Geopolitical Risk

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geopolitical risk acts and threats energy markets

1. Introduction

Geopolitical risk (GPR), according to Caldara and Iacoviello [1], is defined as the risk associated with terror threats, war threats, nuclear threats and military build-ups between states or countries that disrupt the usual, peaceful conduct of international affairs. For instance, Russia's recent invasion of Ukraine on 24 February 2022 has rattled human capital, physical infrastructure, financial markets, international peace and the security system [2]. It is producing a major humanitarian crisis and running amok on an already frail global economy, which was recently hit by the COVID-19 pandemic [3]. GPR has been on the rise in recent decades, with extreme events such as the US bombing of Libya (April 1986), invasion of Kuwait (August 1990), Iraq airstrikes (January 1993), Bosnian war (February 1994), 9/11 attacks (September 2001), Iraq war (March 2003), London bombing (July 2005), the global financial crisis (GFC 2007–2008), Paris attacks (November 2015), US–North Korea (2017–2018), US–Iran tensions (2020), and the current COVID-19 pandemic (2019) [1]. GPR is now ranked even higher than economic uncertainty [4] and is emphasized as a key driver of the state of the economy [5]. Carney [6] includes GPR with economic and policy uncertainty as the "uncertainty trinity" with major financial and economic impacts. "Uncertainty" and "risk" are different, as "uncertainty" cannot be quantified while "risk" is measurable using probabilities, either subjective or physical. Since 1921, economists have debated and modeled this issue. However, the macroeconomics literature muddles this distinction, and explicitly measures "uncertainty" by developing indices described in the text, which most likely also capture some parts of "risk" [7].

Asset prices reflect investors' hopes and fears for the future and generate a tidal wave of activity. In an uncertain and risky environment, investors search for other safe heavens and withdraw their investments, thereby adversely affecting markets. GPR immediately affects the financial and commodity markets by increasing the risk aversion of investors, consumers and firms, which leads to lower consumption and investments, triggering economic slowdown and spilling over to other alternative markets. Furthermore, due to psychological fear, ambiguity, and the desire to avoid future loss, individual investors become reluctant to trade, which negatively affects financial markets [7]. Despite this, there is a lack of literature on the impact of GPR on financial markets because of the difficulty in measuring GPR. Some studies examined the impact of GPR on stock markets [8][9][10], cryptocurrencies [11][12], metals [13][14], energies [15][16], and oil markets [4][17][18][19].

Despite the development of electric cars, renewable-energy production, and ambitious climate goals, the oil market is still regarded as the lifeblood of the world's economic engine [20], meeting around two-thirds of the global energy demand [21]. For this reason, a large body of literature has investigated oil markets from various perspectives, such as the pricing formation [22][23][24], the relationship with the macroeconomy [25][26][27], interlinkages with stock markets [28][29], financialization [30][31], forecasting [32][33] or multifractal characteristics [34][35], among others. The crude-oil market is extraordinarily large and complicated. According to the Crude Oil Global Market Report 2020 (https://www.thebusinessresearchcompany.com/report/crude-oil-global-market-report#:~:text=Crude%20Oil%20Market%20Size,1.2%25%20during%20the%20forecast%20period (accessed on 19 April 2022)) and Natural Gas Global Market Report 2020 (https://www.thebusinessresearchcompany.com/report/natural-gas-global-market-report#:~:text=Natural%20Gas%20Market%20Size,7.7%25%20during%20the%20forecast%20period (accessed on 19 April 2022)), the crude-oil and natural-gas markets are expected to reach market values of about $1407.65 billion and $1031.55 billion by 2022, respectively. It is the geopolitical aspect which distinguishes crude-oil markets from other energies, commodities, and financial assets. Heating oil, on the other hand, commonly known as No. 2 fuel oil, accounts for around 25% of a barrel's yield and had a market value of $163.3 billion in 2019 (https://www.verifiedmarketresearch.com/product/fuel-oil-market/ (accessed on 19 April 2022)).

The consumption of oil, natural gas and coal increases carbon emissions, which represents a barrier to sustainable economic development and contributes to the creation of new geopolitical conditions. For example, GPR can reduce carbon emissions by limiting economic growth and energy consumption. On other hand, it may deter innovation and clean energy and result in increased carbon emissions [36]. Therefore, oil-related issues should be widely investigated from a geopolitical perspective, as governments frequently regard crude oil as a political weapon [37]. Even though oil prices have recovered from historic lows in 2014 and 2015, recent volatility fueled by the Russians, Iran sanctions, United States (US) and China conflicts, and the recent shale revolution has left many concerned, and it shows no signs of easing. This means that GPR has an impact on economic aspects including oil price, production, resource mobility, demand and supply, extraction costs, exchange rates and other alternative investments. A large imbalance could occur if supply channels are blocked or demand collapses due to economic shutdowns triggered by unrest, as happened during the recent COVID-19 pandemic.

