed on economies to produce more and rely more on conventional sources of energy, it can aid in easing the transition of those economies (Chien et al., 2021) to having more sources of alternative enegies. Carfi et al. (2019) worked on economies to attain economic and social Nash equilibrium, businesses need to offer up investment opportunities for international investors. He et al. (2021) have noted that globalisation aids in reducing carbon emissions and enhances climate performance in economies. Existing research on the relationship between aspects of the energy transition and globalisation can be categorised into two primary categories. One school of thought contends that as trade barriers in the economy are removed as a result of economic development, globalisation, and significant rise in the level of energy consumption (Rahman, 2020). Deterioration of the environment results from this. On the contrary, an alternative perspective posits that the phenomenon of globalisation is concomitant with technological progress and the accessibility of resources for the purpose of investing in environmental innovation, thereby leading to enhanced natural resource management (He et al., 2021; Shahbaz et al., 2016; Shahbaz et al., 2018). As globalisation intensifies, a nation's ability to invest in environmental initiatives and facilitate a smooth transition towards sustainable energy is enhanced, thereby fostering a genuine connection. This is made possible by the increased availability of resources.

Based on the extant body of literature, the establishment of an optimal green financial system serves as the fundamental basis for fostering development. China has taken the initiative to pioneer the extensive and prolonged endeavour of developing a green financial system, making it the first country to do so. The economy aims to establish a system that approaches a state of near-perfection. According to Lee et al. (2020) and Wang et al. (2011), The green financial system encompasses a synthesis of diverse systems, institutions, tools, markets, and regulatory control. The establishment of a green financial system plays a crucial role in facilitating the advancement of financial reforms, economic transformation, and the realisation of both economic and environmental benefits. According to Wang and Zhi (2016), an efficient green financial system can coordinate the interaction between ecological and finance and direct the best distribution of financial, natural, and human resources. It effectively eliminates moral hazard and prevents information asymmetry. In order to promote private investment and create sustainable infrastructure, a nation must first create new legislation (Gonzalez Ruiz et al., 2016). It can also examine green finance from a methodical standpoint, according to Hafnera et al. (2020). The direction and support of a top-notch system are inextricably linked to the advancement of theory. Therefore, the development of a green financial system encourages further study.

Scholars should focus on the micro- and macro-level effects of green financial development. Expanding green financing also impacts the national economy and associated financial institutions. Liu and Wen (2019) present a novel examination of the environmental stewardship practises of financial institutions, specifically within the framework of traditional economic development theory. Their work introduces creative viewpoints that contribute to the study of green finance. According to the study conducted by Ren et al. (2020), the utilisation of green finance has been found to effectively reduce carbon intensity, as evidenced by the application of the vector error model. Thomas et al. (2007) conducted an investigation on the economic added value, wherein they found that financial institutions has the capability to offer loans and assess the prospective environmental risk of a project by considering the external environmental cost. There exist divergent perspectives concerning the impact of green financing on financial institutions. One potential outcome of green financing is the expansion of financial institutions. Chami et al. (2002) propose that the use of green finance facilitates strategic growth for financial organisations. The counterargument posits that it hinders and potentially obstructs the growth of financial institutions. According to the findings of He et al. (2019a), the efficacy of banks' investments in renewable energy is diminished by the implementation of green finance, as observed in their research done in China. According to a study done in India, banks must be more motivated to implement a green lending policy, according to Biswas (2011). Thomas & Hilke (2018) integrate the green support element into bank capital supervision, while Niu et al. (2020) employ the twofold difference approach to confirm that a green credit policy boosts the financing convenience of green-listed enterprises in the short run. Sheu & Chen (2012) employ a three-stage game model to argue that in order to foster the development of a low-carbon supply chain, the government should adopt green tax and subsidy policies to encourage enterprises to manufacture green commodities.

The effects of different risks on the operations of energy utilities have been brought to attention in recent study. These risks encompass weather hazards, variable commodity prices, and climate change, as discussed by Lin et al. (2020). The concept of geopolitical risk has been discussed by Finon and Locatelli (2008), while policy uncertainty has been examined by Breitenstein et al. (2022) and Tulloch et al. (2017). Risk disclosure is an essential mechanism employed by publicly traded companies to effectively communicate their identified risks and strategies for risk mitigation. It can assist regulators in identifying systemic hazards associated with energy utilities and assist (possible) investors in developing more accurate cash flow projections. However, from the standpoint of a corporation, the disclosure of significant risks previously undisclosed to the outside world might be linked to unfavourable outcomes like falling share prices. Due to this tendency towards obscurity in risk disclosure (Dobler et al., 2011), investors are less likely to find it beneficial, and the implicit uncertainty about future cash flows may even make stock prices more volatile (Kravet & Muslu, 2013).

This research investigates the potential relationship between improved risk disclosure and the level of stock volatility within the context of energy utilities. Given the significant risk exposures faced by these utilities and the ambiguous nature of risk disclosure, this study aims to determine whether enhanced risk disclosure is associated with higher or reduced stock volatility. Put simply, our objective is to ascertain if investors perceive risk disclosure as negative information or as a sign of a utility's commendable risk management practises. The disclosure of risk holds a distinctive position among the information that is publicly available in annual reports (Kravet & Muslu, 2013). Utility managers generally possess a more comprehensive comprehension of the organization's risk exposure. The primary objective of disclosure initiatives is to mitigate the asymmetry of information between shareholders and managers who possess relevant knowledge. Hence, the primary aims of risk disclosure encompass the principles of transparency, effective risk communication, and proficient risk management. In order to effectively discharge their responsibilities pertaining to the oversight and assessment of risk levels, regulators and rating agencies must also possess the requisite access to this pertinent information (Healy & Palepu, 2001). The process of risk disclosure is characterised by a qualitative approach that encompasses a forward-looking perspective. The provision of quantified forward-looking information regarding corporate risks is often associated with the significant indirect expenses associated with disclosure (Leuz & Wysocki, 2016), particularly when competitors are expected to exploit this information to the detriment of the disclosing company. Forward-looking information encompasses expectations that provide challenges in terms of quantification. Based on empirical research, it has been observed that companies often refrain from disclosing forward-looking and quantitative information (Linsley & Shrives, 2006). Additionally, their risk disclosures are often lacking in transparency and clarity (Dobler et al., 2011), and they tend to rely on generic statements and casual conversation (Dobler, 2008; Kravet & Muslu, 2013). Nevertheless, previous research conducted by Campbell et al. (2014) and Elshandidy & Shrives (2016) provides empirical evidence that substantiates the significance of risk disclosure for individuals involved in the capital market. As a result, readers interested in risk disclosures must take on the job of selecting pertinent information about risks to accurately comprehend it and then evaluate it.

Previous research documented several indices of energy transition, green finance and carbon markets. However, the impacts and relationships could be more conclusive regarding their direction and magnitude. This motivated us to conduct this study and leaves two questions before us and policymakers: (1) What is the precise function of climate change policy indicators in facilitating the process of transitioning to sustainable energy sources? Additionally, it is important to consider the ways in which green finance and climate change policies contribute to energy risk management in the United States. The current study has been formulated with consideration of two specific research inquiries and identified research gaps. Moreover, the present study focuses on three climate change policy indices, namely Climate Change Summits (CCS), Climate Change Government Programmes (CCGB), and Climate Change Tax (CCT), and their effects on green finance, as well as energy and carbon markets in the United States. This is achieved by addressing two specific research questions and addressing existing gaps in the literature.

