

Research article

Do climate change and geopolitical risk influence volatility? Empirical evidence from leading economies

Saroj S. Prasad^{a,*}, Veerma Puri^b, Priti Bakhshi^c^a Department of Economics & Finance, Birla Institute of Technology & Science, Pilani - K. K. Birla, Goa Campus, Goa, India^b Goa Institute of Management, Goa, India^c S P Jain School of Global Management, Mumbai, India

ARTICLE INFO

JEL classification:

G17

C53

E44

Keywords:

Climate change

Geopolitical risk

GARCH-MIDAS

Volatility

ABSTRACT

Our study addresses the two novel objectives: 1) to study the impact of global climate change on stock market volatility, and 2) to study the impact of geopolitical risk on stock market volatility. With 21 years of high-frequency daily stock market returns data for the ten most influential economies encompassing the period from January 2003 to December 2022 (available until December 2022), we find high volatility in the stock markets of Italy, the United Kingdom and Germany due to global climate change and high volatility in the Indian stock market due to geopolitical uncertainty, while the USA and Japan are seen with volatility dampening due to geopolitical uncertainty. Due to the mixed-frequency datasets of dependent and independent variables, we employ the novel GARCH-MIDAS methodology to estimate our results. The originality of our study lies in the adoption of a novel methodology and the creation of a high-frequency dataset for 21 years during which the world has witnessed major geopolitical and climatic disruptions. Our results call for major policy interventions by governments worldwide to mitigate the risks posed by global climate change, adopt more stringent regulations to manage geopolitical uncertainty, and stabilize their financial markets. Additionally, this analysis extends the discussion beyond generic conclusions and provides more discerning policy implications concerning the unique vulnerabilities and resilience factors that each economy is endowed with. Overall, our study has larger implications and calls for international cooperation by the countries to design effective policies to address these pressing issues.

1. Introduction

The United Nations created 17 Sustainable Development Goals (SDGs) in 2012 that provide a holistic and inclusive framework for addressing the world's most pressing challenges, fostering global cooperation, and progress towards a more sustainable, equitable, and prosperous future for all (The 17 Goals, Sustainable Development, n.d.). SDG 13 deals with the issues related to climate change and action needed to mitigate greenhouse gas (GHG) emissions and work towards improving resilience against climate-related hazards (Goal 13, Department of Economic and Social Affairs, n.d.). The National Oceanic and Atmospheric Administration (NOAA) reports that direct warming by 49 % caused by human GHG emissions since 1990. Though climate changes can occur naturally, through trends such as the solar cycle, the term "climate change" most often invokes the rapid variations of climate that have occurred at an unprecedented rate over the past century due to

human activities. Under a business-as-usual (BAU) scenario, climate change is projected to cause \$2328 trillion in economic losses between 2025 and 2100 (Statista, 2024). It is undeniable that the increasing global impact of climate change is putting pressure on the world's largest economies and their financial stabilities (Campiglio et al., 2018; Khalfaoui et al., 2022; Bonato et al., 2022; Chen et al., 2022). This led to the emergence of a new research area, namely climate finance. To name a few, the growing literature on climate finance highlights the importance of understanding the financial implications of climate change (Bakhshi and Chaudhary, 2020; Hong et al., 2020; Giglio et al., 2021; Oloko et al., 2022; Lee et al., 2022; Bakhshi et al., 2023; Care and Weber, 2023; Shang and Jin, 2023; Salisu and Oloko, 2023). Chava (2014) notes that companies with higher environmental externalities tend to have higher costs of capital. Similarly, Ghoul et al. (2016) find that those companies with better environmental performance experience reduced costs of capital.

* Corresponding author.

E-mail addresses: sarojp@goa.bits-pilani.ac.in (S.S. Prasad), puri.veerma@gmail.com (V. Puri), priti.bakhshi@spjain.org (P. Bakhshi).<https://doi.org/10.1016/j.jenvman.2025.127471>

Received 2 July 2025; Received in revised form 19 September 2025; Accepted 27 September 2025

Available online 1 October 2025

0301-4797/© 2025 Elsevier Ltd. All rights reserved, including those for text and data mining, AI training, and similar technologies.

Recent studies suggest climate change strongly impacts both stock market volatility and the volatility of various sectors, particularly the utilities sector (electricity and thermal energy) (Liang et al., 2022; Lv and Li, 2022; Chen et al., 2023; Wang and Li, 2023). However, A study by Oloko et al. (2022) finds that 40 % of Asian stock markets are not affected by climate change. These studies primarily focus on a few major countries, such as the United States, the United Kingdom, and China, with climate policy uncertainty (CPU) as a measuring instrument for climate change, while ignoring the robust, holistic, and global proxy for measuring climate change, such as the 'Global Temperature Anomaly (GTA)'. Thus, the first aim of this study is to examine the global stock market volatility due to global climate change. Recent literature also suggests the nexus between geopolitical risk and climate change (Deere and Birkbeck, 2009; Barnett, 2020; Alam et al., 2024).

Gong et al. (2022) suggest that the US presidential election is a better indicator of international political uncertainty and that political uncertainty influences the risk of companies with high climate risk. Just as climate change is a systemic risk factor affecting all companies and having a potential impact on their investment decisions (Fuss et al., 2008), geopolitical risk may also influence the investment decisions of companies (ShahNazari et al., 2014). Significant decision-making variables, including profit, costs, and consumer surplus, are all affected by uncertainty about carbon policies (Liang and Kettunen, 2017). In fragile states, climate change has the potential to worsen vulnerabilities and the fragility of governance structures, making security more fragile and vulnerable to instability, conflict, and terrorism. It is important to highlight that there are climate change impacts outside the countries; however, the desire to take climate actions can be influenced by pursuing national interests, along with the potential for geopolitical frictions. Here, it is worth mentioning that the Index of Geopolitical Risk increased in 2022, likely driven by the war in Ukraine and Russia (Speech: Geopolitics and Its Impact on Global Trade and the Dollar, 2024). The important question is how, or even whether, global stock markets respond to climate change risks along with geopolitical uncertainties. The reality is that as investors' certainty about the stability of the world declines, their priority shifts, and they dampen the returns they can invest in, since they demand additional risk premiums on risky investments associated with stock market risk. Investors' unwillingness to invest leads to lower stock returns induced by their negative behavior. Li et al. (2018) examine the impact of geopolitical events on stock returns in the United States. The authors note that divestment decisions must take geopolitical risk into account. Caldara and Iacoviello (2022) show the same positive direction of effect in the US market, which is consistent with the study by Li et al. (2018), noting that stock returns generally decline as geopolitical risk increases.

Based on the above-mentioned discussion and existing literature (Apergis et al., 2017; Alqahtani et al., 2020; Baur and Smales, 2020; Salisu et al., 2022; Zhang et al., 2022), the second objective of the study is to examine stock volatility caused by geopolitical risks. Hence, by examining the impact of climate change and geopolitical risk in the global financial market, we will understand a comprehensive picture of global market behaviour. Luo and Sun (2024) note that carbon emissions increase with an increase in geopolitical risk; hence, environmental sustainability and geopolitical risk are associated with each other. This holds in emerging countries with high geopolitical tensions, which further creates dependencies on non-renewable energy and hence compounds the environmental concerns. Previous research has focused on the emerging market while neglecting the advanced economies, which represents a significant gap in understanding global vulnerability. Therefore, our study fills this gap by assessing stock market volatility associated with climate change and geopolitical risk events for the most influential economies, including both developed and emerging. Our study results document the incremental impact of global climate change on the stock market volatilities of Italy, the UK, and Germany, as well as geopolitical risk on India's stock market volatility. Our results also indicate the dampening impact of global climate change on the stock

market volatilities of India and China, and that of geopolitical risk on the stock market volatilities of the US and Japan.

The originality of this study lies in the creation of the high-frequency data set, the methodology adopted, and the chosen study period. The implications of our results are more important to policymakers who must address climate and geopolitical risks to meet their financial markets goals. Data is collected for the top 10 countries in the world over the study period, January 2003 to December 2022. The countries in this sample are examples of strong economies that can influence and improve weaker economies and provide a beacon to underdeveloped and developing economies. Strong economies have a dynamism that suggests new future approaches for economic analysis, and also have a high impact on emerging economies (Jawad et al., 2022); therefore, it can serve as a reasonable guiding narrative. Also, our study contributes to the literature on climate change and geopolitical risk in the context of stock market volatility. Engle (1982) proposed a family of statistical models known as ARCH (Autoregressive Conditional Heteroskedasticity) as a way of preparing for further improvements to the analysis of a financial time series through the volatility properties associated with it. Additionally, this family of models offers several advantages for time series modelling and forecasting of financial data, specifically, estimating conditional volatility for financial market returns.

Since the sample belongs to the mixed frequency data set of high-frequency stock volatility influenced by low-frequency macroeconomic indicators, the study uses the GARCH-MIDAS model. GARCH-MIDAS is a preferable model when the volatility of the financial market is being controlled by macroeconomic variables that are collected at varying frequencies (e.g., daily stock price data and annual conventional Gross Domestic Product data). The contribution of this study further lies in providing the right investment decisions when investing in stocks and recommending policy interventions to the government regarding climate change and geopolitical risks. The materials and methods are explained in Section 2, the results are presented in Section 3, Section 4 includes the discussion, and Section 5 outlines the conclusion.

2. Materials and methods

This section tabulates the review of the relevant literature, highlights the key points discussed, and the contribution of the reviewed papers (Table 1).

To serve the first objective of the study, i.e., to examine the impact of global climate change on the stock market returns, we use monthly Global Temperature Anomalies (GTA) data and daily closing prices data of the indices of the top 10 countries. It should be noted here that due to the unavailability of country-specific monthly temperature anomalies data, the global temperature anomalies are considered. Additionally, GTA is a broad global climate change measurement, and its source credibility is standardized by NASA (Data. GISS: GISS Surface Temperature Analysis (GISTEMP V4), n.d.) website. It reflects a homogeneous proxy to capture Earth's global warming. Additionally, the rise of an average of 0.11°F in Earth's temperature in ten years implies that we must take a long study period (Climate change: global temperature, 2025). This necessitates the selection of a data period from 2003 to 2022. Furthermore, few existing studies have used GTA as a proxy to capture the impact of direct, structured, and long-term change in the Earth's climatic conditions, such as temperature alterations and precipitation. Tumala et al. (2023) used GTA to examine the long-term systematic impact of climate change on the volatility of fossil fuel prices. Similarly, Liu et al. (2022) proxied the climate uncertainty by GTA and reported its significant effect on the return and volatility spillover between clean energy metal and the foreign exchange market.