Other major energy markets such as natural gas are also prone to geopolitical risk. Russia is one of the world's main producers of primary energy resources, with a particularly strong position in global gas markets [38]. It has the world's largest gas reserves and is the world's second-largest gas producer, trailing only the US, which recently overtook Russia due to the shale revolution [39]. Most Russian gas exports go to European and Commonwealth of Independent States (CIS) countries, while Asian exports are likely to grow significantly in the future (https://scholarship.rice.edu/bitstream/handle/1911/91291/CES-pub-GeoGasRussiax-022114.pdf?sequence=1 (accessed on 19 April 2022)). As a result, Russia wields huge influence over prices and geopolitical leverage as well as on the "rules of the game". Along with oil, natural gas is also being used as a key geopolitical weapon. Therefore, the importance of the natural-gas industry for the current and future political and economic situation should not be overlooked. However, the relationship between geopolitical-risk indicators and natural gas has been largely ignored in previous studies. Natural gas is not only the energy sector's backbone, but also one of the most important national and foreign policy tools, being greatly influenced by domestic economic and political events.

GPR's connection with other commodity markets has been studied via numerous analytical methods. These include the fixed-effect regression model [40], random-effect regression model [41], quantile regression [42][43], linear and non-linear probabilistic models and feasible generalized least-square estimator [44][45], time–frequency-based wavelet analysis [46], decomposition and the STVAR model [47] or Bayesian graphical structural VAR [48], among others. However, multifractal aspects of GPR with energies as well as other financial markets have been largely ignored in these studies.

Since their popularization by the Polish-born mathematician Mandelbrot [49], the idea of fractals has roused curiosity and has now been applied in various fields to examine the self-similarity and Hausdorff dimension of an object [50]. Mandelbrot [51] used fractals to study the behavior of cotton prices and discovered that commodity prices follow self-similar complicated patterns rather than being random. Primarily, there are two types of fractal-based methodologies, i.e., mono-fractal and multifractality. The anti-persistent or persistent behavior, also known as long-memory features, were mainly studied by mono-fractals. However, scholars later found that financial markets have complex multi-scale properties, which present a challenge for mono-fractality. Multifractality, according to Mandelbrot [52], may quantify the complexity of financial time series better than mono-fractality and it has a wider use in empirical studies such as physics [53][54], chemistry [55][56] (10–11), biology [57][58], hydrology [59], environment [60], linguistics [61], physiology [62], psychology [63][64], behavioral sciences [65] economics [66] and even in music [67].

At the same time, several researchers recognize multifractality in energy markets as a stylized fact [68]. Multifractal dynamics, for example, give a new model with appealing stochastic qualities that can reproduce some stylized facts including volatility clustering, fat tails, multi-scaling, and long-term dependence [69]. However, the combinatorial character of older versions of multifractal models, as well as their non-stationarity due to the constraint to a finite interval, limit their practical application. The pioneer methodologies involved rescaled range analysis (R/S) [70] and detrended fluctuation analysis (DFA) [71] for mono-fractality. However, R/S is prone to causing the bias error because of its vulnerability to short-range dependence (Lo, [72]). Hence, DFA compared to R/S and other above-mentioned methodologies has the benefit of long-range correlation detection in non-stationary time series. Furthermore, it eliminates the spurious analysis of long-range correlations, which is a non-stationary artifact [73].

Later, an extension of the DFA, i.e., multifractal detrended fluctuation analysis (MFDFA) by Kantelhardt, et al. [74] was derived, and this has been employed to examine the multifractality of various financial time series such as crude oil [75], stock markets [76][77][78], cryptocurrencies [79], and even sin markets [80]. Meanwhile, based on the concept of the DFA, Podobnik, et al. [81] developed the detrended cross-correlation analysis (DCCA) to examine the long-range cross-correlations between two non-stationary time series, which has been applied to various analyses [82][83]. However, it is easy to obtain λ as a scaling exponent in the case of the DCCA, but it lacks complete interpretation and severely distorts or even spuriously amplifies multifractal cross-correlation measures. To overcome this issue, Zhou [84] proposed the multifractal detrended cross-correlation analysis (MF-DCCA) by combining the DCCA and MFDFA, which has lately become popular [85][86][87]. The MF-DCCA approach can detect and quantify subtle features of multifractal cross-correlations between two financial time series. Furthermore, the multifractal spectrum analysis in the MF-DCCA quantifies the multifractal intensity of cross-correlations and explains the time series' internal complexity and local properties.