3. Data and Methodology

3.1 *Data specification*

This paper examines climate policies' effect on energy risk, green finance, and carbon market indices in the USA. We have garnered daily data from 01 August 2014 to 31 August 2022. In order to delineate the extent of climate policies as outlined by Ardia et al. (2022), this study examines three distinct climate change measures: Climate Summits, Government Programmes, and the climate Carbon Tax. The data utilised in this analysis were obtained from the MCCC (2023) database. To benchmark the energy risk, we used the Dow Jones U.S. Oil & Gas (DJOGI) and S&P Global Clean Energy Indices (SPCE) to represent traditional and non-traditional energy markets. Based on the streaming literature, we have selected S&P Green Bond (SPGBI) and IHS Markit Global Carbon (IHSM) indices as the proxy for the carbon market and green finance, respectively. The utilisation of the Datastream database facilitates the examination of the green finance, carbon, and energy markets. The selection of the time range was conducted with careful consideration, taking into account notable occurrences such as COP21, which led to the establishment of the Paris climate change agreement. Moreover, the COVID-19 epidemic and the recent conflict between Russia and Ukraine have amplified the vulnerabilities linked to climate change and the energy sector. These events are characterised by notable disruptions in structure and heightened levels of volatility, wherein market conditions exhibit both downward and upward movements. The objective of the analysis is to assess the influence of these significant events on the markets under study, taking into account a wide temporal scope.

$$V=\sum_{j=1}^{M} r^{2} \quad \ldots. (1)$$

The variable rt,j denotes the return on the jth day of time period t. The variable "M" represents the number of observations on a given day, denoted as "t". These observations can be characterised as a return, which is represented in the following manner:

$$R_{it} = \ln\left(\frac{T_{it}}{T_{t-1}}\right) \ldots\ldots\ldots (2)$$

Where:

T_{it}: index at time t

T_{t-1}: index at time t-1

R_{it}: index volatility at time t

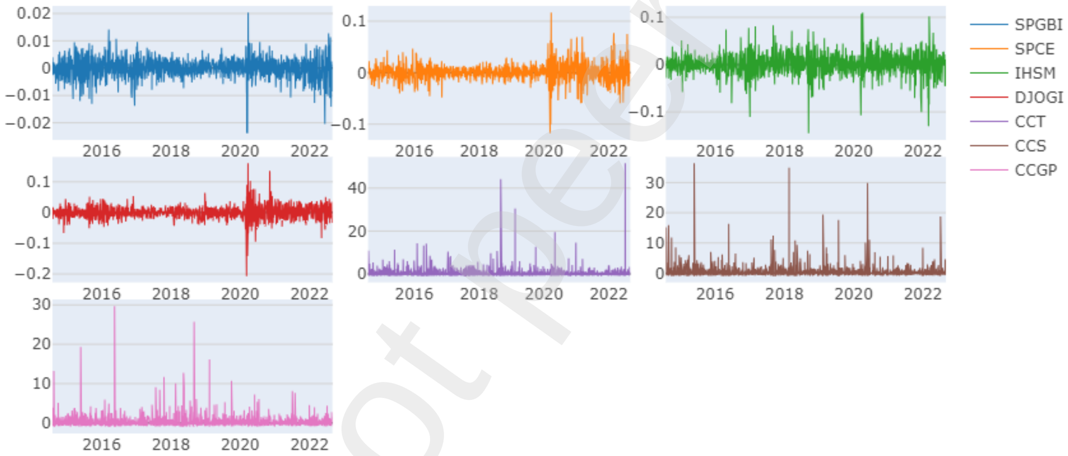

Figure 1. Return series of climate, green finance energy and carbon markets indices

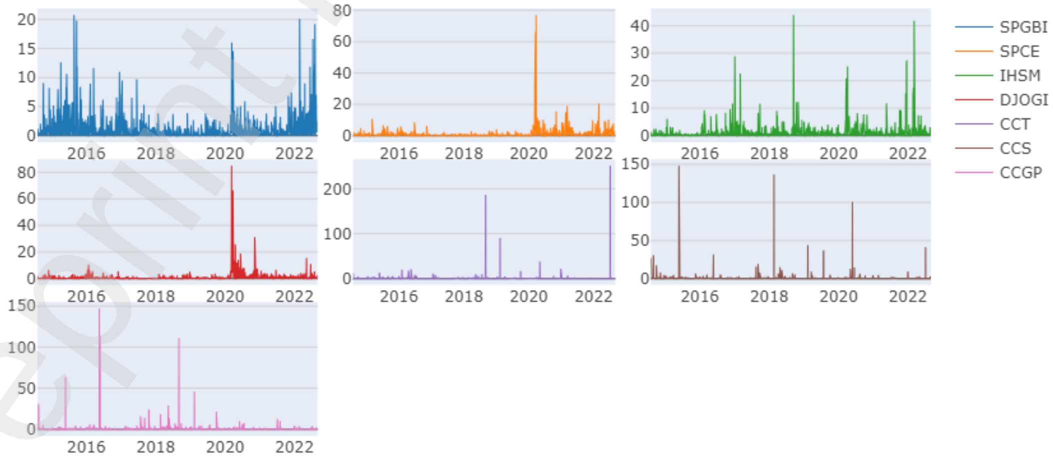

Figure 2. Volatility series of climate, green finance energy, and carbon markets indices

3.2 Novel quantile connectedness

The novel quantile introduced by Ando et al. (2022) for the Vector-Autoregressive (VAR) model, as suggested by Diebold and Yilmaz (2012, 2014), is frequently employed in scholarly works to assess the dynamic, time-frequency, and nonlinear association between the corporate bond market and uncertainty indices under various market conditions (namely, bearish, normal, and bullish). The mathematical representation of the QVAR approach is as follows:

$$y = u\,(\tau) + \sum\nolimits_{j=1}^{n} \emptyset_j(\tau) y_{t-1} + u\,(\tau) = \; u\,(\tau) + \sum\nolimits_{j=1}^{n} \Omega_j(\tau) y_{t-1} \qquad (3)$$

The specification of the generalised forecast error variance (GFEVDs) with a future horizon H (namely, 10 in this example) can be determined:

$$\psi_{ij}\,(\mathrm{h}) = \frac{\sum q_{\overline{jj}}^{\,1} \;\; \sum_{h=0}^{h-1} (k_i' \, \Omega_h(\tau) \sum (q) k_j)^2}{\sum_{h=0}^{h-1} (k_{i\,h}' \Omega_h(\tau) \sum (q) k_i)} \qquad (4)$$

The QVAR model offers many measures of connectedness, namely the overall connectedness index and decompositions, which may be computed using equations 5 to 7, given that k_i represents a zero vector.

the total connectedness index can be written as:

$$\mathrm{TCI}_t = K^{-1} \sum\nolimits_{j=0}^{k} FROM_{jt} \qquad (5)$$

The measurement assesses the extent of risk spillover during the entire duration. Connectedness with others can be defined as:

$$FROM_{jt} = \sum\nolimits_{i=1,\, i\neq 1}^{k} \phi^{\sim}{}_{jt}(H) \qquad (6)$$

The presented analysis demonstrates the interdependence of variables, wherein each variable is subject to external shocks originating from other variables. Whilst

$$TO_{jt} = \sum\nolimits_{i=1,\, i\neq 1}^{k} \phi^{\sim}{}_{jt}(H) \qquad (7)$$

it defines the return spillover transmitter. Finally, $NET_{jt} = TO_{jt} - FROM_{jt}$ this study aims to examine the concept of net directional connectivity and elucidate the distinction between from connectedness and to connectedness.