While climate policy uncertainty (CPU) is an index based on the climate-related text of 11.27 million news articles, it reflects the country-specific climate policies published in these print media (Baker et al., 2016, 2022; Gavrilidis, 2021; Ma et al., 2023). Evidently, the CPU

Table 1
Sample literature reviews.

Authors and Year	Key Points	Contribution
Balcilar et al. (2018)	Geopolitical risk and volatility	This study inspects the impact of geopolitical risks (GPRs) on the stock volatility behaviour of BRICS markets. The results show heterogeneous responses to geopolitical tensions, as the effects of GPRs are inconsistent across markets. Among the BRICS, Russia and China are the most sensitive to GPR shocks, regardless of the nature of the shocks, and are therefore the main vectors of geopolitical instability. However, India has shown a greater resilience to shocks; Brazil and South Africa show little volatility. The results illustrate the ability of volatility to spill over across the BRICS economies and illustrate the need for strong financial systems and openness to leverage off geopolitical shocks and curb the herding effect of developing nations.
Bouras et al. (2019)	Geopolitical risk and volatility	The impact of country-specific and worldwide (GPRs) on the monthly volatility of 18 developing market countries for the period of 1998–2017 is examined. Although country-specific GPR does not affect stock returns, the positive impact on volatility of the stock market is statistically small. But if we look at the broad measure of the global GPR, even though yields are not yet affected, the impact on volatility is statistically and economically stronger than what is seen for the national GPR, underlining the predominance of international shocks over domestic ones.
Noh and Park (2023)	Greenhouse gas and stock market volatility	The study finds a robust positive correlation between GHG emissions and stock market volatility in 35 OECD countries from 1992 to 2018. This relationship is primarily driven by the large GHG emitter contributing to this relationship, but there may also be uncertainty associated with the role GHG emissions potentially have on economic development. This study supports that climate change has an indirect and direct impact on financial markets, particularly equity market volatility. Companies and investors should work to manage their climate risk exposures to maintain financial stability. Institutional investors should adopt better measures to price and hedge financial securities.
Zhou and Ma (2025)	Climate risk and stock volatility	Aggregate climate risk is the most substantial predictor of forecasted stock volatility in 32 international markets after accounting for economic uncertainty measures and financial uncertainty measures (Faccini et al., 2023); the impact of climate risk is robust statistically and economically. In the short term, the predictive properties of aggregate climate risk weaken when the economic outlook is worsening and then improve after the Paris

Table 1 (continued)

Authors and Year	Key Points	Contribution
Fassnacht et al. (2020)	Climate change	Agreement, since their underlying response behaviors of investors to climate risks are unique across regions, and have unique regional properties that likely drive how information is transmitted in the form of climate risk and investor responses to it. Climate change is a significant change in the ecological and environmental which has meaningful implications for the living beings on the earth.
Schlenker and Taylor (2021)	Infrastructure disruption	Climate change has a significant negative impact on the disruption of not only physical infrastructure but also disrupts business activities as production and supply chains, and hence affects profitability and firm performance.
Wang et al. (2024); Lee and Wang (2021)	Geopolitical risk	GPR is defined as risks arising from political-geographical tensions, including wars, terrorism, and intercountry conflicts.
Duan et al. (2022); Penzin et al. (2024)	Health and economic impact	Climate change directly affects health, well-being, and living conditions, and hence has an indirect, significant economic impact.
Venturini (2022)	Corporate financial effects	Funds spent to mitigate climate change impact cash flow for operating expenses and ultimately decreases the return for investors.
Caldara and Iacoviello (2022)	Geopolitical Risk Index	Using the data from 1985 to 2020, geopolitical risk is quantified through a global index. The study finds significant spikes during major events like 9/11.
Salisu et al. (2022)	Impact of uncertainty, stock, and market volatility	Heightened geopolitical risk creates uncertainty, leading investors and firms to delay decisions. Increased geopolitical risk decreases investor confidence and raises stock market volatility.
Wang and Li (2023)	Global economy & stability	Maintaining a stable international environment is vital for global economic vitality and growth.
Cevik (2023); Nguyen et al. (2023)	Geopolitical events	Geopolitical events shape global actions, influencing economic, commercial, and social orders, and may contract global GDP.
Zhang et al. (2022)	Impact of geopolitical risk on the investor decision	PricewaterhouseCoopers, n.d. survey revealed that geopolitical risk heavily influences investment decisions.
Feng et al. (2023)	Emergence of Capital flight and its impact on foreign investment	Capital flight increases with the increase in GPR, and investors look for investment in safe regions. foreign investors tend to prefer investment in those countries that have lower GPR.
Demiralay et al. (2024)	Key impediments	The two major issues in maintaining global stability are Climate Change and geopolitical risks.
Penzin et al. (2024)	Investor uncertainty and market volatility	Using the GARCH-MIDAS Model to consider a unique dataset of 1880–2018 for the various markets, an occasional relationship between climate change and stock returns volatility with differential effects to the intensity of temperature anomalies and technology shocks is noted. Given this, the authors encourage increasing the policy dialogue to include the prerogative to invest in climate technologies for the

(continued on next page)

Table 1 (continued)

Authors and Year	Key Points	Contribution
		mitigation of GHG emissions and adopting a strategy to diversify green investments. Finally, transitioning climate risks, which provides a baseline for technological innovations, is the best route for clients to mitigate stock market exposure to the physical climate risks.

Source: Computed by authors

index reflects the news coverage and policies framed under a specific government's regime, which may be skewed on a period-specific basis. Hence, this can lead to information reporting bias in the data. As the study aims to capture long-run mean variance for the study period of 21 years, it requires consistency of data. Additionally, there is a lack of complete CPU data ranging from the year 2003 for a few countries such as India, Germany, and Japan (Ma et al., 2024; Ji et al., 2024; Berestycki et al., 2022). Hence, it has limitations in terms of availability and comparability across different countries.

We select the top 10 countries based on their global gross domestic product (GDP): India, Brazil, the USA, Japan, China, Italy, Germany, the UK, France, and Canada (James, 2024). Here, we choose GDP over market capitalization, as GDP measures a country's overall economic output, while market capitalization measures the total value of listed stocks traded on a stock exchange. We select the study period, ranging from January 2003 to December 2022 (data available until), based on the following criteria: First, the availability of data to ensure the consistency of both objectives. Second, the sample period represents major global geopolitical and climate-related events (Table 2). The daily closing prices of the indices (Nifty 50, Dow Jones Industrial Average, Shanghai Composite, DAX Germany, Nikkei, FTSE 100, CAC 40, FTSE MIB Italy, BOVESPA, TSX) are sourced from the Bloomberg Finance Terminal. To measure climate change, various proxies are used in the literature, such as GH, environmental scores (E), emission intensity, carbon emission levels (CO₂), Carbon Disclosures Project (CDP), and global temperature anomalies (GTA). To ensure consistency across countries in measuring climate change and based on its availability, we use GTA as a proxy for climate change, retrieved from the NASA (Data. GISS: GISS Surface Temperature Analysis (GISTEMP V4), n.d.) website.

Table 2
Global geopolitical and climate-related events.

Geopolitical Events	Date	Climate-Related Events	Date
Invasion of Iraq	2003	Indian Ocean Tsunami	2004
European Union (EU) Expansion	2004	Hurricane Katrina	2005
North Korea's First Nuclear Test	2006	Deepwater Horizon Oil Spill	2010
Global Financial Crisis	2007	Fukushima Nuclear Disaster	2011
Election of Barack Obama	2008	Superstorm Sandy	2012
Arab Spring	2011	Paris Climate Agreement:	2015
Annexation of Crimea	2014	Hurricane Harvey, Irma, and Maria	2017
Brexit Referendum	2016	Global Climate Strikes	2018
Election of Donald Trump	2016	Amazon and Australian Wildfires:	2019
North Korea's Missile Tests	2017	Australian Bushfires:	2020
COVID-19 pandemic	2019	Record Arctic Sea Ice Loss	2020
U.S. Presidential Election	2020	The Intergovernmental Panel on Climate Change IPCC Report:	2021
U.S. Capitol Riot	2021	Climate Change Conference (COP26)	2021
Russian Invasion of Ukraine	2022	Inflation Reduction Act (IRA)	2022

Source: Computed by authors.

Global temperature anomalies represent the long-term average temperature change (over a base period) in the Earth's climate. Hence, it is a true indicator of change, not the absolute temperatures.

Further, we include the COVID-19 period in the study period, as we aim to analyze in-sample volatility by investigating whether the country-specific volatility is affected by climate change and geopolitical risk.

The study does not predict out-of-sample volatility, so excluding COVID-19 from the sample period is unnecessary. Further, its inclusion will broaden the scope of the study, and it would be significant for understanding global stock market resilience. Additionally, the GARCH-MIDAS model is well-equipped to integrate short-term shocks, without biasing the overall analysis. Thus, the empirical results would be more realistic in capturing the volatility. Moreover, following the insights of (Virk et al., 2024; Liu et al., 2024; Wegener et al., 2025; Li et al., 2023; Wang et al., 2024), our study uses a GARCH-MIDAS model where the GARCH component automatically absorbs the short-term volatility caused by the non-persistent events, such as the COVID-19 pandemic, and MIDAS absorbs the long-term structural drivers of the volatility.

To pursue our second objective of examining the impact of GPR on stock market returns, the study uses monthly country-specific geopolitical risk Index data (Caldara and Iacoviello, 2022). We adopt the GARCH-MIDAS model to capture the volatility of the stock market caused by two macroeconomic variables of long-term dynamics, namely GTA and GPR. While the basic GARCH family models can be used to capture the volatility clustering in the market. However, it requires that both the dependent and the explanatory variable belong to the same frequency (Lin, 2018). In our study, GTA and GPR are explanatory variables that belong to the monthly low-frequency dataset. Meanwhile, the stock returns are the dependent variable and are in daily high-frequency data. This leads to the creation of a frequency mismatch, which the basic GARCH family models cannot incorporate. Additionally, if we transform the frequency of any of the variables, valuable information can be lost and falsified, and can lead to spurious and biased results (Salisu et al., 2022). We underscore that our study examines the in-sample volatility, but it is also found to be a superior model for forecasting out-of-sample volatility (Asgharian et al., 2013; Conrad and Kleen, 2020; Girardin and Joyeux, 2013; Yu and Huang, 2021; Fang et al., 2020; Wang et al., 2024). Additionally, Conrad & Kleen (2020) noted that the standard GARCH model suffers from the extreme value of kurtosis caused by the existence of macroeconomic factors. Therefore, it is one of the most fit models for capturing long-term volatility persistence. Hence, our study uses the GARCH MIDAS model, which uses mixed-frequency data for measuring the stock volatility developed by Engle et al. (2013), and has gained popularity in recent studies (Girardin and Joyeux, 2013; Chen et al., 2020; Ndako et al., 2021; Salisu et al., 2022).