Understanding the relationship and the role of geopolitical risk in asset prices is important for investors, companies, and government policymakers, in order to incorporate the magnitude of geopolitical risk into the valuation of asset prices and risk insurance, as well as to support markets in effectively absorbing the impacts of such risks.

2. Geopolitical Risk

The pioneering literature on GPR was based on individual geopolitical events [88][89][90]. However, after the recent development of the novel GPR index, a new stream of literature has investigated its impact on stock markets, exchange rates, renewable energy markets and energy markets. For instance, Yang and Yang [9] employed the monthly GPR index for stock markets and found that GPR is significant enough to capture the long and medium-term trends of stock markets. Similarly, Yang, et al. [91] employed the GARCH-MIDAS and found that global and regional monthly GPR indices have a significant impact on Chinese stock markets. The monthly GPR index is also found to be the best predictor of Kuwaiti and Omani stock markets [45]. However, Das, et al. [92] and Kannadhasan and Das [93] found that GPR has a less negative impact than Economic Policy Uncertainty (EPU) on the stock markets of emerging countries. Likewise, GPR is a major long run driver for the exchange rate of ASEAN countries [94] as well as the exchange rates of the UK, Republic of Korea, Japan, China and Canada [95]. Yang, Wei, Li and He [15] employed delta conditional Value-at-Risk techniques and found that the geopolitical-risk spillover to renewable energy markets is much smaller than that from equity and oil markets. The major shortcoming in previous literature is that most of it focused either on individual geopolitical events or the monthly frequency of the GPR indices, where major geopolitical events could be missed [1].

The literature on GPR in energy markets deals mostly with the crude-oil market rather than other energy markets. For instance, Antonakakis, et al. [96] employ the VAR-BEKK-GARCH model and find that GPR has a severe impact on the mean return and variability of oil markets compared to stock markets. Similarly, using nonlinear Granger causality tests and a DCC-MVGARCH model, Huang, et al. [97] find that the impact of GPR on the volatility of oil through the jump component is higher than its returns. While the correlation between volatility jumps and GPR seems to be positive, Mei, Ma, Liao and Wang [98] report that GPR is positively linked with the realized volatility of oil and can be used to predict the short-term volatility of oil futures. Liu, Ma, Tang and Zhang [17] proposed a new model, GARCH-MIDAS-GPR, which uses GPR and serious GPR to forecast the volatility of oil futures in order to gain higher economic gains. Despite a great number of empirical studies on the relationship between GPR and energy markets, the multifractal dimension of GPR with energies is mostly overlooked.

In addition, for better policy making, it is important for policy makers, and market participants to have extensive knowledge about the different impact of geopolitical acts and threats on financial markets. However, only a few studies have examined this. For instance, Bouoiyour, Selmi, Hammoudeh and Wohar [5] separate the shocks and find that the impact of geopolitical threats on oil price dynamics is moderate or non-significant while the impact of geopolitical acts is stronger and positive. Geopolitical acts, as opposed to threats, help to forecast the long-term volatility of oil markets [98]. Likewise, Salisu, Pierdzioch and Gupta [4] report that geopolitical acts decrease tail risk at longer forecasting horizons in oil markets, while threats increase tail risk. Hence, geopolitical threats are the major predictors of oil markets' tail risk.

Society's survival and advancement depends on energy, which can be seen as a key driver of global economic expansion [99][100]. Energy plays an important role in any country's development [101]. There has been a rise in the amount of energy consumed as a percentage of world consumption. Energy price stability has become a major concern for many countries because of the importance of energy for economic growth. However, because of its scarcity, vital strategy, the geographical dispersion of supply and demand, and low price elasticity of demand, the price of energy is particularly susceptible to geopolitical risk [18]. Consequently, it is important to study the impact of geopolitical risk on the energy market.

The current literature has focused primarily on the relationship between GPR and oil markets and ignored other energy markets such as natural gas and heating oil. Researchers could only find the study by Qin, et al. [102], who examined the relationship between GPR indices and energy markets of crude oil as well as natural gas and heating oil by using the quantile regression approach. These authors found no significant impact of GPR on natural gas, while the impact of GPR on heating oil and crude oil seems to be negatively significant. Geopolitical threats, compared to acts, have a statistically negative impact on the volatility of heating oil and natural gas in various quantiles. In a recent study, Aloui and Hamida [103] demonstrate the relevance of geopolitical risk in the oil-stock nexus in a time-frequency domain. The authors applied the wavelet coherence method to show that geopolitical risk weakens oil-stock connectedness in the short term and lowers the oil-stock magnitude and volatility correlation. Similarly, Bouri, et al. [104] used logistic regressions to conclude that Bitcoin jumps are dependent on jumps in the geopolitical-risk index.