4. Results

Concerning the median values, all of the values are close to their corresponding means except for the climate change indices. This indicates that the likelihood of outliers in the estimation process is higher for the climate change indices than for the energy, green finance, and carbon indices, which will help the process later on. Similarly, the low SD values for all variables, except the climate indices, indicate that the data points remain relatively close to their mean values. Moreover, the examination of skewness and kurtosis provides intriguing observations regarding the variables. The examination of skewness and kurtosis suggests that the variables do not exhibit a normal distribution. Furthermore, the study of kurtosis indicates that a majority of the parameters display a higher degree of tail heaviness, as shown by kurtosis values surpassing the threshold of three. The coefficients of skewness exhibit variability, with values deviating from zero, suggesting the presence of non-symmetrical series. The statistical significance of the Jarque-Bera test suggests that the returns within the series deviate from a normal distribution.

Table 1. Descriptive statistic

	CCGP	CCS	CCT	DJOGI	IHSM	SPCE	SPGBI
Mean	0,368	0,447	0,463	0,000	0,001	0,000	0,000
Median	0,004	0,008	0,000	0,000	0,000	0,001	0,000
Maximum	29,670	36,401	51,581	0,160	0,110	0,117	0,020
Minimum	-0,960	-0,986	-0,968	-0,207	-0,145	-0,117	-0,024
Std, Dev,	1,649	2,028	2,199	0,019	0,020	0,015	0,003
Skewness	8,747	9,079	12,335	-0,459	-0,332	-0,217	-0,576
Kurtosis	121,580	126,275	237,441	16,829	8,304	11,471	7,921
Jarque-Bera	1262516	1364388	4883300	16879,05	2510,64	6321,5	2244,7
Probability	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Observations	2109	2109	2109	2109	2109	2109	2109

The figures presented in Figure 3 depict the Total Cost of Insurance (TCI) of volatility at different quantile levels (10th, 50th, and 90th) during the expected time frame. It is worth noting that the TCI demonstrates greater values in the upper quantile compared to the lower quantile and the mean, respectively. The higher quantiles of the data set are greater than the mean. The TCI exceeds 60% at the upper quantile during significant events like the Paris Agreement's reinforcement in 2016, the COVID-19 pandemic's announcement in the first month of 2020, and the Russo-Ukrainian Armed Conflict. This suggests that the interdependence of climate risk, green finance, carbon markets, and renewable and non-renewable markets is particularly sensitive to bullish market conditions. It is important to note that although these values rise in response to the same events at normal and lower quantiles, they do so at a lower rate than at the upper quantile. This observation is depicted in the analysis of the prior studies (Saleheen, 2021; Sinha et al., 2022b; Vetter, 2022).

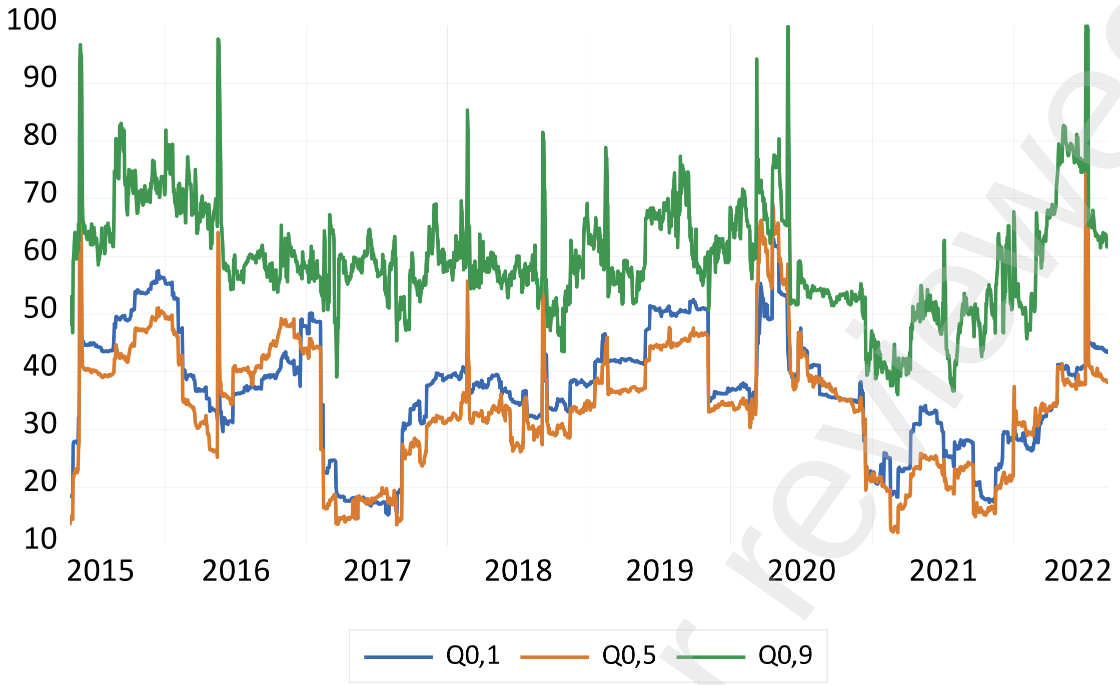

Figure 3. TCI of the volatility

Figures 4, 5, and 6 illustrate the dynamic connection of the networks CCGP, CCS, CCT, DJOGI, IHSM, SPCE, and SPGBI at the 90th, 50th, and 10th quantiles, respectively. The colour scheme is utilised to differentiate between yellow connections, which represent net receivers, and blue connections, which represent net transmitters. This study examines the impact of three market conditions (10th, 50th, and 90th quantile) on three climate risks identified by Climate Summits, Government Programmes, and the climate Carbon Tax network. The findings reveal that these risks serve as robust conduits for transmitting shocks to the volatility of green and non-green energy, carbon market, and green finance indices. Tables 2, 3, and 4 provide more detailed information on the average and degrees of information transmission and shock impact across quantiles, with the upper quantiles demonstrating higher transmission levels than the normal and lower quantiles. It demonstrates that tax and government programs' climate policy indices are important in information transmission. They transmit about 17% and 11% more information at the upper extreme quantile than at the normal and lower quantiles (9% and 3%, respectively). It demonstrates that the climate summit index transmits a 6.66% shock at the upper quantile. This transmission decreases to 4.18% than 3% at the normal ad lower extreme quantiles, respectively.

While the information was transmitted under bullish market conditions, the clean energy index was identified as the primary shock receptor at the mean and lower quantile by 8.75 and 1.35, respectively. In contrast to the Clean Energy Index, the Traditional Energy Index (DJOGI) is expected to show the opposite pattern. It is expected to function as a shock transmitter at the 90th quantile while receiving data at the 10th and 50th quantiles (Awijen et al., 2022; Chishti et al., 2023; Tiba & Belaid, 2020). Based on the findings shown in Table 2, it can be inferred that the Green Finance Asset and Carbon Market Index networks have a higher propensity to serve as key recipients of shocks in terms of overall volatility across various market situations. With values of around -20 and 16, respectively, IHSM and SPGBI are identified as the largest net shock receivers. Furthermore, as shown in Tables 3 and 4, the intensity of shock reception decreases at the mean and lower quantiles. On average, the intensity drops to -9 at the mean and -4.5 at the lower quantile.