We calculate the logarithmic returns for the daily stock returns of our 10 sample countries. We follow the GARCH MIDAS-X as our predictor model, which suggests the long-term impact of the predictor series by providing the slope coefficient, wherein the X signifies the exogenous variable, i.e., GTA and GPR separately.

$$r_{i,t} = \mu + \sqrt{\tau t \times h_{i,t}} \times \varepsilon_{i,t}, \varepsilon_{i,t} \stackrel{(1)}{\sim} \Phi_{i-1,t} \tilde{N}(0, 1), \forall i = 1, \dots, N_t \quad (1)$$

$$h_{i,t} = (1 - \alpha - \beta) + \alpha \frac{(r_{i-1,t} - \mu)^2}{\tau_1} + \beta h_{i-1,t} \quad (2)$$

$$\tau(rw) = m(rw) + \theta(rw) \sum_{k=1}^k \Phi(w1, w2) Xi - k(rw) \quad (3)$$

Equation (1) gives the mean equation that shows mu (μ) as the unconditional mean variance, while the conditional variance components given for short- and long-term components are given in Equations (2) and (3), respectively. In equation (2), the Alpha (α) coefficient represents the ARCH term, and the Beta (β) coefficient represents the GARCH term. W represents the fitted beta polynomial weight, and m represents

the long-term constant term. In equation (3), the Theta (θ) coefficient represents the influence of the predictor variables.

3. Results

The graph shown in Fig. 1 shows the variability of surface temperatures around the globe. The graph shows higher-than-normal temperatures (red) and lower-than-normal temperatures (blue). Strong temperature variations can be identified, especially in the area below the North Pole (Arctic region). Variability indicates rapid changes taking place in the Arctic due to climate change. Climate change is predominantly attributed to anthropogenic influence. This calls for coordinated global action to reduce GHG emissions and mitigate climate change

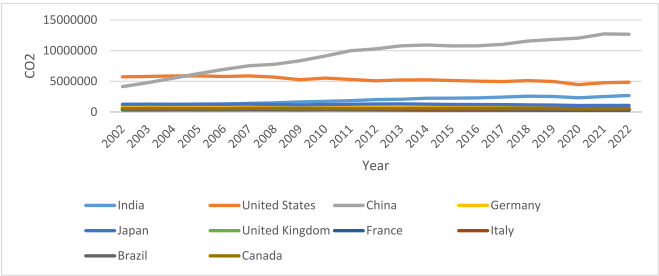


Fig. 2. Country-wise CO2 level emissions. Source: Computed by authors.

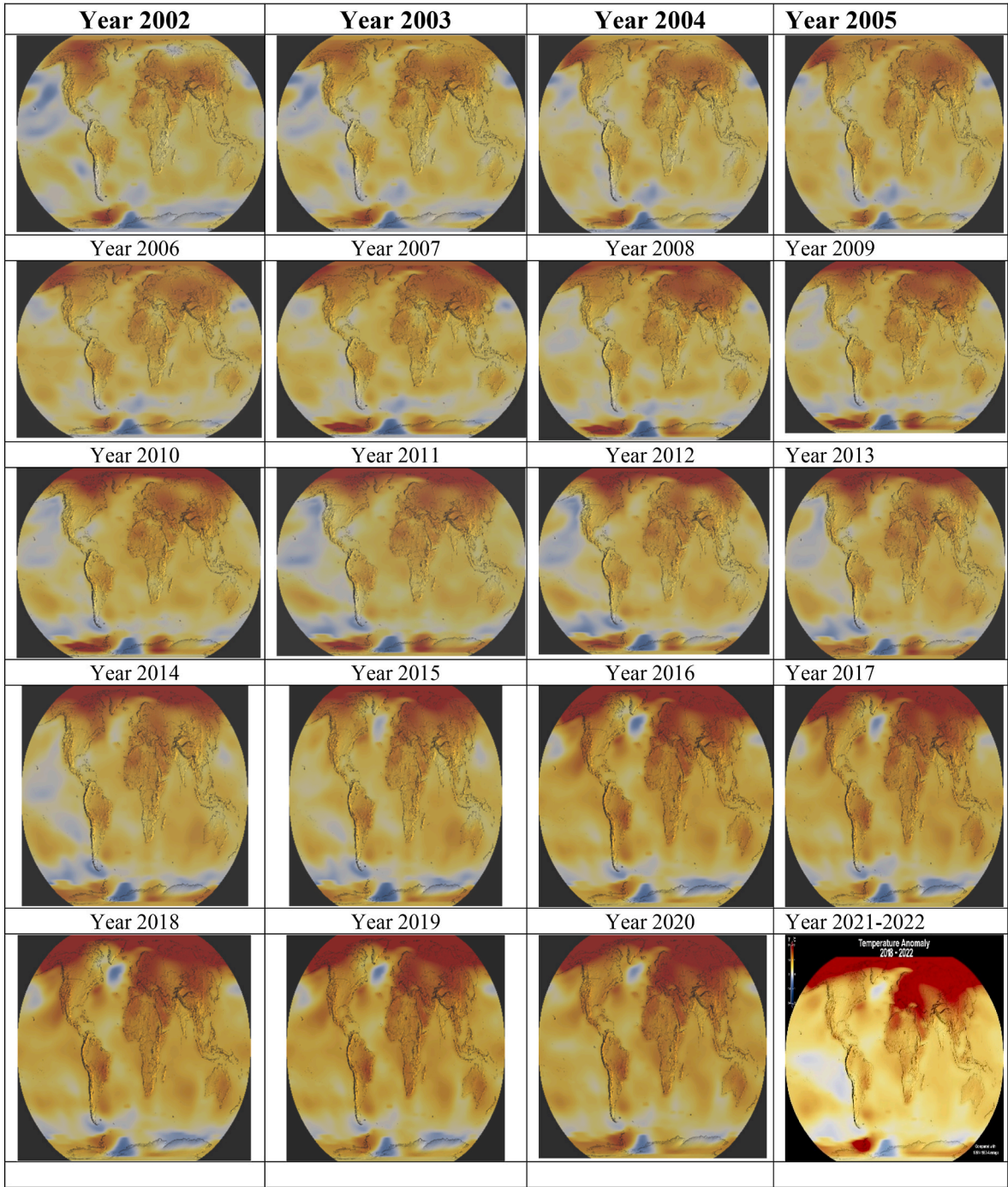


Fig. 1. Global Temperature Anomalies in climate Fahrenheit from 2002 to 2022. Source: NASA website.

impacts. Fig. 2 shows the CO₂ emissions in each of the sample countries. The country-specific data on CO₂ is fetched from the Emissions Database for Global Atmospheric Research. The results suggest that among the world's top economies, China is the biggest emitter of CO₂, followed by the USA. After that, the next biggest emitters of CO₂ are India and Japan. Urbanization and industrialization have resulted in high energy use and emissions, with an increase in overall temperatures in pursuit of rapid economic growth, as we can also confirm with Fig. 1.

Table 3 shows the descriptive statistics results for GTA and GPR, which show that the standard deviation (0.180) of GTA is higher than its mean (0.028), indicating greater global temperature variability relative to the average global mean. A temperature anomaly represents the deviation of the actual temperature from the expected value, usually occurring over a period of 30 years. The positive average temperature (0.028) shows that days worldwide are warmer than before, over a period of 19 years, which is shorter than the expected period of 30 years. This shows a global increase in warming. The standard deviation (0.180) means large temperature fluctuations. Likewise, a positive mean GPR for all 10 sample countries indicates an increase in geopolitical tensions or uncertainty in those countries. The USA (2.309) has the highest political uncertainty, followed by China (0.567) and France (0.544). The imposition of tariffs on Chinese goods by the US is also retaliated against by China with tariffs on US goods. This reciprocal tariff exchange disrupted global supply chains and increased costs for businesses and consumers in both countries, as well as third countries that rely on these trade flows. This can be seen from the high standard deviation (0.877) and (0.567) for the USA and China, respectively. Continuing the descriptive statistics, Table 4 represents the performance of the stock returns of the ten leading economies in the form of their summary statistics. Among the 10 countries, the mean return is highest for India (0.056) with the risk (1.399), followed by Brazil (0.045) with the highest risk (1.727); while Italy is reported with the lowest mean returns (−0.000). The results exhibit that global economic power is shifting into the hands of emerging economies (e.g., India and Brazil) due to their faster economic growth rates (PricewaterhouseCoopers, n.d.). Italian stocks were observed to be traded at a 50 % discount because of the country's high public debt and COVID-19 disruptions (<https://www.reuters.com/markets/europe/growing-italy-risk-puts-equities-deepest-discount-35-years-2023-11-07/>, n.d.).

Before proceeding with the GARCH MIDAS-X model, we attempt to find out the correlation between GTA and GPR (Table 5). We find a negative correlation between the GTR and GPR; the probability that justifies the statement may be that in the case of high geopolitical risk, such as internal economic dispute, conflict, or political instability, it results in economic downturn. The results in slowing of industrial production, less business activities, less logistic activities, and less energy consumption, which leads to less emission of CO₂ and GHG. For the short term, this whole activity contributes less to climate change risk and

Table 3
Descriptive statistics of GTA and GPR.

Variables	Mean	Std. Dev.	Kurtosis
Global temp. anomalies	0.028	0.180	0.102
Global Political Risk	Mean	Std. Dev.	Kurtosis
India	0.204	0.094	11.548
USA	2.309	0.877	19.388
China	0.567	0.567	7.803
Germany	0.428	0.318	21.606
Japan	0.235	0.151	4.228
UK	0.329	0.329	38.645
France	0.544	0.339	14.695
Italy	0.144	0.093	6.962
Brazil	0.052	0.035	5.466
Canada	0.202	0.115	11.903

Note: Summary statistics of Global Temperature Anomalies and Global Political Risk.

Source: Computed by authors

Table 4
Summary statistics of Indices.

Countries	Mean	Std. Dev.	Kurtosis
India	0.056	1.399	12.326
USA	0.027	1.155	15.614
China	0.017	1.520	4.884
Germany	0.030	1.368	7.264
Japan	0.022	1.440	7.342
UK	0.012	1.127	9.932
France	0.014	1.356	7.994
Italy	−0.000	1.504	10.288
Brazil	0.045	1.727	8.155
Canada	0.021	1.078	20.563

Note: Summary statistics of 10 market indices.