Other studies on the relationship of GPR focus on precious metals [13][14], gold [105], corporate cash holdings [106], corporate investments [107], financial constraints [108], insurance [109], merger and acquisition [110], natural resource rents [111], tourism [112] and others.

References

1. Caldara, D.; Iacoviello, M. Measuring Geopolitical Risk. Am. Econ. Rev. 2022, 112, 1194–1225.
2. Legrenzi, G.; Heinlein, R.; Mahadeo, S. Ukraine and the Financial Markets: The Winners and Losers so Far. 2022. Available online: https://researchportal.port.ac.uk/en/publications/ukraine-and-financial-markets-the-winners-and-losers-so-far (accessed on 4 March 2022).
3. Moritsch, S. The Geopolitical Impact of the Conflict in Ukraine. 2022. Available online: https://home.kpmg/xx/en/home/insights/2022/03/the-geopolitical-impact-of-the-conflict-in-

ukraine.html (accessed on 4 March 2022).

4. Salisu, A.A.; Pierdzioch, C.; Gupta, R. Geopolitical risk and forecastability of tail risk in the oil market: Evidence from over a century of monthly data. Energy 2021, 235, 121333.
5. Bouoiyour, J.; Selmi, R.; Hammoudeh, S.; Wohar, M.E. What are the categories of geopolitical risks that could drive oil prices higher? Acts or threats? Energy Econ. 2019, 84, 104523.
6. Carney, M. Uncertainty, the Economy and Policy; Bank of England: London, UK, 2016; Available online: https://www.bis.org/review/r160704c.pdf (accessed on 4 March 2022).
7. Levy, O.; Galili, I. Terror and trade of individual investors. J. Socio-Econ. 2006, 35, 980–991.
8. Sharif, A.; Aloui, C.; Yarovaya, L. COVID-19 pandemic, oil prices, stock market, geopolitical risk and policy uncertainty nexus in the US economy: Fresh evidence from the wavelet-based approach. Int. Rev. Financ. Anal. 2020, 70, 101496.
9. Yang, J.; Yang, C. The impact of mixed-frequency geopolitical risk on stock market returns. Econ. Anal. Policy 2021, 72, 226–240.
10. Aslam, F.; Kang, H.-G. How different terrorist attacks affect stock markets. Def. Peace Econ. 2015, 26, 634–648.
11. Kyriazis, N.A. The effects of geopolitical uncertainty on cryptocurrencies and other financial assets. SN Bus. Econ. 2021, 1, 1–14.
12. Colon, F.; Kim, C.; Kim, H.; Kim, W. The effect of political and economic uncertainty on the cryptocurrency market. Financ. Res. Lett. 2021, 39, 101621.
13. Baur, D.G.; Smales, L.A. Hedging geopolitical risk with precious metals. J. Bank Financ. 2020, 117, 105823.
14. Yilanci, V.; Kilci, E.N. The role of economic policy uncertainty and geopolitical risk in predicting prices of precious metals: Evidence from a time-varying bootstrap causality test. Resour. Policy 2021, 72, 102039.
15. Yang, K.; Wei, Y.; Li, S.; He, J. Geopolitical risk and renewable energy stock markets: An insight from multiscale dynamic risk spillover. J. Clean. Prod. 2021, 279, 123429.
16. Alsagr, N.; van Hemmen, S. The impact of financial development and geopolitical risk on renewable energy consumption: Evidence from emerging markets. Environ. Sci. Pollut. Res. 2021, 28, 25906–25919.
17. Liu, J.; Ma, F.; Tang, Y.; Zhang, Y. Geopolitical risk and oil volatility: A new insight. Energy Econ. 2019, 84, 104548.
18. Su, C.-W.; Khan, K.; Tao, R.; Nicoleta-Claudia, M. Does geopolitical risk strengthen or depress oil prices and financial liquidity? Evidence from Saudi Arabia. Energy 2019, 187, 116003.