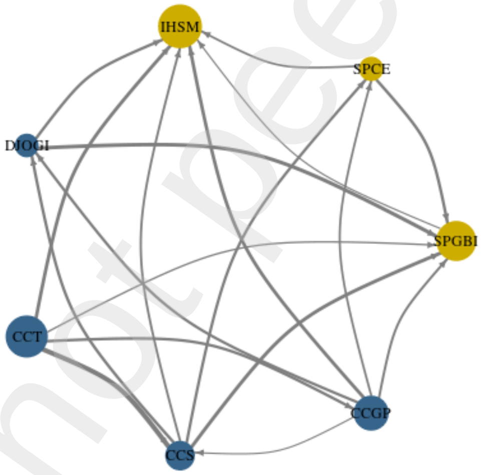

Figure 4. Network connectedness at the upper quantile

Table 2. Average dynamic connectedness of the volatility at the 90th quantile

	SPGBI	SPCE	IHSM	DJOGI	CCT	CCS	CCGP	FROM
SPGBI	38.18	16.39	10.61	15.16	6.83	6.63	6.20	61.82
SPCE	12.71	39.39	10.77	18.27	6.73	6.70	5.44	60.61
IHSM	12.40	13.37	37.28	13.29	9.59	6.05	8.03	62.72
DJOGI	10.51	17.56	9.69	43.06	6.72	6.15	6.32	56.94
CCT	4.77	5.52	5.32	6.08	50.19	11.57	16.55	49.81

CCS	2.26	3.20	3.18	2.52	17.60	53.44	17.82	46.56
CCGP	3.21	2.75	3.83	2.86	20.12	16.09	51.14	48.86
TO	45.85	58.78	43.39	58.17	67.58	53.18	60.36	387.32
Inc.Own	84.03	98.17	80.67	101.23	117.77	106.62	111.51	cTCI/TCI
NET	-15.97	-1.83	-19.33	1.23	17.77	6.62	11.51	64.55/55.33
NPT	1.00	2.00	0.00	3.00	6.00	4.00	5.00	

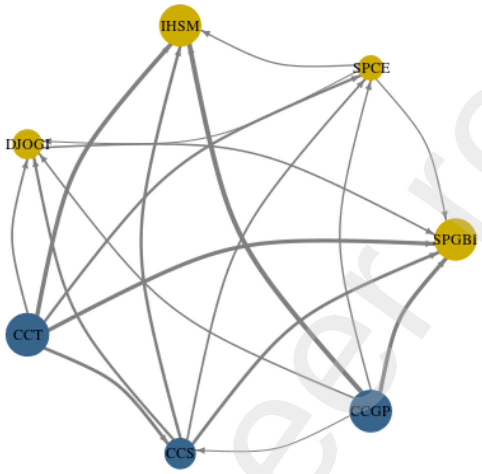

Figure 5. Network connectedness at the medium quantile

Table 3. Average dynamic connectedness of the volatility at the mean

	SPGBI	SPCE	IHSM	DJOGI	CCT	CCS	CCGP	FROM
SPGBI	77.79	6.00	4.14	4.07	2.83	2.21	2.96	22.21
SPCE	5.03	75.48	3.29	11.63	1.89	1.47	1.20	24.52
IHSM	4.25	4.30	77.31	3.19	3.48	3.17	4.30	22.69
DJOGI	2.85	12.46	2.87	76.89	1.63	1.84	1.46	23.11
CCT	0.31	0.14	0.78	0.30	63.37	14.41	20.69	36.63
CCS	0.18	0.10	1.23	0.11	16.48	63.54	18.35	36.46
CCGP	0.44	0.09	1.29	0.28	20.05	17.54	60.31	39.69
TO	13.06	23.09	13.61	19.58	46.37	40.64	48.95	205.30
Inc.Own	90.84	98.57	90.92	96.47	109.75	104.18	109.26	cTCI/TCI
NET	-9.16	-1.43	-9.08	-3.53	9.75	4.18	9.26	34.22/29.33
NPT	1.00	3.00	0.00	2.00	5.00	4.00	6.00	

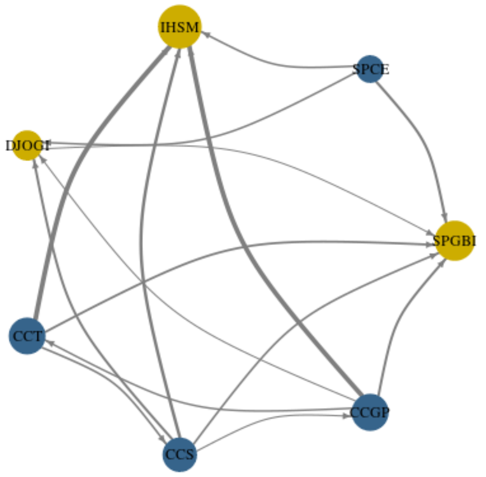

Figure 6. Network connectedness at the lower quantile

Table 4. Average dynamic connectedness of the volatility at the 10th quantile

	SPGBI	SPCE	IHSM	DJOGI	CCT	CCS	CCGP	FROM
SPGBI	74.08	9.04	6.94	5.40	1.66	1.09	1.80	25.92
SPCE	8.03	68.54	6.39	14.89	0.95	0.62	0.59	31.46
IHSM	6.54	7.11	71.85	5.46	2.95	2.60	3.50	28.15
DJOGI	4.93	15.61	5.30	70.89	1.05	1.21	1.00	29.11
CCT	0.80	0.53	1.10	0.60	64.10	12.72	20.13	35.90
CCS	0.32	0.24	1.40	0.27	13.48	68.34	15.96	31.66
CCGP	0.85	0.29	1.70	0.50	19.44	16.48	60.73	39.27
TO	21.47	32.82	22.83	27.12	39.53	34.72	42.97	221.46
Inc.Own	95.55	101.36	94.68	98.01	103.63	103.06	103.71	cTCI/TCI
NET	-4.45	1.36	-5.32	-1.99	3.63	3.06	3.71	36.91/31.64
NPT	0.00	3.00	1.00	2.00	5.00	5.00	5.00	

4.1 Robustness check

In order to assess the reliability of the results obtained from the QVAR model applied to the volatility indices, we implemented this model on the return indices using a rolling window of 150 observations and a forward forecasting of 20 periods. The results are presented in Figures 7 through 12. The displayed colour code ranges from dark blue, representing a high receiving asset, to dark red, representing a high transmitter asset. Colder shades of blue indicate low net recipients, while less intense shades of red suggest a minor transmitter shock. The dominance of the Climate Change Summit (CCS) index as a net shock transmitter was observed at both the upper and lower quantiles, except for the period preceding and during the third wave of the COVID-19 pandemic. This discovery provides further evidence in line with prior research (Belaïd et al., 2021; Belaïd & Zrelli, 2019; Olson & Lenzmann, 2016), demonstrating that various climate risk indices have an impact on the dissemination of information within the energy, green finance, and carbon markets, albeit at distinct temporal intervals and under diverse market circumstances. In contrast, SPCE was just recognised as a diminutive transmitter at the outermost quantile, but it seems to be received with a net effect at the average. The discovery was made that DJOGI serves as the principal net shock transmitters at upper quantile levels, particularly in the context of the COVID-19 pandemic. The SPGBI and IHSM networks were the primary recipients of the shock. The aforementioned findings are consistent with the prior outcomes of QVAR in relation to the volatility and the use of a 200-window rolling window for 20-variate forward forecasting.