Source: Computed by authors

Table 5
Correlation of GTA and GPR.

Correlation	GTA	GPR
GTA	1	−0.194
GPR	−0.194	1

Source: Computed by authors

global warming and eventually forms a low temperature anomaly. Our results validate this discussion as we can observe stagnation in the economic activities during the years 2008 and the COVID-19 pandemic. This finding is inconsistent with the study by Chu et al. (2023), in which they confirm GPR does not affect the climate of the E7 countries during the period 2000–2019. On the contrary, Luo and Sun (2024) did find GPR to have a positive relationship with consumption-based carbon emissions (CCO₂) and that CCO₂ is higher in developing countries as compared to developed countries.

As we research more about the causes of geopolitical risks (Geopolitical Risk Dashboard, BlackRock Investment Institute, n.d.), we analyze the number of terrorist attacks for the sample countries (Fig. 3). We collect the data from the Global Terrorism Database (Herre and Roser, 2023), and find that though India has a low GPR but it experiences the highest number of terrorist attacks. It records ten times more terrorist attacks than its followed country, the UK, which poses more security challenges. However, after 2016, the numbers show a downward trend, implying its resilience towards improvement in counter terrorism policies, diplomacy, and strategic moves. To address geopolitical risk globally, there is a need to understand the balancing of political, economic, and security dimensions faced by any country. In the next sub-section, we present the results of our GARCH MIDAS-X using GTA and GPR as predictors.

3.1. GTA and stock market volatility

Table 6 shows the results of the GARCH MIDAS-X analysis of the impact of climate change on the ten largest stock markets in the world.

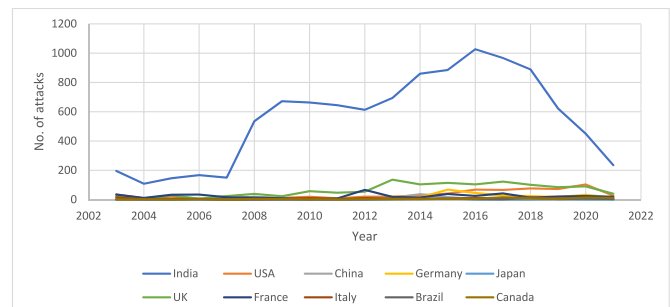


Fig. 3. Number of terrorist attacks by country. Source: Computed by authors.

Table 6

Global temperature anomalies and stock market volatility.

Countries	Mu	Alpha	Beta	Gamma	m	Theta	w2
India	0.053 (0.000*)	0.025 (0.067*)	0.879 (0.000*)	0.140 (0.000*)	0.510 (0.010*)	−2.176 (0.000*)	1.044 (0.16E-*)
USA	0.029 (0.981)	0.010 (0.996)	0.866 (0.886)	0.195 (0.907)	−0.097 (0.0997)	0.131 (0.999)	3.166 (0.999)
China	0.017 (0.000*)	0.062 (0.000*)	0.920 (0.000*)	0.011 (0.000*)	0.829 (0.000*)	−1.802 (0.000*)	1.000 (0.000*)
Germany	0.03E-3 (0.000*)	0.000 (0.000*)	0.89E- (0.000*)	0.15E- (0.000*)	0.29E- (0.000*)	0.03E- (0.000*)	2.67E- (0.000*)
Japan	0.027 (0.000*)	0.027 (0.000*)	0.854 (0.000*)	0.153 (0.000*)	0.560 (0.000*)	−0.638 (0.000*)	48.745 (0.000*)
UK	0.006 (0.000*)	0.000 (0.000*)	0.003 (0.000*)	0.001 (0.000*)	−0.008 (0.000*)	0.002 (0.000*)	1.00E+ (0.000*)
France	0.019 (0.000*)	0.000 (0.000*)	0.001 (0.000*)	0.003 (0.000*)	0.001 (0.000*)	−0.002 (0.000*)	0.000 (0.000*)
Italy	0.016 (0.000*)	0.009 (0.000*)	0.904 (0.000*)	0.138 (0.000*)	0.423 (0.000*)	1.579 (0.000*)	1.752 (0.000*)
Brazil	0.030 (0.000*)	0.017 (0.000*)	0.893 (0.000*)	0.105 (0.000*)	0.906 (0.000*)	−0.427 (0.000*)	1.000 (0.000*)
Canada	0.022 (0.000*)	0.003 (0.000*)	0.894 (0.000*)	0.154 (0.000*)	−0.441 (0.000*)	−1.858 (0.000*)	1.794 (0.000*)

Note: The p-value is within the parentheses, at the significance level of 5 %.

Source: Computed by authors

The model has three main coefficients (α , β , and θ) that help investors and policymakers conclude. Alpha (α) measures the impact of recent shocks on short-term volatility. Beta (β) measures the persistence of volatility and its relationship to past volatility, thereby influencing the long-term volatility trend. Mu represents the unconditional (time-independent) mean returns for the indices already discussed in Table 3. Considering the results of the individual alpha and beta coefficients, Table 6 shows the temporary volatility triggered by an information shock in the market for all ten countries, since the sum of the coefficients (α and β) is less than 1. This means that the returns revert to the mean and the data is stationary, which is confirmed by a statistical test such as the ADF or PP test. The Ljung-Box test can also be used to check the ARCH effect, i.e., the volatility clustering in the data. However, the significant alpha and beta values of all indices except the USA indicate persistent short- and long-term volatility in stock returns. Whereas the summation of alpha and beta equals 1 indicates the clustering of volatility in the long run. Next, Theta (θ) represents the slope coefficient and depicts the influence of GTA on the long-term stock volatility.

The Theta coefficient (θ) results show a positive significance of GTA in three countries (UK, Germany, and Italy), indicating that these countries are at risk from climate change and negatively affect financial markets. Surprisingly, different causes of climate change are evident in these countries; however, the most alarming theta coefficient (1.579) is for Italy, pointing to a serious level of environmental challenges for the Italian economy. Of these, waste management, air pollution, and global warming are the major challenges facing Italy; 40 % of respondents agreed with the statement (*Italy: Most Concerning Environmental Issues*, 2019; Statista, 2024). Italy is allegedly the highest CO₂ emitter of the G20 countries, which is indicative of a major threat to many industries such as farming and fishing, infrastructure, and tourism, etc., conservatively estimated to be worth a loss of 3.7 % of GDP by 2050 and 8.5 % by 2100. This loss can be ameliorated by 2.2 % by 2050 should the Italian government act to pursue environmental friendliness and sustainability measures (Admin, 2021).

The United Kingdom is the second-most damaged country from climate change (0.002). In the UK, environmental deterioration and transport, mainly bound by climate factors, have contributed to climate change. This may lead to a loss of GDP of 12 % which is much higher than 5.1 % and a GDP loss of 12 % after the 2008 global recession, as well as after the Covid-19 pandemic (*Nature Degradation Could Cause a 12 % Loss to UK GDP* University of, 2024). Hertig et al. (2023) found that the increase in GHG emissions due to the heavy dependence on

fossil fuels is the main cause of climate change in Germany and has catastrophic effects that directly or indirectly lead to infectious, non-communicable, and mental illnesses in humans.

The above implies that the financial markets in these countries face great swings in stock prices from risks, uncertainties, and the effects of climate change. A large theta coefficient rejects the null hypothesis that it is 0; that is, the macroeconomic variable is affecting long-term volatility. This is true for the UK, Germany, and Italy, while the other six countries (India, China, Japan, Brazil, France, and Canada) experienced lower volatility in their stock returns by leveraging the GTA, shown by their significant negative theta (θ) coefficient. This indicates that climate change is providing these six countries with stabilization on long-term market volatility. This does not indicate that climate change is irrelevant for these countries; however, we can suggest that climate risk may not yet be fully integrated into market valuations, thus reducing or muting the climate risk effect in these countries' equity returns.

Lastly, the insignificant theta (θ) coefficient indicates that GTA has no impact on the US stock returns. This is also evident in the study by Oloko et al. (2022), who also find that India (NSE) is not impacted by climate change. Surprisingly, though China is the largest emitter of CO₂ (Fig. 2), it is not affected by climate change. However, few studies claim that climate influences stock volatility when climate policy uncertainty (CPU) and climate-related news are used as variables to measure climate change (Lv and Li, 2022; Wang and Li, 2023; Chen et al., 2023).

Though climate change increases the volatility in Italy, the UK, and Germany, while the US and China exhibit muted volatility, this is indeed thought-provoking. China, being the largest CO₂ emitter in the world, is negatively affected by climate change. Existing studies in China evidently show that there are other relevant factors, such as regulatory norms, policy framework, market mood, investors' sentiment, the choice of market proxy, climate-disclosures, and the selection of the climate change proxy bring heterogeneity in the results. He and Ma (2004) demonstrate the negative correlation between extreme temperatures and Chinese stock returns, which they rationalized with the depressed mood generated by the weather for stock investors. Chinese stock volatility is found to be negatively correlated with climate change, wherein extreme temperatures are used as a proxy. The study finds that climatic weather conditions drive the investors' sentiment in the market (Liang et al., 2020). mentions that the prevailing Investors' sentiment in the market creates volatility in the market. Telecom and financial sectors are found to be the most volatile and affected sectors due to climate change, where the CPU is used as a proxy. Similarly, CPU has shown the

predictive variable in explaining the variability in the utility, healthcare, energy, and consumer sectors, finding heterogeneity in results for these sectors (Lv and Li, 2022).

In 2015, the Paris Agreement emphasized the practices of sustainable and carbon-neutral projects, which brought a shift in governments' regulatory norms globally. Strategic norms and climate policy documents are being implemented by the government, targeting zero emissions at the sector level. However, its execution and implementation differ with respect to the countries' boundaries (Awosusi et al., 2023).

China implements its nationally determined contribution (NDC) policies at the national level (Yuan et al., 2023). Though it is working towards reducing GHG emissions, it will achieve its target point on or before 2030 due to its aggressive goals of industrial expansion. Additionally, China has committed to achieving carbon neutrality by 2060, which appears to be unachievable in its current strategies (Evro et al., 2024). Chinese investors prefer long-term industrial expansion, and hence, climate uncertainty negatively impacts their stock market volatility in the long run (Xu et al., 2023). Our study results also corroborate the same. Similarly, regulatory government frameworks may also dampen the market volatility (Li and Liu, 2024). China's national team is established by the government of China, which is authorized to invest and trade in new shares to stabilize the stock market and investors. Using a difference-in-difference method, the study finds that the investments made by the national team don't decrease the stock return volatility. However, national team ownership reduces stock crash risk by 30–45 % and reduces stock volatility by 1.85 % for firms with pledged shares. The study shows that national team stock ownership decreased risk-taking behavior in treated firms, evidenced by less capital expenditure and research & development investments. The study suggests that national team ownership plays a role in the case of treated firms being more conservative and inductive in their decision-making.