19. Lee, C.-C.; Lee, C.-C.; Li, Y.-Y. Oil price shocks, geopolitical risks, and green bond market dynamics. N. Am. J. Econ. Financ. 2021, 55, 101309.
20. Lang, K.; Auer, B.R. The economic and financial properties of crude oil: A review. N. Am. J. Econ. Financ. 2020, 52, 100914.
21. Karasu, S.; Altan, A.; Bekiros, S.; Ahmad, W. A new forecasting model with wrapper-based feature selection approach using multi-objective optimization technique for chaotic crude oil time series. Energy 2020, 212, 118750.
22. Peng, J.; Li, Z.; Drakeford, B.M. Dynamic characteristics of crude oil price fluctuation—From the perspective of crude oil price influence mechanism. Energies 2020, 13, 4465.
23. Khan, K.; Su, C.-W.; Umar, M.; Yue, X.-G. Do crude oil price bubbles occur? Resour. Policy 2021, 71, 101936.
24. Akdoğan, K. Fundamentals versus speculation in oil market: The role of asymmetries in price adjustment? Resour. Policy 2020, 67, 101653.
25. Faseli, O. The relationship between European Brent crude oil price development and US macroeconomy. Int. J. Res. Bus. Soc. Sci. 2020, 9, 80–87.
26. Lyu, Y.; Tuo, S.; Wei, Y.; Yang, M. Time-varying effects of global economic policy uncertainty shocks on crude oil price volatility: New evidence. Resour. Policy 2021, 70, 101943.
27. Gong, X.; Wang, M.; Shao, L. The impact of macro economy on the oil price volatility from the perspective of mixing frequency. Int. J. Financ. Econ. 2020, 1–28.
28. Jiang, Z.; Yoon, S.-M. Dynamic co-movement between oil and stock markets in oil-importing and oil-exporting countries: Two types of wavelet analysis. Energy Econ. 2020, 90, 104835.
29. Alkathery, M.A.; Chaudhuri, K. Co-movement between oil price, CO2 emission, renewable energy and energy equities: Evidence from GCC countries. J. Environ. Manag. 2021, 297, 113350.
30. Tudor, C.; Anghel, A. The Financialization of Crude Oil Markets and Its Impact on Market Efficiency: Evidence from the Predictive Ability and Performance of Technical Trading Strategies. Energies 2021, 14, 4485.
31. Liu, P.; Vedenov, D.; Power, G.J. Commodity financialization and sector ETFs: Evidence from crude oil futures. Res. Int. Bus. Financ. 2020, 51, 101109.
32. Bredin, D.; O'Sullivan, C.; Spencer, S. Forecasting WTI crude oil futures returns: Does the term structure help? Energy Econ. 2021, 100, 105350.
33. Leng, N.; Li, J.-C. Forecasting the crude oil prices based on Econophysics and Bayesian approach. Phys. A Stat. Mech. Its Appl. 2020, 554, 124663.

34. Ghazani, M.M.; Khosravi, R. Multifractal detrended cross-correlation analysis on benchmark cryptocurrencies and crude oil prices. Phys. A Stat. Mech. Its Appl. 2020, 560, 125172.
35. Yao, C.-Z.; Liu, C.; Ju, W.-J. Multifractal analysis of the WTI crude oil market, US stock market and EPU. Phys. A Stat. Mech. Its Appl. 2020, 550, 124096.
36. Anser, M.K.; Syed, Q.R.; Apergis, N. Does geopolitical risk escalate CO2 emissions? Evidence from the BRICS countries. Environ. Sci. Pollut. Res. 2021, 28, 48011–48021.
37. Escribano, G.; Valdes, J. Oil prices: Governance failures and geopolitical consequences. Geopolitics 2017, 22, 693–718.
38. Kutcherov, V.; Morgunova, M.; Bessel, V.; Lopatin, A. Russian natural gas exports: An analysis of challenges and opportunities. Energy Strategy Rev. 2020, 30, 100511.
39. Umar, M.; Su, C.H.; Rizvi, S.; Lobont, O.R. Driven by fundamentals or exploded by emotions: Detecting bubbles in oil prices. Energy 2021, 231, 120873.
40. Li, F.; Yang, C.; Li, Z.; Failler, P. Does Geopolitics Have an Impact on Energy Trade? Empirical Research on Emerging Countries. Sustainability 2021, 13, 5199.
41. Alsagr, N.; Almazor, S.F.V.H. Oil rent, geopolitical risk and banking sector performance. Int. J. Energy Econ. Policy 2020, 10, 305.
42. Gkillas, K.; Gupta, R.; Pierdzioch, C. Forecasting realized gold volatility: Is there a role of geopolitical risks? Financ. Res. Lett. 2020, 35, 101280.
43. Das, D.; Kannadhasan, M.; Bhowmik, P. Geopolitical risk and precious metals. J. Econ. Res. 2019, 24, 49–66.
44. Plakandaras, V.; Gupta, R.; Wong, W.-K. Point and density forecasts of oil returns: The role of geopolitical risks. Resour. Policy 2019, 62, 580–587.
45. Alqahtani, A.; Bouri, E.; Vo, X.V. Predictability of GCC stock returns: The role of geopolitical risk and crude oil returns. Econ. Anal. Policy 2020, 68, 239–249.
46. Uddin, G.S.; Bekiros, S.; Ahmed, A. The nexus between geopolitical uncertainty and crude oil markets: An entropy-based wavelet analysis. Phys. A Stat. Mech. Appl. 2018, 495, 30–39.
47. Ding, Z.; Zhang, X. The Impact of Geopolitical Risk on Systemic Risk Spillover in Commodity Market: An EMD-Based Network Topology Approach. Complexity 2021, 2021, 2226944.
48. Bouri, E.; Gupta, R.; Hosseini, S.; Lau, C.K.M. Does global fear predict fear in BRICS stock markets? Evidence from a Bayesian Graphical Structural VAR model. Emerg. Mark. Rev. 2018, 34, 124–142.
49. Mandelbrot, B.B. The Fractal Geometry of Nature; WH Freeman: New York, NY, USA, 1982; Volume 1.