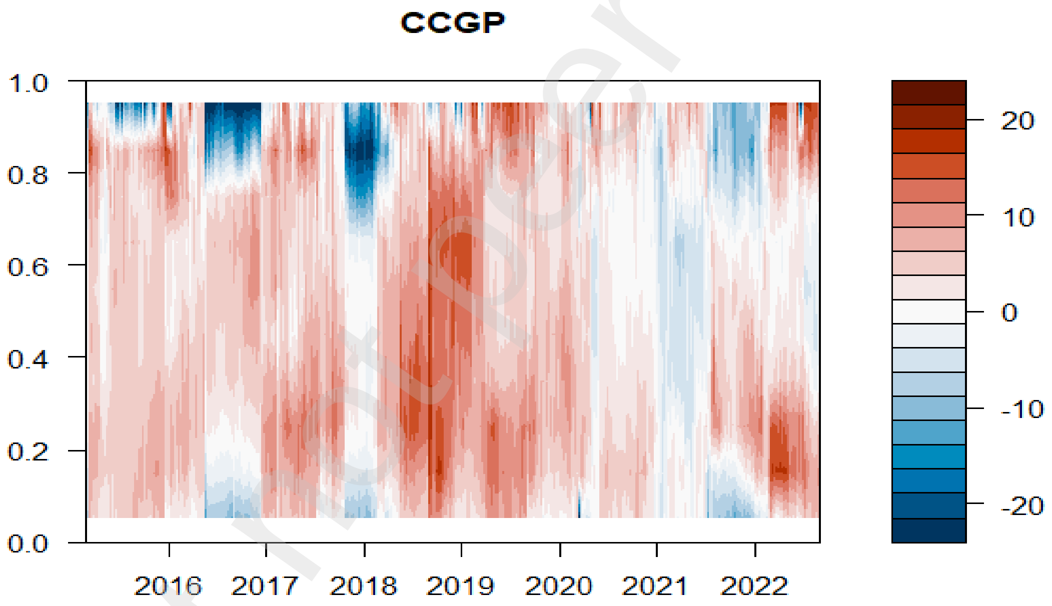

Figure7. NTDC for the Government Programs climate risk

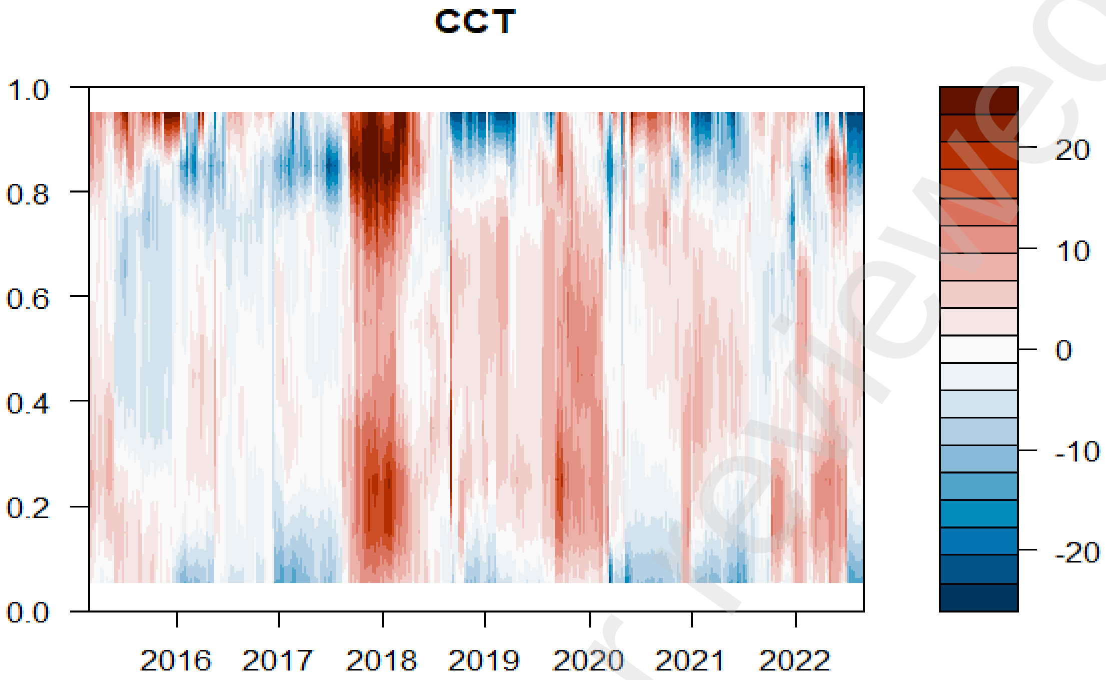

Figure8. NTDC for the tax climate risk

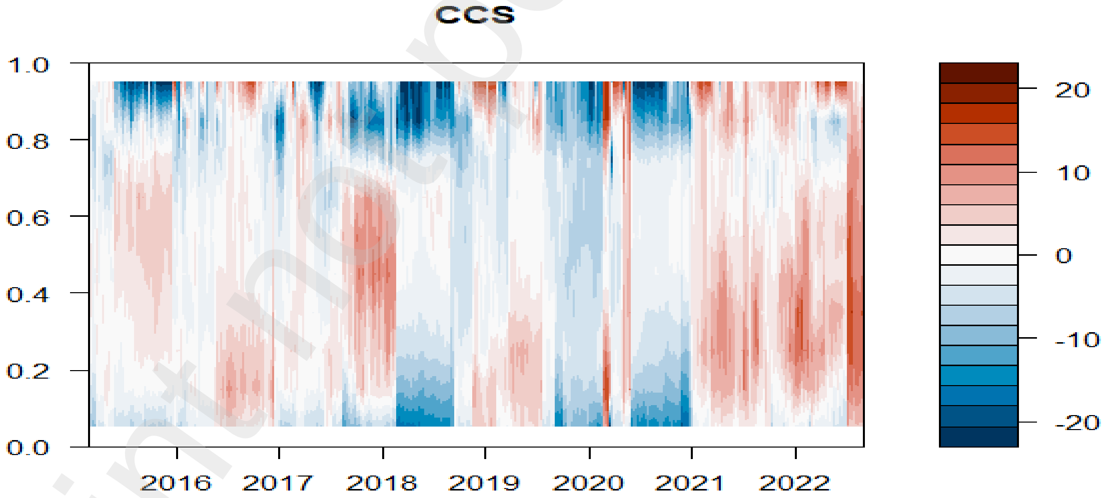

Figure9. NTDC for the summit climate risk

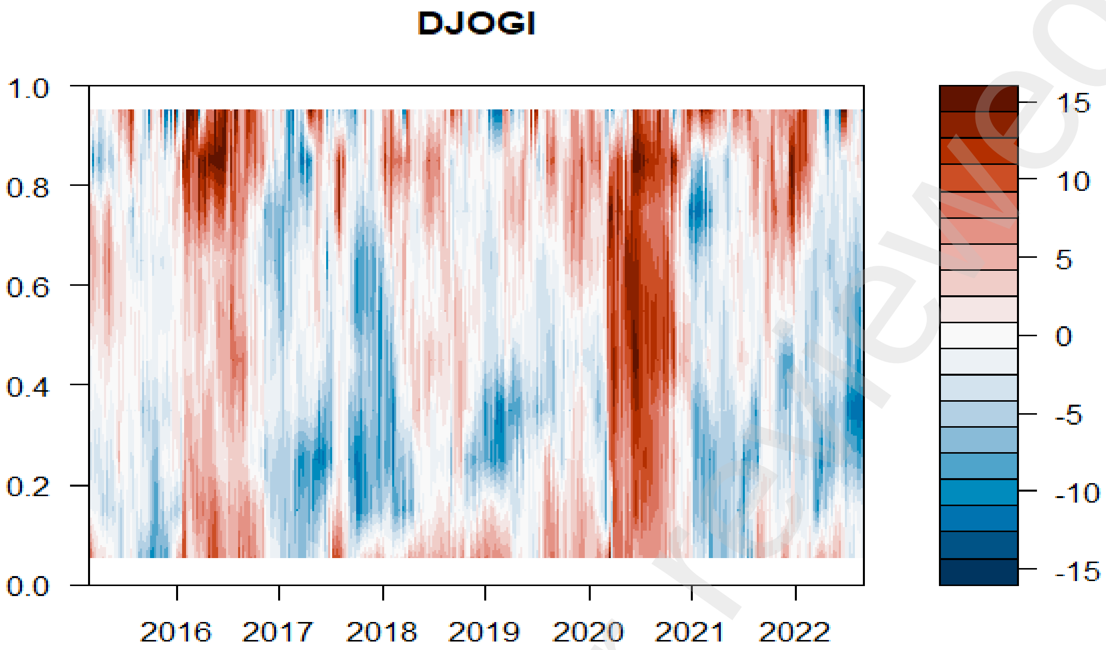

Figure10. NTDC for the traditional energy index

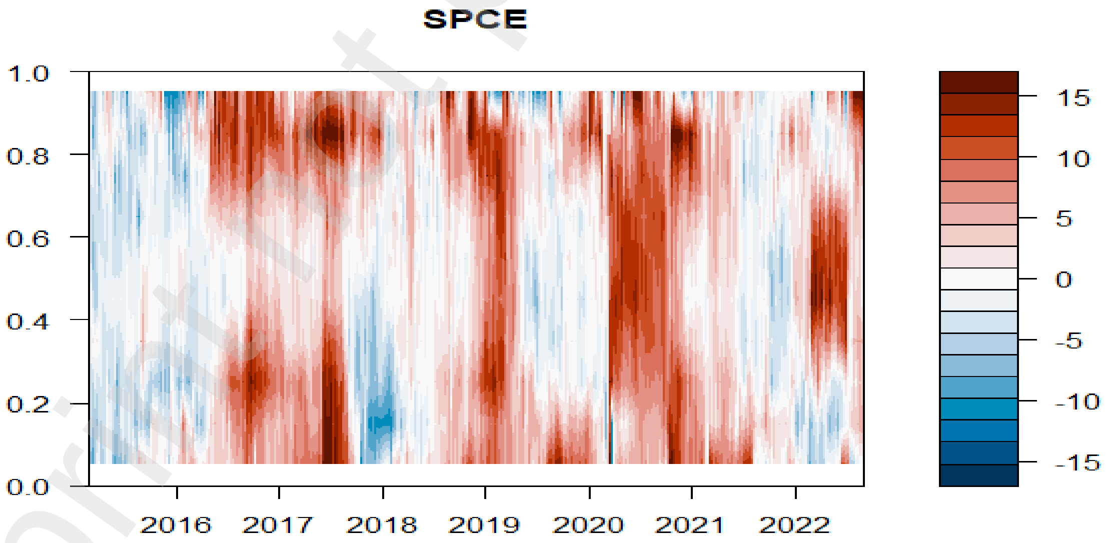

Figure10. NTDC for the clean energy index

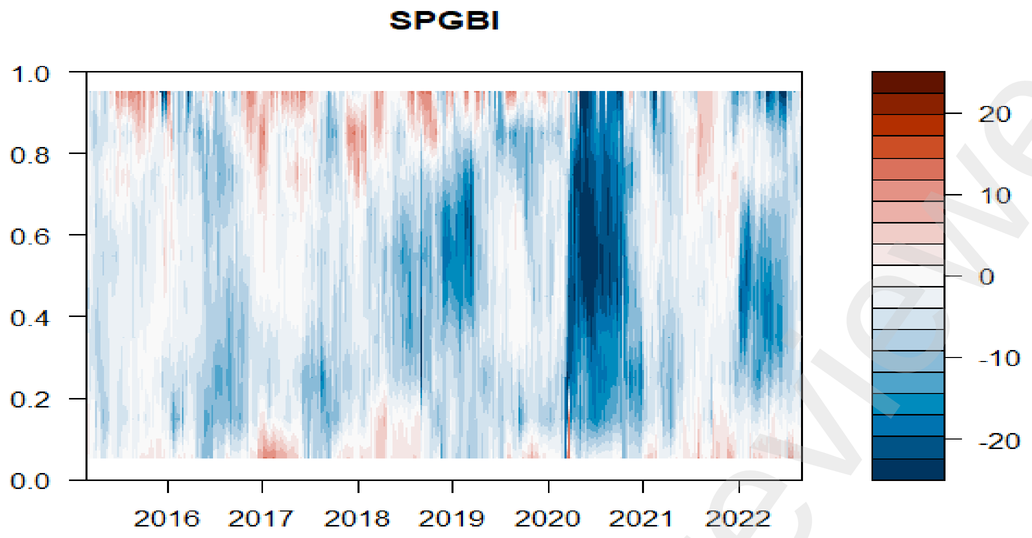

Figure11. NTDC for the green finance

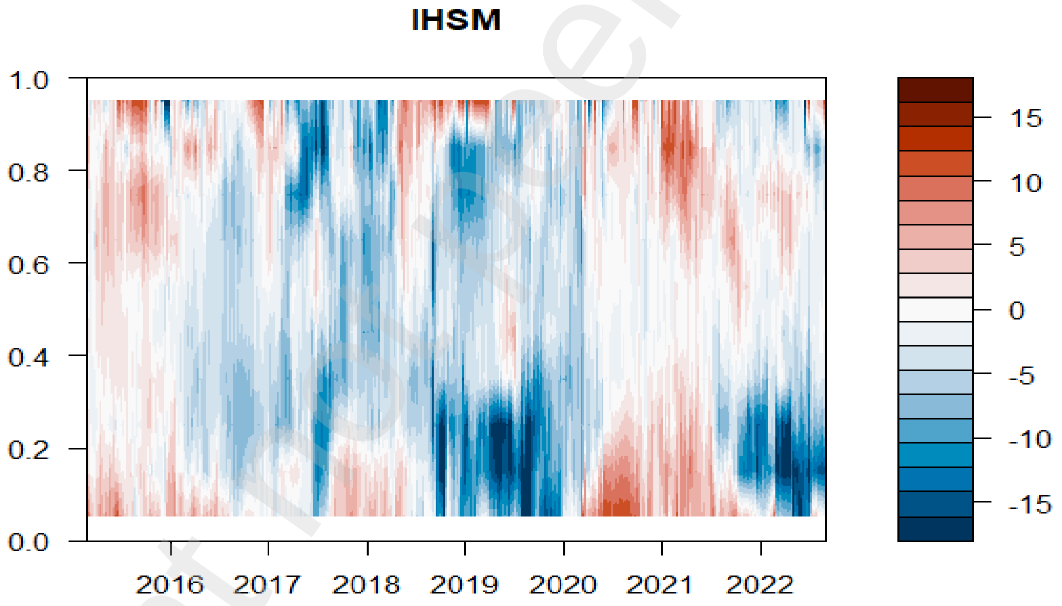

Figure12. NTDC for the carbon market

4.2 Cross-sectional ADL results or (regression results on TCI)

This section investigates the variables that explain the dynamic interconnectedness of climate risk, conventional and non-conventional energy, green finance, and the carbon market. The researcher employed a linear regression model to elucidate the determinants of TCI on the mean, as presented in Table 3. The linear regression model employed in the analysis was derived from prior scholarly investigations (Balcilar et al., 2017; Charfeddine et al., 2022; Ji et al., 2019). This scholarly investigation employed financial variables and indicators of Economic Policy Uncertainty (EPU) and the Oil Volatility Index (OVX) as key determinants to analyse the levels of interconnectedness. Through a comprehensive understanding of these variables, policymakers and market participants are able to formulate efficient strategies aimed at effectively managing the risks and capitalising on the possibilities that arise from this interdependence. Carbon Emissions Futures, a notable financial factor used in this analysis, enable the purchase or trading of futures contracts representing a defined quantity of carbon emissions. These futures contracts are traded on platforms like the Intercontinental Exchange (ICE). They serve various functions, allowing businesses to mitigate their carbon emissions risk and speculators to speculate on future carbon emissions prices. Carbon Emissions Futures are established based on the use of carbon credits, which confer the entitlement to release a specific quantity of greenhouse gases. These credits are generated by governments or governing organisations. In our analysis, we incorporate the climate change aggregate developed by Ardia et al. (2022), which assesses the efficacy of climate change uncertainty using a dataset of recent publications from the United States. Furthermore, we took into account the GPR index as proposed by Caldara and Iacoviello (2018, 2022), and we utilised the Economic Policy Uncertainty (EPU) measure developed by Baker et al. (2016, 2022) as our chosen indicator of uncertainty. The aforementioned two pieces of information were acquired from the Federal Reserve Bank of St. Louis. In order to incorporate the effects of the Covid-19 epidemic into our research, we employed a binary variable commonly referred to as a "dummy variable." The dummy variable is assigned a value of 1 throughout the period of the Covid-19 epidemic and 0 prior to the outbreak. In the course