Conversely, the adoption of the US NDC differs from state to state. While some states, such as California, strongly support climate policies, others, like West Virginia, are less supportive due to their huge dependence on fossil fuels for industrial development (Sahu & Kumar, 2023). Therefore, US investors are less wary of global climate change. Similar results for the US market are found in the study by Kayani et al. (2024). The article examines the effects of CPU and global Energy Uncertainty (EU) on U.S. sectoral stock returns. Results show that positive CPU shocks negatively impact the consumer services, financials, Industries, telecommunications, and Utilities in the long term, while negative CPU shocks insignificantly predict these returns. Conversely, negative EU

shocks increase the returns of consumer Services, Financials, and health care industries.

3.2. GPR and stock market volatility

Table 7 extends the discussion for Table 5 and presents GRCH MIDAS-X results showing the influence of GPR on the stock returns of the sample countries. Since the details of Mu, Alpha, and Beta coefficients are already discussed in section 4.1, we will only discuss the Theta coefficient, whose non-zero significant value implies the impact of GPR on the stock returns. All ten countries exhibit a momentary volatility caused by long-term geopolitical risk because the sum of (α and β) is less than 1. The significant positive (θ) coefficient for the only country, India (6.436), confirms that although the stock returns are highest in the country, it also has high volatility due to geopolitical uncertainty. Similarly, the study by Salisu et al. (2022) finds that India is affected by the GPR. Internal political instability, cross-border disputes, and unstable foreign policy are the prime reasons that make Indian investors more sensitive to any political and economic uncertainty. The stock returns of the US and Japan are less affected by the GPR, indicating geopolitical stability in these countries, as shown by their negative and significant (θ) coefficient. While the GPR is highest for the US (2.309) (Table 2), this distress does not result in volatile stock returns. This can be explained by the potential factors, such as timely federal bank intervention, strong economic fundamentals, and global corporate diversification, that boost investor confidence and sentiment. However, our results for the US market differ from the prior study by (Segnon et al., 2023; Caldara and Iacoviello, 2022). We find that there are three main reasons highlighting this discrepancy: inherent economic stability, the selection of the study period, and the choice of the correct market proxy. Segnon et al. (2023) find that the intrinsic economic stability of the US economy makes it less vulnerable to external shocks. Moreover, the informational content of the GPR events is short-lived and only impacts intraday investors. The US Volatility Index (VIX) is significantly volatile due to the changes in geopolitical economic uncertainty in the market, wherein VIX is considered to be the true proxy for the market, as it reflects the investors' sentiment and uncertainty prevailing in the market Caldara and Iacoviello (2022). Further, the authors' study period comprises of long period of 34 years, beginning from 1985 to 2019. It is worth mentioning that this period includes significant geopolitical events, reported in Table 8. Whereas our selection of the market proxy is based on the top leading US firms that reflect the economic performance

Table 7
Global Political Risk and stock market volatility.

Countries	Mu	Alpha	Beta	Gamma	m	Theta	w2
India	0.055 (0.000*)	0.026 (0.016*)	0.883 (0.000*)	0.135 (0.000*)	−0.841 (0.038*)	6.436 (0.002*)	1.000 (0.623)
USA	0.030 (0.003*)	0.008 (0.583)	0.866 (0.000*)	0.198 (0.000*)	0.698 (0.088)	−0.359 (0.022*)	6.808 (0.000*)
China	0.015 (0.340)	0.062 (0.000*)	0.924 (0.000*)	0.012 (0.383)	1.224 (0.005*)	−0.629 (0.400)	2.322 (0.087)
Germany	0.034 (0.013*)	0.00E+ (0.999)	0.895 (0.000*)	0.156 (0.000*)	0.155 (0.769)	0.318 (0.785)	1.000 (0.928)
Japan	0.027 (0.097)	0.023 (0.141)	0.848 (0.000*)	0.160 (0.000*)	1.054 (0.000*)	−2.358 (0.002*)	1.301 (0.128)
UK	0.007 (0.535)	0.020 (0.129)	0.866 (0.000*)	0.163 (0.000*)	−0.010 (0.940)	−0.114 (0.243)	3.397 (0.053*)
France	0.017 (0.212)	0.000 (0.999)	0.875 (0.000*)	0.199 (0.000*)	0.380 (0.165)	0.082 (0.823)	3.955 (0.779)
Italy	0.017 (0.233)	0.010 (0.284)	0.906 (0.000*)	0.136 (0.000*)	1.582 (0.020*)	−7.859 (0.086)	1.934 (0.003*)
Brazil	0.030 (0.143)	0.016 (0.021*)	0.895 (0.000*)	0.104 (0.000*)	1.034 (0.003*)	−2.884 (0.663)	6.011 (0.808)
Canada	0.023 (0.013*)	0.014 (0.135)	0.895 (0.000*)	0.141 (0.000*)	−0.299 (0.160)	−0.828 (0.105)	34.689 (0.353)

Note: The P value is within the parentheses, at the significance level of 5 %.

Source: Computed by authors

Table 8

Top 10 Major events occurred in the US market.

Sr. No.	Period	Top 10 Major events in the US market
1.	1990–91	Gulf War I
2.	1993	World Trade Center blast
3.	2001	(9/11) terrorist attack
4.	2006	The first nuclear test by North Korea
5.	2008–09	Global financial crisis
6.	2011	Assassination of Osama Bin Laden
7.	2011	Syrian Civil War.
8.	2014	Escalation of the Ukraine conflict
9.	2015	Iran nuclear deal
10.	2018–19	US-China trade war.

Note: Computed by authors.

of the US market. Thus, future research may use VIX as a market index to measure the financial volatility regressed by an uncertain risky explanatory variable. However, our results are based on a 21-year period, which is a narrow in period by 13 years.

The GPR predictor was found to be insignificant for the seven countries (China, Germany, the UK, France, Italy, Brazil, and Canada), implying that the GPR does not cause volatility in stock returns in these markets. This is consistent with Agoraki et al. (2022), using the study period of 1985–2020. This shows that investors do not perceive geopolitical events or tensions as significant factors influencing their investment decisions in these countries. However, the results differ from Yang et al. (2021), who find that the Chinese market is a significant country for the study period from 2011 to 2022. This implies that GPR is a predictor in explaining stock volatility in the recent period.

Our study incrementally contributes to the existing literature of Oloko et al. (2022), first, in terms of the selection of the sample countries. Oloko et al. (2022) studied the top 10 Asian countries, including two market indices each from China and India, which is a regional representation. However, our study includes the top 10 countries based on their GDP contribution, representing America, Asia, and the European continent. Similarly, Salisu et al. (2022) mention that their results are specific to a sample of 11 emerging countries only. Hence, the sample of countries used in our study represents the broader view of the global market.

While prior studies (Oloko et al., 2022; Salisu et al., 2022) predominantly focused on measuring the volatility with the impact of risks, wherein GTA and GPR were analyzed separately. Our study extends the scope of analysis by including both climate and geopolitical risks faced by the largest economies globally. Hence, this presents a comprehensive picture of the impact of these two risks in different market paradigms. Additionally, this analysis extends the discussion beyond generic conclusions and provides more discerning policy implications concerning the unique vulnerabilities and resilience factors that each economy is endowed with.

4. Discussion

This study finds the volatility of stock returns for 10 countries (India, USA, China, Germany, Japan, UK, France, Italy, Brazil, and Canada) triggered by the long-term macro variables, i.e., global climate change, and geopolitical risk using the GARCH MIDAS-X model. The research provides a holistic macro-level perspective on stock market volatility and creates data from cross-country developed and developing economies, allowing researchers to analyze the differential effects across regions. The study holds its policy implications for managers and policy regulators as it provides a clear picture of the existence and relevance of climate and geopolitical risk in explaining volatility in stock returns. Policy implications for the financial managers of Italy, the UK, and Germany are to rebalance the portfolios, including ESG-aligned investments, while staying away from carbon-intensive assets and hence promoting green finance opportunities to various stakeholders in their

countries.

The policy recommendations for these European markets include the government, financial institutions, bankers, and market regulators. They are required to implement stringent policies and regulations that can absorb the long-term climate shocks while ensuring the financial market remains unaffected. This requires a comprehensive reform and strategies for policymakers to make the financial market resilient. The listed companies should be mandated to disclose their ESG scores, follow sustainable practices, obtain third-party ESG ratings, create an ESG-based index, subsidize interest rates to renewable energy projects, carbon footprint, and issuance of green bonds. This results in building the reputation, gaining the competitive advantage, creating social capital, and creating goodwill in the market (Ghani et al., 2024; Ahmad et al., 2024; Chen et al., 2023; Iannone et al., 2025).

Similarly, the government's sovereign bonds, securities, and pension fund portfolios should be inclined more towards ESG-based and frequent monitoring of greenwashing practices among companies (Ahmad et al., 2024; Mustafa et al., 2024; Gavrilakis and Floros, 2023). During times of economic turbulence or extreme climate shocks, there is a need to conduct free awareness programs, highlighting the requirement for ESG investing. Additionally, financial regulators should align the importance of ESG portfolios equally with value investing, realizing their ability to deliver long-term abnormal returns (Cunha et al., 2021; Cardillo et al., 2023; Albuquerque et al., 2020). Also, the policymakers of these countries should set high standards for achieving the carbon neutrality target by investing in carbon-neutral infrastructure and rapidly transitioning to low-carbon technologies. These initiatives will work toward shielding the financial system from long-term (pervasive) volatility.

Report by McKinsey Global Institute indicates that India's GDP may drop by 2.5 % in its annual GDP and drop of 25 % in wheat yield by 2100, due to climate change. Major coastal cities such as Chennai and Mumbai are threatened by pollution from urban and marine water scarcity. Therefore, Indian financial institutions are advised to incorporate climate-based scenario and stress testing while lending in climate-sensitive and coastal-prone areas, such as agriculture, solar power projects, and real estate construction.

This study seeks the US markets' attention to the fact that though the Inflation Control Act of 2002 was framed in response to address the US climate change challenge. Recommending issuing green bonds in the market, however, the emergence of political backlash restrains progress. In response to Japan's vulnerabilities to climate change, there is a need to frame the plans in alignment with the regulatory framework by the Bank of Japan, which will bring stability in energy pricing.