50. Leary, C.C.; Ruppe, D.A.; Hartvigsen, G. Fractals, average distance and the Cantor set. Fractals 2010, 18, 327–341.
51. Mandelbrot, B.B. The variation of the prices of cotton, wheat, and railroad stocks, and of some financial rates. In Fractals and Scaling in Finance; Springer: Berlin/Heidelberg, Germany, 1997; pp. 419–443.
52. Mandelbrot, B.B. The variation of certain speculative prices. In Fractals and Scaling in Finance; Springer: Berlin/Heidelberg, Germany, 1997; pp. 371–418.
53. Muzy, J.-F.; Bacry, E.; Baile, R.; Poggi, P. Uncovering latent singularities from multifractal scaling laws in mixed asymptotic regime. Application to turbulence. EPL (Europhys. Lett.) 2008, 82, 60007.
54. Subramaniam, A.R.; Gruzberg, I.A.; Ludwig, A.W. Boundary criticality and multifractality at the two-dimensional spin quantum Hall transition. Phys. Rev. B 2008, 78, 245105.
55. Stanley, H.E.; Meakin, P. Multifractal phenomena in physics and chemistry. Nature 1988, 335, 405–409.
56. Udovichenko, V.; Strizhak, P. Multifractal properties of copper sulfide film formed in self-organizing chemical system. Theor. Exp. Chem. 2002, 38, 259–262.
57. Rosas, A.; Nogueira Jr, E.; Fontanari, J.F. Multifractal analysis of DNA walks and trails. Phys. Rev. E 2002, 66, 061906.
58. Makowiec, D.; Dudkowska, A.; Gałaska, R.; Rynkiewicz, A. Multifractal estimates of monofractality in RR-heart series in power spectrum ranges. Phys. A Stat. Mech. Appl. 2009, 388, 3486–3502.
59. Telesca, L.; Lapenna, V.; Macchiato, M. Multifractal fluctuations in earthquake-related geoelectrical signals. New J. Phys. 2005, 7, 214.
60. Farjah, E. Proposing an Efficient Wind Forecasting Agent Using Adaptive MFDFA. J. Power Technol. 2019, 99, 152–162.
61. Drożdż, S.; Oświęcimka, P.; Kulig, A.; Kwapień, J.; Bazarnik, K.; Grabska-Gradzińska, I.; Rybicki, J.; Stanuszek, M. Quantifying origin and character of long-range correlations in narrative texts. Inf. Sci. 2016, 331, 32–44.
62. Nagy, Z.; Mukli, P.; Herman, P.; Eke, A. Decomposing multifractal crossovers. Front. Physiol. 2017, 8, 533.
63. Kelty-Stephen, D.G. Threading a multifractal social psychology through within-organism coordination to within-group interactions: A tale of coordination in three acts. Chaos Solitons Fractals 2017, 104, 363–370.