of our study, it is possible to incorporate a dummy variable into our model to consider the distinct effects and alterations linked to the Covid-19 period. Subsequently, the ICI data obtained from Yahoo Finance was received. In addition, it is worth noting that the Chicago Board Options Exchange (CBOE) has been actively disseminating the crude oil volatility indicator (OVX) since the middle of 2007. This particular instrument holds significant importance as it allows for the assessment of oil price volatility. The equation can alternatively be expressed in the following manner:

$$TCI_t = \psi_0 + \psi_1 CCA_t + \psi_2 OVX_t + \psi_3 GPR_t + \psi_4 EPU_{it} + \psi_5 ICI_t + + \psi_6 CF_{it} + \mu$$

Initial results indicate that climate risk has a significant positive effect on TCI during the period estimation. As a result, as the world strives for a more sustainable future, there is an increasing focus on the importance of investing in zero carbon (Shahzad et al., 2023; Vats & Mathur, 2022). Simultaneously, the carbon market shows a positive trend, whereas COVID-19 has a negative impact due to its relatively short duration from 2020 to 2022 compared to the overall estimation period encompassing April 30, 2015, to August 31, 2022. The empirical evidence suggests that there is a positive correlation between Economic Policy Uncertainty (EPU) and Global Political Risk (GPR) with the Total Connectedness Index (TCI). This finding aligns with prior research that has recognised EPU and GPR as important factors contributing to the interdependence observed in the US carbon market. According to Adekoya et al. (2021) and Nakhli et al. (2022), The positive and significant relationship of OVX, as observed in this study, aligns with the findings of Qu et al. (2021), who demonstrated that fluctuations in oil prices have a major impact on the transmission of volatility to new energy sectors, particularly in the context of achieving net zero carbon emissions.

Table 5 Cross-sectional ADL results

	Coefficient
CCA	0.036876
se	(0.013761)***
OVX	0.625900
se	(0.023231)***
ICI	0.118750
se	(0.011671)***
GPR	-0.031332
se	(0.015158)**
EPU	0.049569
se	(0.012908)**
COVID19	-0.515331
se	(0.025423)***
Intercept	0.946127
se	(0.118480)***
	0.002163
	(0.003396)

5. Conclusion

This study investigates the impact of three climate change policy indicators, namely climate change summits (CCS), climate change government programmes (CCGB), and climate change tax (CCT), on green finance and energy and carbon markets. The Quantile Vector Autoregressive (QVAR) model is employed to analyse these relationships. The total connectedness index (TCI) indicates that the interconnectedness of climate risk, green finance, carbon markets, and renewable and non-renewable markets exhibits heightened sensitivity during periods of optimistic market conditions. Furthermore, the colour scheme serves to differentiate the net receiver, which is represented by the colour yellow, from the net transmitter, which is shown by blue connections. This study examines the impact of three market conditions (10th, 