Likewise, geopolitical risk is found to be a predictor of volatility across all three countries (India, the USA, and Japan). Indicating the Indian market is incredibly volatile, while the USA and Japan are seen with volatility dampening. The vulnerability of the Indian market is attributed to investors' sentiments, import of crude oil, ideological rigidities, security issues, external reliance on natural gas, and fertilizers. The Indian market exhibits high volatility in the case of any geopolitical shocks (Zhang et al., 2022; J and Majid, 2020; Pode, 2010; Prakash et al., 2022). However, recent literature in the Indian market depicts investors' positive sentiment towards high ESG score portfolios. This calls for policymakers to foster investment in renewable energy, green bonds, and carbon-neutral projects. Indian market regulators are required to make investors aware of the benefits of ESG investing (Hoque and Zaidi, 2020).

Further, we propose that researchers and scholars explore the power of ESG premium in explaining the stock returns in the Indian market. This can be one of the extended factors in the Fama-French three-factor asset pricing model (Fama and French, 1993). ESG-based companies have the potential to generate extra stock returns over the conventional firms and exhibit market resilience during the crisis period (Hasan et al., 2025; Gidage et al., 2024).

Additionally, India is always at a cross-border terrorism risk since it is surrounded by nuclear-based neighboring countries such as China and

Pakistan, and hence is always exposed to cross-border disputes. Therefore, investment in the IT, healthcare, domestic resilient sectors, and renewable energy sectors should be the preferred areas for Indian investors.

Though the U.S. is the global leader, its deal with the AI groups is always subject to political risks. American investors are advised to invest in US Treasury bonds or precious metals. Japan, being an energy importer, requires its investors to hedge their portfolios based on energy sectors. Comprehensively, the governments globally should consider this study as a policy recommendation to mitigate their climate and geopolitical risk for maintaining financial market stability.

5. Conclusion

Our study fulfills the objective of examining the impact of climate change and geopolitical risk on the stock market volatility of the world's ten most influential economies. Based on eleven years of high frequency dataset of daily stock market returns of all the ten countries, and lower frequency data related to GTA and GTR during that time, our findings reveal that while GTA significantly predicts the stock market volatility of Italy, the UK and Germany, GTR has a considerable predicting impact in causing stock market volatility in India, USA and Japan. The investors in countries like Italy, the UK, and Germany are really concerned and show increased awareness about the disastrous impact caused by the global climate change circumstances brought on by CO₂ emissions, GHG emissions, and global warming, etc. Such events cause instability in their financial markets, which may also affect other economies. Therefore, the Governments in these economies ought to implement stricter regulations to regulate the industries causing such climatic disruptions. Similarly, high volatility in the Indian stock market, while the USA and Japan are seen with volatility dampening impacted by the geopolitical uncertainties caused mainly by terrorist attacks, trade wars, frequent changes in foreign policies, etc. Such geopolitical uncertainties necessitate immediate resolution, which not only creates turbulence in their own financial markets but also has a ripple effect in other markets. Governments in these countries should pay special heed to such geopolitical shocks and should implement stricter policy measures to overcome these issues. This will not only instill the confidence of their own investors but also directly and indirectly attract foreign investors. Overall, our study has larger implications and calls for international cooperation by the countries to design effective policies to address these pressing issues.

The study also touches on some limitations of the research. While we do utilize a multi-country sample, it does not include all economies in the world. So, the results based on the inclusion of the top 10 economies by GDP surely cannot be generalized for vulnerable countries, including islands such as Honduras, Myanmar, and Vanuatu, which are commonly devastated by floods and cyclones (Adil et al., 2025). Future research should therefore focus on examining the impact of climate change on developing countries, island states, climate-vulnerable states, and underdeveloped states to compare the results with this study and generate comparative insights. Thus, future studies could look at other economies to then compare the results with those of this study, to generate comparative insights. Also, we suggest that direct proxies like country-specific (CPU) or extreme weather event data can be used to examine the stock volatility in future research. Similarly, additional macroeconomic variables specific to countries could be considered (e.g., stage of economic development), utilizing them in a different scope from that of this study (e.g., using them in a moderating or mediating role), to understand in greater depth the influence of climate change and geopolitical risk on stock market volatility.

CRedit authorship contribution statement

Saroj S. Prasad: Writing – original draft, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Veerma Puri:**

Writing – review & editing. **Priti Bakhshi:** Writing – review & editing, Supervision.

Funding sources

This research received no external funding.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

References

- Adil, L., Eckstein, D., Künzel, V., Schäfer, L., Germanwatch, 2025. Climate risk index 2025. In: Goulston, A. (Ed.), Climate Risk Index. Germanwatch e.V. <https://www.germanwatch.org/sites/default/files/2025-02/Climate%20Risk%20Index%202025.pdf>.
- Admin, 2021. Italy- G20 climate risk atlas. G20 Climate Risk Atlas. <https://www.g20climate.org/italy/#:~:text=Economic%20Impacts&text=Italy%20faces%20multiple%20threats%20from,rises%20to%208.5%25%20by%202100>.
- Agoraki, M.E.K., Kouretas, G.P., Laopodis, N.T., 2022. Geopolitical risks, uncertainty, and stock market performance. *Econ. Polit. Stud.* 10 (3), 253–265. <https://doi.org/10.1080/20954816.2022.2095749>.
- Ahmad, H., Yaqub, M., Lee, S.H., 2024. Environmental, social, and governance related factors for business investment and sustainability: a scientometric review of global trends. *Environ. Dev. Sustain.* 26 (2), 2965–2987.
- Alam, A., Banna, H., Alam, A.W., Bhuiyan, M.B.U., Mokhtar, N.B., 2024. Climate change and geopolitical conflicts: the role of ESG readiness. *J. Environ. Manag.* 353, 120284. <https://doi.org/10.1016/j.jenvman.2024.120284>.
- Albuquerque, R., Koskinen, Y., Yang, S., Zhang, C., 2020. Resiliency of environmental and social stocks: an analysis of the exogenous COVID-19 market crash. *Rev. Corp. Finan. Stud.* 9 (3), 593–621. <https://doi.org/10.1093/rcfs/cfaa011>.
- Alqahtani, A., Bouri, E., Vo, X.V., 2020. Predictability of GCC stock returns: the role of geopolitical risk and crude oil returns. *Econ. Anal. Pol.* 68, 239–249. <https://doi.org/10.1016/j.eap.2020.09.017>.
- Apergis, N., Bonato, M., Gupta, R., Kyei, C., 2017. Does geopolitical risks predict stock returns and volatility of leading defense companies? Evidence from a nonparametric approach. *Defen. Peace Econ.* 1–13. <https://doi.org/10.1080/10242694.2017.1292097>.
- Asgharian, H., Hou, A.J., Javed, F., 2013. The importance of the macroeconomic variables in forecasting stock return variance: a GARCH-MIDAS approach. *J. Forecast.* 32, 600–612. <https://doi.org/10.1002/for.2256>.
- Awosusi, A.A., Ozdeser, H., Seraj, M., Abbas, S., 2023. Can green resource productivity, renewable energy, and economic globalization drive the pursuit of carbon neutrality in the top energy transition economies? *Int. J. Sustain. Dev. World Ecol.* 30 (7), 745–759. <https://doi.org/10.1080/13504509.2023.2192007>.
- Baker, S.R., Bloom, N., Davis, S.J., 2016. Measuring economic policy uncertainty. *Q. J. Econ.* 131 (4), 1593–1636. <https://doi.org/10.1093/qje/qjw024>.
- Baker, S.R., Davis, S.J., Levy, J.A., 2022. State-level economic policy uncertainty. *J. Monetary Econ.* 132, 81–99. <https://doi.org/10.1016/j.jmoneco.2022.08.004>.
- Bakhshi, P., Chaudhary, R., 2020. Responsible business conduct for the sustainable development goals: lessons from Covid-19. *Int. J. Disast. Recov. Busi. Contin.* 11 (1), 2835–2841.
- Bakhshi, P., Agrawal, R., Mendon, S., Birau, R., Bărbăciaru, I.C., 2023. Framework of SDG leadership among SMEs in South Asian nations-using interpretive structural modelling. *Cogent Busi. Manag.* 10 (3), 2253607.
- Balcilar, M., Bonato, M., Demirer, R., Gupta, R., 2018. Geopolitical risks and stock market dynamics of the BRICS. *Econ. Syst.* 42 (2), 295–306. <https://doi.org/10.1016/j.ecosys.2017.05.008>.
- Barnett, J., 2020. Global environmental change II: political economies of vulnerability to climate change. *Prog. Hum. Geogr.* 44 (6), 1172–1184. <https://doi.org/10.1177/0309132519898254>.
- Baur, D.G., Smales, L.A., 2020. Hedging geopolitical risk with precious metals. *J. Bank. Finance* 117, 105823. <https://doi.org/10.1016/j.jbankfin.2020.105823>.
- Berestyski, C., et al., 2022. Measuring and assessing the effects of climate policy uncertainty. In: OECD Economics Department Working Papers, No. 1724. OECD Publishing, Paris. <https://doi.org/10.1787/34483d83-en>.
- Bonato, M., Cepni, O., Gupta, R., Pierdzioch, C., 2022. Climate risks and realized volatility of major commodity currency exchange rates. *J. Financ. Mark.* 100760. <https://doi.org/10.1016/j.finmar.2022.100760>.
- Bouras, C., Christou, C., Gupta, R., Suleman, T., 2019. Geopolitical risks, returns, and volatility in emerging stock markets: evidence from a panel GARCH model. *Emerg. Mark. Finance Trade* 55 (8), 1841–1856.