64. Stephen, D.G.; Hsu, W.-H.; Young, D.; Saltzman, E.L.; Holt, K.G.; Newman, D.J.; Weinberg, M.; Wood, R.J.; Nagpal, R.; Goldfield, E.C. Multifractal fluctuations in joint angles during infant spontaneous kicking reveal multiplicativity-driven coordination. Chaos Solitons Fractals 2012, 45, 1201–1219.
65. Ihlen, E.A.; Vereijken, B. Multifractal formalisms of human behavior. Hum. Mov. Sci. 2013, 32, 633–651.
66. Drożdż, S.; Kwapień, J.; Oświęcimka, P.; Rak, R. The foreign exchange market: Return distributions, multifractality, anomalous multifractality and the Epps effect. New J. Phys. 2010, 12, 105003.
67. Jafari, G.; Pedram, P.; Hedayatifar, L. Long-range correlation and multifractality in Bach's inventions pitches. J. Stat. Mech. Theory Exp. 2007, 2007, P04012.
68. Ali, H.; Aslam, F.; Ferreira, P. Modeling Dynamic Multifractal Efficiency of US Electricity Market. Energies 2021, 14, 6145.
69. Barunik, J.; Aste, T.; Di Matteo, T.; Liu, R. Understanding the source of multifractality in financial markets. Phys. A Stat. Mech. Appl. 2012, 391, 4234–4251.
70. Hurst, H.E. Long-term storage capacity of reservoirs. Trans. Am. Soc. Civ. Eng. 1951, 116, 770–799.
71. Peng, C.-K.; Buldyrev, S.V.; Havlin, S.; Simons, M.; Stanley, H.E.; Goldberger, A.L. Mosaic organization of DNA nucleotides. Phys. Rev. E 1994, 49, 1685.
72. Lo, A.W. Long-term memory in stock market prices. Econom. J. Econom. Soc. 1991, 59, 1279–1313.
73. Green, E.; Hanan, W.; Heffernan, D. The origins of multifractality in financial time series and the effect of extreme events. Eur. Phys. J. B 2014, 87, 1–9.
74. Kantelhardt, J.W.; Zschiegner, S.A.; Koscielny-Bunde, E.; Havlin, S.; Bunde, A.; Stanley, H.E. Multifractal detrended fluctuation analysis of nonstationary time series. Phys. A Stat. Mech. Its Appl. 2002, 316, 87–114.
75. He, L.-Y.; Chen, S.-P. Are crude oil markets multifractal? Evidence from MF-DFA and MF-SSA perspectives. Phys. A Stat. Mech. Its Appl. 2010, 389, 3218–3229.
76. Aslam, F.; Ferreira, P.; Ali, H.; Kauser, S. Herding behavior during the COVID-19 pandemic: A comparison between Asian and European stock markets based on intraday multifractality. Eurasian Econ. Rev. 2021, 1–27.
77. Aslam, F.; Ferreira, P.; Mohti, W. Investigating Efficiency of Frontier Stock Markets using Multifractal Detrended Fluctuation Analysis. Int. J. Emerg. Mark. 2021, 1–27, ahead-of-print.

78. Aslam, F.; Ferreira, P.; Mughal, K.S.; Bashir, B. Intraday Volatility Spillovers among European Financial Markets during COVID-19. Int. J. Financ. Stud. 2021, 9, 5.
79. Mnif, E.; Jarboui, A.; Mouakhar, K. How the cryptocurrency market has performed during COVID-19? A multifractal analysis. Financ. Res. Lett. 2020, 36, 101647.
80. Aslam, F.; Ferreira, P.; Amjad, F.; Ali, H. The Efficiency of Sin Stocks: A Multifractal Analysis of Drug Indices. Singap. Econ. Rev. 2021, 1–22.
81. Podobnik, B.; Jiang, Z.-Q.; Zhou, W.-X.; Stanley, H.E. Statistical tests for power-law cross-correlated processes. Phys. Rev. E 2011, 84, 066118.
82. Ferreira, P.; Dionísio, A.; Zebende, G. Why does the Euro fail? The DCCA approach. Phys. A Stat. Mech. Appl. 2016, 443, 543–554.
83. Ferreira, P.J.S.; Dionísio, A. G7 stock markets: Who is the first to defeat the DCCA correlation? Rev. Socio-Econ. Perspect. 2016, 1, 107–120.
84. Zhou, W.-X. Multifractal detrended cross-correlation analysis for two nonstationary signals. Phys. Rev. E 2008, 77, 066211.
85. Devi, P.; Kumar, P.; Kumar, S. Multi-fractal detrended cross-correlation analysis (MFDCCA) approach to study effect of global crisis and demonetization on financial sector of India. Math.Eng. Sci. Aerosp. (MESA) 2021, 12, 601–614.
86. Gu, D.; Huang, J. Multifractal detrended cross-correlation analysis of high-frequency stock series based on ensemble empirical mode decomposition. Fractals 2020, 28, 2050035.
87. Aslam, F.; Bibi, R.; Ferreira, P. Cross-correlations between economic policy uncertainty and precious and industrial metals: A multifractal cross-correlation analysis. Resour. Policy 2022, 75, 102473.
88. Agnew, J. Geopolitics: Re-Visioning World Politics; Routledge: London, UK, 2002.
89. Kaplanski, G.; Levy, H. Sentiment and stock prices: The case of aviation disasters. J. Financ. Econ. 2010, 95, 174–201.
90. Hudson, R.; Urquhart, A. War and stock markets: The effect of World War Two on the British stock market. Int. Rev. Financ. Anal. 2015, 40, 166–177.
91. Yang, M.; Zhang, Q.; Yi, A.; Peng, P. Geopolitical risk and stock market volatility in emerging economies: Evidence from GARCH-MIDAS model. Discret. Dyn. Nat. Soc. 2021, 2021, 1159358.
92. Das, D.; Kannadhasan, M.; Bhattacharyya, M. Do the emerging stock markets react to international economic policy uncertainty, geopolitical risk and financial stress alike? N. Am. J. Econ. Financ. 2019, 48, 1–19.