50th, and 90th quantile) on three climate risks identified by Climate Summits, Government Programmes, and the climate Carbon Tax network. The findings reveal that these climate risks serve as robust channels for transmitting shocks to the volatility of green and non-green energy, carbon market, and green finance indices. Moreover, the findings indicate that the climate policy indices of tax and government programmes have a significant impact on the transition to renewable energy sources and the promotion of environmentally sustainable financial practises. At the most extreme quantile, the transmission of information is approximately 17% and 11% higher compared to the normal and lower quantiles, respectively, where the increase in information transmission is around 9% and 3% for the normal and lower quantiles, respectively. Additionally, it can be shown that the climate summit index exhibits a significant 6.66% impact at the upper quantile. The observed transmission rate exhibits a drop of 4.18% compared to the baseline rate of 3% for the quantiles corresponding to the normal and lower extremes, respectively.

During the period preceding and throughout the third wave of the COVID-19 pandemic, it was seen that the Climate Change Summit (CCS) index played a significant role as the primary transmitter of net shocks, both in the upper and lower quantiles. The present discovery provides further validation to prior research conducted by Belaïd et al. (2021), Belaïd and Zrelli (2019), and Olson and Lenzmann (2016). These studies collectively demonstrate that various climate risk indices have distinct impacts on the transmission of information within the energy, green finance, and carbon markets, which occur at different temporal intervals and under diverse market circumstances. In contrast, SPCE was solely recognised as a minor transmitter at the far end of the quantile spectrum, but it exhibited a positive net reception at the average level. The discovery was made that DJOGI serves as the principal net shock transmitters at upper quantile levels, particularly in the context of the COVID-19 pandemic. The SPGBI and IHSM networks were the primary recipients of the shock. The observed outcomes align with the prior findings about the effects of QVAR on volatility, as assessed by a 200-window rolling window approach and 20-variate forward forecasting. The results of our study suggest that there is a positive relationship between Economic Policy Uncertainty (EPU) and Global Political Risk (GPR) on the Total Connectedness Index (TCI). This finding aligns with previous research that has also recognised EPU and GPR as important factors contributing to the interdependence observed in the US carbon market. According to Adekoya et al. (2021) and Nakhli et al. (2022), The positive and substantial relationship of OVX, as observed in this study, aligns with the findings of Qu et al. (2021), who discovered that fluctuations in oil prices contribute to the transmission of volatility in the new energy sector, specifically in relation to achieving net zero carbon emissions.