- Caldara, Dario, Iacoviello, Matteo, 2022. Measuring geopolitical risk. *Am. Econ. Rev.* 112 (4), 1194–1225. <https://doi.org/10.1257/aer.20191823>.
- Campiglio, E., Dafermos, Y., Monnin, P., Ryan-Collins, J., Schotten, G., Tanaka, M., 2018. Climate change challenges for central banks and financial regulators. *Nat. Clim. Change* 8 (6), 462–468.
- Cardillo, G., Bendinelli, E., Torluccio, G., 2023. COVID-19, ESG investing, and the resilience of more sustainable stocks: evidence from European firms. *Bus. Strat. Environ.* 32 (1), 602–623.
- Care, R., Weber, O., 2023. How much finance is in climate finance? A bibliometric review, critiques, and future research directions. *Res. Int. Bus. Finance* 64, 101886. <https://doi.org/10.1016/j.ribaf.2023.101886>.
- Cevik, M.S., 2023. Long Live Globalization: Geopolitical Shocks and International Trade. International Monetary Fund.
- Chava, S., 2014. Environmental risk, cost of capital, and capital structure. *J. Environ. Econ. Manag.* 68 (1), 163–183.
- Chen, S., Gong, W., Li, S., Wang, J., 2020. Hurricane risk and stock market returns: evidence from the United States. *Int. Rev. Financ. Anal.* 72, 101542.
- Chen, X., Chen, X., Xu, L., Wen, F., 2022. Attention to climate change and downside risk: evidence from China. *Risk Anal.* <https://doi.org/10.1111/risa.13975>. Forthcoming.
- Chen, Z., Zhang, L., Weng, C., 2023. Does climate policy uncertainty affect Chinese stock market volatility? *Int. Rev. Econ. Finance* 84, 369–381. <https://doi.org/10.1016/j.iref.2022.11.030>.
- Chu, L.K., Doğan, B., Abakah, E.J.A., et al., 2023. Impact of economic policy uncertainty, geopolitical risk, and economic complexity on carbon emissions and ecological footprint: an investigation of the E7 countries. *Environ. Sci. Pollut. Control Ser.* 30, 34406–34427. <https://doi.org/10.1007/s11356-022-24682-2>.
- Climate change: global temperature, 2025. NOAA climate.gov. <https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature>.
- Conrad, C., Kleen, O., 2020. Two are better than one: volatility forecasting using multiplicative component GARCH-MIDAS models. *J. Appl. Econ.* 35, 19–45. <https://doi.org/10.1002/jae.2742>, 2020.
- Cunha, F.A.F.D.S., Meira, E., Orsato, R.J., 2021. Sustainable finance and investment: review and research agenda. *Bus. Strat. Environ.* 30 (8), 3821–3838. <https://doi.org/10.1002/bse.2842>.
- Data. GISS: GISS surface temperature analysis (GISTEMP v4) (n.d.). <https://data.giss.nasa.gov/gistemp/>.
- Deere, Birkbeck, C., 2009. Global governance in the context of climate change: the challenges of increasingly complex risk parameters. *Int. Aff.* 85 (6), 1173–1194. <https://doi.org/10.1111/j.1468-2346.2009.00856.x>.
- Demiralay, S., Wang, Y., Chen, C., 2024. Geopolitical risks and climate change stocks. *J. Environ. Manag.* 352, 119995.
- Duan, H., Yuan, D., Cai, Z., Wang, S., 2022. Valuing the impact of climate change on China's economic growth. *Econ. Anal. Pol.* 74, 155–174.
- Engle, Robert F., 1982. Autoregressive conditional heteroscedasticity with estimates of the variance of United Kingdom inflation. *Econometrica* 50 (4), 987–1007.
- Engle, R.F., Ghysels, E., Sohn, B., 2013. Stock market volatility and macroeconomic fundamentals. *Rev. Econ. Stat.* 95 (3), 776–797. <https://doi.org/10.1162/resta00300>.
- Evro, S., Oni, B.A., Tomomewo, O.S., 2024. Global strategies for a low-carbon future: lessons from the US, China, and EU's pursuit of carbon neutrality. *J. Clean. Prod.* 461, 142635. <https://doi.org/10.1016/j.jclepro.2024.142635>.
- Faccini, R., Matin, R., Skiadopoulos, G., 2023. Dissecting climate risks: Are they reflected in stock prices? *J. Bank. Financ.* 155, 106948.
- Fama, E.F., French, K.R., 1993. Common risk factors in the returns on stocks and bonds. *J. Financ. Econ.* 33 (1), 3–56. [https://doi.org/10.1016/0304-405x\(93\)90023-5](https://doi.org/10.1016/0304-405x(93)90023-5).
- Fang, T., Lee, T.H., Su, Z., 2020. Predicting the long-term stock market volatility: a GARCH-MIDAS model with variable selection. *J. Empir. Finance* 58, 36–49.
- Fassnacht, S.R., Patterson, G.G., Venable, N.B., Cherry, M.L., Pfohl, A.K., Sanow, J.E., Tedesche, M.E., 2020. How do we define climate change? Considering the temporal resolution of Niveo-Meteorological data. *Hydrology* 7 (3), 38.
- Feng, C., Han, L., Vigne, S., Xu, Y., 2023. Geopolitical risk and the dynamics of international capital flows. *J. Int. Financ. Mark. Inst. Money* 82, 101693.
- Fuss, S., Szolgayova, J., Obersteiner, M., Gusti, M., 2008. Investment under market and climate policy uncertainty. *Appl. Energy* 85, 708–721.
- Gavrilidis, K., 2021. Measuring climate policy uncertainty. Available at: SSRN 3847388.
- Gavrilakis, N., Floros, C., 2023. ESG performance, herding behavior and stock market returns: evidence from Europe. *Oper. Res. Int. J.* 23, 3. <https://doi.org/10.1007/s12351-023-00745-1>.
- Geopolitical Risk Dashboard BlackRock investment institute. (n.d.). BlackRock. <https://www.blackrock.com/corporate/insights/blackrock-investment-institute/interactive-charts/geopolitical-risk-dashboard>.
- Ghani, U., Zhu, B., Qin, Q., Ghani, M., 2024. Forecasting US stock market volatility: evidence from ESG and CPU indices. *Finance Res. Lett.* 59, 104811.
- Ghoul, S., Guenaoui, N., Picard, A., 2016. Does corporate social responsibility reduce the cost of capital? *Ecol. Econ.* 124, 83–92.
- Gidage, M., Bhide, S., Paturkar, R., Kolte, A., 2024. ESG performance and systemic risk nexus: role of firm-specific factors in Indian companies. *J. Risk Financ. Manag.* 17 (9), 381. <https://doi.org/10.3390/jrfm17090381>.
- Giglio, S., Kelly, B., Stroebe, J., 2021. Climate finance. *Ann. Rev. Financ. Econ.* 13 (1), 15–36. <https://doi.org/10.1146/annurev-financial-102620-103311>.
- Girardin, Joyeux, 2013. Macro Fundamentals as a Source of Stock Market Volatility in China: a GARCH-MIDAS Approach. <https://doi.org/10.1016/j.econmod.2012.12.001>.
- Goal 13 Department of Economic and Social Affairs.(n.d.). <https://sdgs.un.org/goals/goal13>.
- Gong, X., Fu, C., Huang, Q., Lin, M., 2022. International political uncertainty and climate risk in the stock market. *J. Int. Financ. Mark. Inst. Money* 81, 101683. <https://doi.org/10.1016/j.intfin.2022.101683>.
- Hasan, I., Singh, S., Kashiramka, S., 2025. Exploring the financial performance of ESG investing in India: evidence using asset-pricing models. *China Account. Financ. Rev.* 421–466. <https://doi.org/10.1108/CAFR-12-2023-0153>.
- He, J., Ma, X., 2004. Extreme temperatures and firm-level stock returns. *Int. J. Environ. Res. Publ. Health* 18 (4), 2004. <https://doi.org/10.3390/ijerph18042004>. PMID: 33669558; PMCID: PMC7922310.
- Herre, B., Roser, M., 2023. The global terrorism database: how do researchers measure terrorism? Our world in data. <https://ourworldindata.org/the-global-terrorism-database-how-do-researchers-measure-terrorism>.
- Hertig, E., Hunger, I., Kaspar-Ott, I., Matzarakis, A., Niemann, H., Schulte-Droesch, L., Voss, M., 2023. Climate change and public health in Germany - an introduction to the German status report on climate change and health 2023. *J. Health Monit.* 8 (Suppl. 3), 6–32. <https://doi.org/10.25646/11400>.
- Hong, H., Andrew Karolyi, G., Scheinkman, José A., 2020. Climate finance. *Rev. Financ. Stud.* 33 (3), 1011–1023. <https://doi.org/10.1093/rfs/hhz146>.
- Hoque, M.E., Zaidi, M.A.S., 2020. Global and country-specific geopolitical risk uncertainty and stock return of fragile emerging economies. *Borsa Istanbul Rev.* 20 (3), 197–213. <https://doi.org/10.1016/j.bir.2020.05.001>.
- <https://www.reuters.com/markets/Europe/Growing-italy-risk-puts-equities-deepest-discount-35-years-2023-11-07/>. (n.d.).
- Iannone, B., Dutillo, P., Gattone, S.A., 2025. Evaluating the resilience of ESG investments in European markets during turmoil periods. *Corp. Soc. Responsib. Environ. Manag.* 32 (4), 5006–5020. <https://doi.org/10.1002/csr.3225>.
- Italy: most concerning environmental issues 2019 Statista, 2024. Statista. <https://www.statista.com/statistics/865499/top-three-most-concerning-environmental-issues-in-%20italy/#:~:text=The%20environmental%20issue%20that%20worried,air%20pollution%20and%20global%20warming>.
- J, C.R.K., Majid, M.A., 2020. Renewable energy for sustainable development in India: current status, future prospects, challenges, employment, and investment opportunities. *Energy Sustain. Soc.* 10 (1). <https://doi.org/10.1186/s13705-019-0232-1>.
- James, 2024. World Economy Ranking 2024: Top 10 Countries Across the World List - AWDI. AWDI. <https://awdi.in/world-economy-ranking-2024-top-10-countries-across-the-world-list/>.
- Jawad, M., Naz, M., Rizwan, S., Maroof, Z., Waheed, N., Majeed, A., Rashid, T., 2022. Impact of long run investment of stock in developed & developing economies. *Cogent Econ. Financ.* 10 (1). <https://doi.org/10.1080/23322039.2022.2085378>.
- Ji, Q., Ma, D., Zhai, P., Fan, Y., Zhang, D., 2024. Global climate policy uncertainty and financial markets. *J. Int. Financ. Mark. Inst. Money*, 102047.
- Kayani, U., Sheikh, U.A., Khalfaoui, R., Roubaud, D., Hammoudeh, S., 2024. Impact of climate policy uncertainty (CPU) and global energy uncertainty (EU) news on U.S. sectors: the moderating role of CPU on the EU and U.S. sectoral stock nexus. *J. Environ. Manag.* 366, 121654. <https://doi.org/10.1016/j.jenvman.2024.121654>.
- Kevers, Mustafa, Tunçel, Mert Baran, Gürsoy, Samet, Zeren, Feyyaz, 2024. The impact of environmental, social and governance (ESG) scores on stock market: evidence from G7 countries. *J. Glob. Respons.* 305–319. <https://doi.org/10.1108/JGR-04-2023-0070>.
- Khalfaoui, R., Mefteh-Wali, S., Viviani, J., Jabeur, S.B., Abedin, M.Z., Lucey, B.M., 2022. How do climate risk and clean energy spillovers, and uncertainty affect US stock markets? *Technol. Forecast. Soc. Change* 185, 122083.
- Lee, C.C., Wang, C.W., 2021. Firms' cash reserve, financial constraint, and geopolitical risk. *Pac. Basin Finance J.* 65, 101480.
- Lee, C.C., Li, X., Yu, C.H., Zhao, J., 2022. The contribution of climate finance toward environmental sustainability: new global evidence. *Energy Econ.* 111, 106072. <https://doi.org/10.1016/j.eneco.2022.106072>.
- Li, H., Liu, K., 2024. China's national team: a game changer in stock market stabilization? *Finance Res. Lett.* 61, 104984. <https://doi.org/10.1016/j.frl.2024.104984>.
- Li, X., Ma, F., Zhang, J., 2018. Geopolitical risk and stock returns: evidence from the US market. *Finance Res. Lett.* 24, 14–21.
- Li, X., Ye, C., Bhuiyan, M.A., Huang, S., 2023. Volatility forecasting with an extended GARCH-MIDAS approach. *J. Forecast.* 43 (1), 24–39. <https://doi.org/10.1002/for.3023>.
- Liang, Chen, Kettunen, Janne, 2017. Is certainty in carbon policy better than uncertainty? *Eur. J. Oper. Res.* 258. <https://doi.org/10.1016/j.ejor.2016.08.033>.
- Liang, C., Tang, L., Li, Y., Wei, Y., 2020. Which sentiment index is more informative to forecast stock market volatility? Evidence from China. *Int. Rev. Financ. Anal.* 71, 101552. <https://doi.org/10.1016/j.irfa.2020.101552>. Lv, W., & Li, B. (2022).
- Liang, C., Umar, M., Ma, F., Huynh, T.L., 2022. Climate policy uncertainty and world renewable energy index volatility forecasting. *Technol. Forecast. Soc. Change* 182, 121810. <https://doi.org/10.1016/j.techfore.2022.121810>.
- Lin, Z., 2018. Modelling and forecasting the stock market volatility of SSE composite index using GARCH models. *Future Gener. Comput. Syst.* 79, 960–972.
- Liu, Y., Qiao, T., Han, L., 2022. Does clean energy matter? Revisiting the spillovers between energy and foreign exchange markets. *J. Futures Mark.* 42 (11), 2068–2083.
- Liu, T., Choo, W., Tunde, M.B., Wan, C., Liang, Y., 2024. Enhancing stock volatility prediction with the AO-GARCH-MIDAS model. *PLoS One* 19 (6), e0305420. <https://doi.org/10.1371/journal.pone.0305420>.
- Luo, H., Sun, Y., 2024. Effects of geopolitical risk on environmental sustainability and the moderating role of environmental policy stringency. *Sci. Rep.* 14 (1). <https://doi.org/10.1038/s41598-024-60773-5>.