93. Kannadhasan, M.; Das, D. Do Asian emerging stock markets react to international economic policy uncertainty and geopolitical risk alike? A quantile regression approach. Financ. Res. Lett. 2020, 34, 101276.
94. Hui, H.C. The long-run effects of geopolitical risk on foreign exchange markets: Evidence from some ASEAN countries. Int. J. Emerg. Mark. 2021.
95. Kisswani, K.M.; Elian, M.I. Analyzing the (a) symmetric impacts of oil price, economic policy uncertainty, and global geopolitical risk on exchange rate. J. Econ. Asymmetries 2021, 24, e00204.
96. Antonakakis, N.; Gupta, R.; Kollias, C.; Papadamou, S. Geopolitical risks and the oil-stock nexus over 1899–2016. Financ. Res. Lett. 2017, 23, 165–173.
97. Huang, J.; Ding, Q.; Zhang, H.; Guo, Y.; Suleman, M.T. Nonlinear dynamic correlation between geopolitical risk and oil prices: A study based on high-frequency data. Res. Int. Bus. Financ. 2021, 56, 101370.
98. Mei, D.; Ma, F.; Liao, Y.; Wang, L. Geopolitical risk uncertainty and oil future volatility: Evidence from MIDAS models. Energy Econ. 2020, 86, 104624.
99. Chen, G.; Wu, X. Energy overview for globalized world economy: Source, supply chain and sink. Renew. Sustain. Energy Rev. 2017, 69, 735–749.
100. Tian, M.; Li, W.; Wen, F. The dynamic impact of oil price shocks on the stock market and the USD/RMB exchange rate: Evidence from implied volatility indices. N. Am. J. Econ. Financ. 2021, 55, 101310.
101. Chen, J.; Zhu, X. The effects of different types of oil price shocks on industrial PPI: Evidence from 36 sub-industries in China. Emerg. Mark. Financ. Trade 2021, 57, 3411–3434.
102. Qin, Y.; Hong, K.; Chen, J.; Zhang, Z. Asymmetric effects of geopolitical risks on energy returns and volatility under different market conditions. Energy Econ. 2020, 90, 104851.
103. Aloui, C.; Hamida, H.B. Oil-stock Nexus in an Oil-rich Country: Does Geopolitical Risk Matter in Terms of Investment Horizons? Def. Peace Econ. 2021, 32, 468–488.
104. Bouri, E.; Gupta, R.; Vo, X.V. Jumps in Geopolitical Risk and the Cryptocurrency Market: The Singularity of Bitcoin. Def. Peace Econ. 2020, 33, 150–161.
105. Triki, M.B.; Maatoug, A.B. The GOLD market as a safe haven against the stock market uncertainty: Evidence from geopolitical risk. Resour. Policy 2021, 70, 101872.
106. Kotcharin, S.; Maneenop, S. Geopolitical risk and corporate cash holdings in the shipping industry. Transp. Res. Part E Logist. Transp. Rev. 2020, 136, 101862.

107. Le, A.-T.; Tran, T.P. Does geopolitical risk matter for corporate investment? Evidence from emerging countries in Asia. J. Multinatl. Financ. Manag. 2021, 62, 100703.

108. Lee, C.-C.; Wang, C.-W. Firms' cash reserve, financial constraint, and geopolitical risk. Pac.-Basin Financ. J. 2021, 65, 101480.

109. Lee, C.-C.; Lee, C.-C. Insurance activity, real output, and geopolitical risk: Fresh evidence from BRICS. Econ. Model. 2020, 92, 207–215.

110. Shen, H.; Liang, Y.; Li, H.; Liu, J.; Lu, G. Does geopolitical risk promote mergers and acquisitions of listed companies in energy and electric power industries. Energy Econ. 2021, 95, 105115.

111. Dogan, E.; Majeed, M.T.; Luni, T. Analyzing the impacts of geopolitical risk and economic uncertainty on natural resources rents. Resour. Policy 2021, 72, 102056.

112. Baek, S.; Lee, K.Y. The risk transmission of COVID-19 in the US stock market. Appl. Econ. 2021, 53, 1976–1990.