5.1. Theoretical Implications

The existing body of scholarly literature in the field of energy economics has undertaken numerous endeavours to elucidate the concept of the energy transition. The majority of these approaches focused on the demand side of the problem. The energy was being measured at present. In order to assess the extent to which the demand side issues discussed in existing research have influenced the transitional output, it is crucial to record the output side picture throughout the transition. The consideration of the Energy Ladder Hypothesis is crucial when examining the shift in energy generating patterns. This hypothesis categorises energy sources based on their energy efficiency or carbon content. Based on this theoretical framework, the process of achieving an energy transition involves the adoption of energy sources characterised by either diminished carbon emissions or enhanced energy efficiency. In this context, the process of energy transition necessitates the incorporation of two key transformations: the shift from fossil fuel-based energy sources to renewable alternatives, and the transition from less efficient renewable energy sources to more efficient ones. The Energy Transition measure proposed in this study incorporates updates to the Lilien (1982) measure, enabling it to effectively capture both characteristics simultaneously. The aforementioned adjustment involves the incorporation of a weighted average including diverse energy sources within both the fossil fuel and renewable classifications. This approach assigns greater significance to cleaner and more efficient energy sources, while assigning lesser significance to dirtier and less efficient alternatives. By conforming to the principles of the Energy Ladder Hypothesis, this index is able to effectively represent the progression within and among energy alternatives. This index serves as an output-side indicator, enabling the assessment of a nation's progress in its energy transformation endeavours. In contrast to existing energy transition indices, the present index has the capacity to provide a comprehensive depiction of the energy transition landscape. The utilisation of this index has numerous prospects for the empirical assessment of each nation's progress in transitioning towards a sustainable energy future. In order to align with the Sustainable Development Goal (SDG) targets and fulfil their commitments under the COP26 agreement, it is imperative for states across the globe to revise their existing energy policies. It might be necessary for this procedure to comprehend the current state of the energy transition. This index serves as an output-side indicator that can aid in identifying possible areas for policy intervention. It supports decision-makers in formulating effective energy strategies. The identification of these intervention areas can also aid in the identification of the causal factors that contributed to the particular situation, so enabling policies to have a wide-ranging impact. This approach has the potential to facilitate the identification of a comprehensive solution that addresses many Sustainable Development Goals (SDGs) in a synchronised manner. The present paper offers a theoretical contribution in this regard.

The drivers of the energy transition were hindered by social inequality, while they were enhanced by effective government. The development of a policy framework is important in order to effectively address and internalise societal imbalances. The establishment of a conducive environment is essential to facilitate the successful execution of policy. The policy framework will be developed in a phased approach. The primary emphasis of the policy framework should be on addressing economic disparity, with subsequent attention given to gender inequality. This prioritisation is based on the recognition that social imbalance encompasses both dimensions and has been found to have a more pronounced and wide-ranging effect compared to gender inequality. The initial phase of the policy framework entails the mitigation of economic disparity by means of enhancing job prospects. The generation of employment opportunities can be facilitated through improvements in public infrastructure. In addition, it is possible for authorities to enact legislation and establish regulations aimed at ensuring a proportional representation of female employees within organisations, concurrently with the creation of job opportunities. This will facilitate the retention of women in the labour force and, thus, initiate the progression towards mitigating gender inequality. However, these implementation strategies will result in financial consequences. Hence, it may be necessary for policymakers to formulate initiatives aimed at recovering the expenses accrued during this phase. Hence, it is imperative that the subsequent phase of the policy framework places emphasis on achieving financial recuperation alongside effectively managing the energy transition. At this juncture, financial institutions can be employed to smooth the transition. Financial institutions have the potential to adopt a differential interest rate mechanism that is linked to the carbon footprint of enterprises. This approach aims to discourage the use of fossil fuels and promote the use of environmental technology, hence enhancing public acceptability of such technologies. Consequently, enterprises will be disincentivized from adopting environmentally harmful technologies and fossil fuel-dependent solutions, leading to a gradual shift towards renewable energy alternatives. The partnership will also provide lower-cost access to loans and advances for enterprises that are comparatively cleaner. Furthermore, it is plausible that regulators might allocate the expenses associated with the implementation of environmental technology in a proportional manner. Additionally, individuals may opt to obtain financial assistance through loans and advances from financial institutions as a means to gain access to these aforementioned solutions. This will enhance the affordability of environmental technologies. Moreover, the implementation of Pigouvian Taxation on emissions would serve as an incentive for corporations to embrace environmentally sustainable technologies. The potential enhancement of the nations' financial stability might be facilitated by the accrual of interest income and tax revenue derived from these two aforementioned sources. The aforementioned financial resources have the potential to be used towards the funding of various solutions intended for household use. Policymakers may consider implementing interest rate holidays that are contingent upon the income levels of households as a means to enhance the affordability of such measures. Following the period of reduced interest rates, the repayment of household loans will contribute to the realignment of the nation's fiscal income.

The stability of environmental technology deployment and the initiation of the energy transition process are contingent upon the policy framework's inclusion of grassroots-level engagement. After the initial implementation of the first two phases of the policy framework, it may be necessary for policymakers to allocate additional funding towards the education sector. This allocation would serve two primary purposes: firstly, to modify curricula in a manner that prioritises the environmental advantages associated with clean energy solutions; and secondly, to provide financial support for research and development endeavours conducted within higher education institutions (HEIs), with the aim of discovering more sophisticated technological solutions. The primary aim of incubator facilities within Higher Education Institutions (HEIs) is to attain economies of scale in the advancement of these technologies, hence resulting in a reduction of the overall cost associated with these technologies. Both the industrial sector and households stand to gain advantages from this development. During the fourth phase, it is imperative for authorities to effectively stabilise the overall political landscape by proactively mitigating any potential hindrances that may impede the progress of the energy transition. During this phase, governments may implement import substitution initiatives as a means to deter the utilisation of the globalisation pathway for the importation of environmentally unsustainable energy solutions. It is imperative for politicians to effectively address domestic deterrents and eradicate external obstacles. Enhancing legal enforcement and reducing rent-seeking mechanisms can potentially enhance the overall policy climate for the energy transition. In addition to mitigating the unlawful utilisation of natural resources as common resources, this enhancement in governance would also facilitate the expansion of newly founded renewable energy enterprises in sharing their knowledge and services throughout the country. The utilisation of a framework can also contribute to the achievement of other Sustainable Development Goals (SDGs) that may be indirectly related. The tangential achievement of these Sustainable Development Goals (SDGs) will contribute to the long-term sustainability of the policy framework. The maintenance of this policy framework necessitates the enhancement of the educational infrastructure, which may entail a need to extend efforts to the grassroots level through the upgrading of educational curriculum. This policy initiative will contribute to the provision of high-quality education to pupils, in alignment with Sustainable Development Goal 4. The progressive internalisation of social inequalities and the implementation of the policy framework would contribute to the rise in awareness and facilitate the attainment of sustainable economic growth, as outlined in Sustainable Development Goal 8. Upon the attainment of these two ancillary aims, the aforementioned nations can effectively establish an environment conducive to peaceful coexistence and robust institutional frameworks, as outlined in Sustainable Development Goal 16. The study's scope has been constrained by the restricted availability of data across a longer time series. The inclusion of longer time-series data would have facilitated a more comprehensive understanding of the historical progression of the energy transition in these nations. Further research can be conducted in the future to explore the comparative scenario between different groupings of developed and developing countries in this particular direction.

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