- Lv, W., Li, B., 2022. Climate policy uncertainty and stock market volatility: evidence from different sectors. *Finance Res. Lett.* 51, 103506. <https://doi.org/10.1016/j.frl.2022.103506>.
- Ma, Y.R., Liu, Z., Ma, D., Zhai, P., Guo, K., Zhang, D., Ji, Q., 2023. A news-based climate policy uncertainty index for China. *Sci. Data* 10 (1), 881.
- Ma, D., Zhang, D., Guo, K., Ji, Q., 2024. Coupling between global climate policy uncertainty and economic policy uncertainty. *Finance Res. Lett.* 69, 106180.
- Nature degradation could cause a 12% loss to UK GDP, 2024. University of. <https://www.nature.com/articles/d41586-024-00000-0>.
- Ndako, U.B., Salisu, A.A., Ogunsiji, M.O., 2021. Geopolitical risk and the return volatility of Islamic stocks in Indonesia and Malaysia: a GARCH-MIDAS approach. *Asian Econ. Lett.* 2 (3). <https://doi.org/10.46557/001c.24843>.
- Nguyen, D.T., Le, T.H., Do, D.D., Nguyen, H.N., 2023. Does geopolitical risk hinder sustainable development goals? Evidence from a panel analysis. *J. Environ. Manag.* 347, 119204.
- Noh, J.H., Park, H., 2023. Greenhouse gas emissions and stock market volatility: an empirical analysis of OECD countries. *Int. J. Clim. Change Strat. Manag.* 15 (1), 58–80. <https://doi.org/10.1108/IJCCSM-10-2021-0124>.
- Oloko, T.F., Adediran, I.A., Fadiya, O.T., 2022. Climate change and Asian stock markets: a GARCH-MIDAS approach. *Asian Econ. Lett.* 5. <https://doi.org/10.46557/001c.37142>. Early View.
- Penzin, D.J., Isah, K.O., Salisu, A.A., 2024. Climate change-stock return volatility nexus in advanced economies: the role of technology shocks. *J. Econ. Stud.*
- Pode, R., 2010. Addressing India's energy security and options for decreasing energy dependency. *Renew. Sustain. Energy Rev.* 14 (9), 3014–3022. <https://doi.org/10.1016/j.rser.2010.07.007>.
- Prakash, O., Ahmad, A., Kumar, A., Chatterjee, R., Sharma, S., Alayi, R., Monfared, H., 2022. The compressive study of energy security prospects in India through solar power. *Int. J. Low Carbon Technol.* <https://doi.org/10.1093/ijlct/ctac075>.
- PricewaterhouseCoopers. PWC Indonesia. PwC. n.d. <https://www.pwc.com/id/en/ot-migrated/shift-of-global-economic-power-to-emerging-economies-set-to-cont.htm>.
- Sahu, R., Kumar, P., 2023. The missing nexus: a historical and contemporary position of the United States on climate change action. *Int. Stud.* 60 (4), 444–479.
- Salisu, A., Oloko, T., 2023. Climate risk measures: a review. *Asian Econ. Lett.* 4 (1). <https://doi.org/10.46557/001c.39728>.
- Salisu, A.A., Ogbonna, A.E., Lasisi, L., Olaniran, A., 2022. Geopolitical risk and stock market volatility in emerging markets: a GARCH-MIDAS approach. *N. Am. J. Econ. Finance* 62, 101755. <https://doi.org/10.1016/j.najef.2022.101755>.
- Schlenker, W., Taylor, C.A., 2021. Market expectations of a warming climate. *J. Financ. Econ.* 142 (2), 627–640.
- Segnon, M., Gupta, R., Wilfling, B., 2023. Forecasting stock market volatility with regime-switching GARCH-MIDAS: the role of geopolitical risks. *Int. J. Forecast.* 40 (1), 29–43. <https://doi.org/10.1016/j.ijforecast.2022.11.007>.
- ShahNazari, M., McHugh, A., Maybee, B., Whale, J., 2014. The effect of political cycles on power investment decisions: expectations over the repeal and reinstatement of carbon policy mechanisms in Australia. *Appl. Energy* 130, 157–165. <https://doi.org/10.1016/j.apenergy.2014.05.040>.
- Shang, Q., Jin, X., 2023. A bibliometric analysis on climate finance: current status and future directions. *Environ. Sci. Pollut. Control Ser.* 30, 119711–119732. <https://doi.org/10.1007/s11356-023-31006-5>.
- Speech, 2024. Geopolitics and its Impact on Global Trade and the Dollar. IMF. <https://www.imf.org/en/News/Articles/2024/05/07/sp-geopolitics-impact-global-trade-a-dollar-gita-gopinath>.
- Statista, 2024. Global climate finance and losses due to climate change 2025-2100, by scenario. <https://www.statista.com/statistics/1448971/global-climate-finance-a-dollar-losses-due-to-climate-change-by-scenario/>.
- n.d. THE 17 GOALS Sustainable Development <https://sdgs.un.org/goals>.
- Tumala, M.M., Salisu, A., Nmadu, Y.B., 2023. Climate change and fossil fuel prices: a GARCH-MIDAS analysis. *Energy Econ.* 124, 106792.
- Venturini, A., 2022. Climate change, risk factors and stock returns: a review of the literature. *Int. Rev. Financ. Anal.* 79, 101934.
- Virk, N., Javed, F., Awartani, B., Hyde, S., 2024. A reality check on the GARCH-MIDAS volatility models. *Eur. J. Finance* 30 (6), 575–596.
- Wang, J., Li, L., 2023. Climate risk and Chinese stock volatility forecasting: evidence from ESG index. *Finance Res. Lett.* 55, 103898. <https://doi.org/10.1016/j.frl.2023.103898>.
- Wang, Q., Ren, F., Li, R., 2024. Does geopolitical risk impact sustainable development? A perspective on linkage between geopolitical risk and sustainable development research. *J. Clean. Prod.* 451, 141980.
- Wang, Z., Xing, T., Wang, X., 2024. Economic uncertainty and stock market asymmetric volatility: analysis based on the asymmetric GARCH-MIDAS model. *Int. J. Emerg. Mark.* <https://doi.org/10.1108/ijoem-05-2023-0841>.
- Wegener, C., Basse, T., Maiani, S., Nguyen, T.H., 2025. Predictive power of oil prices on CDS spread dynamics of oil-producing countries. *Energy Econ.*, 108375 <https://doi.org/10.1016/j.eneco.2025.108375>.
- Xu, X., Huang, S., Lucey, B.M., An, H., 2023. The impacts of climate policy uncertainty on stock markets: Comparison between China and the US. *Int. Rev. Financ. Anal.* 88, 102671. <https://doi.org/10.1016/j.irfa.2023.102671>.
- Yang, M., Zhang, Q., Yi, A., Peng, P., 2021. Geopolitical risk and stock market volatility in emerging economies: evidence from GARCH-MIDAS model. *Discrete Dynam Nat. Soc.* 1–17. <https://doi.org/10.1155/2021/1159358>, 2021.
- Yu, X., Huang, Y., 2021. The impact of economic policy uncertainty on stock volatility: evidence from GARCH-MIDAS approach. *Phys. Stat. Mech. Appl.* 570, 125794.
- Yuan, Y., Li, G., Duan, H., 2023. The achievement of multiple nationally determined contribution goals and regional economic development in China. *Environ. Resour. Econ.* 84 (4), 1155–1177.
- Zhang, Y., He, J., He, M., Li, S., 2022. Geopolitical risk and stock market volatility: a global perspective. *Finance Res. Lett.* 53, 103620. <https://doi.org/10.1016/j.frl.2022.103620>.
- Zhou, M., Ma, Y., 2025. Climate risk and predictability of global stock market volatility. *J. Int. Financ. Mark. Inst. Money* 101, 102135. <https://doi.org/10.1016/j.intfin.2025.102135>.