“Quantile-based analysis of geopolitical risk spillovers across sustainable finance, energy markets, precious metals, and FinTech”

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QUANTILE-BASED ANALYSIS OF GEOPOLITICAL RISK SPILLOVERS ACROSS SUSTAINABLE FINANCE, ENERGY MARKETS, PRECIOUS METALS, AND FINTECH

Abstract

This study aims to investigate how geopolitical risk shocks influence return dynamics, volatility transmission, and hedging properties across sustainable financial assets, financial technology instruments, energy markets, and precious metals during major global crisis episodes over a daily period from June 15, 2018, to September 14, 2024. We examined three major events: the trade conflict between the United States and China from June 15, 2018, to November 30, 2019; the COVID-19 pandemic from December 22, 2019, to February 23, 2023; and the ongoing wars between Russia and Ukraine, as well as Hamas and Israel, from February 24 to September 14, 2024. We found anomalies explained by the volatility of these returns. Using static, dynamic, and fractional QVAR methodology, we concluded that gold and two indicators of green finance can be considered safe-haven assets and hedging instruments, while FinTech plays a stabilizing role during these crises. Spillovers and connectivity networks at the median quantile validate the negative impact of geopolitical risk on non-renewable energy. However, we observed that the geopolitical risk index does not significantly affect green finance indicators, eco-friendly cryptocurrencies, or various measures of FinTech, with a low sensitivity of this index to gold prices.

Keywords green finance, geopolitical risk, eco-friendly cryptocurrencies, FinTech, clean energy, QVAR fractional technique

JEL Classification G10, G01

INTRODUCTION

The rapid industrial growth and increasing reliance on fossil fuels led to considerable environmental challenges in recent decades, placing an extraordinary strain on the planet's ecosystems. In the face of this ecological crisis, governments around the world are committing to an essential transition: a shift toward a more sustainable and environmentally friendly energy system. Achieving this ambitious goal requires urgent financing, particularly for "green" projects aimed at promoting sustainability, reducing pollution emissions, and boosting renewable energy production (Long et al., 2022; Su et al., 2022).

In this context, green bonds emerge as a crucial financial tool for mobilizing capital in support of environmental initiatives. By facilitating access to financing for environmental projects, green bonds play a key role in combating pollution and promoting sustainable technologies, thereby helping to overcome obstacles to funding for environmental management reforms (Arif et al., 2022; Rasoulinezhad et al., 2020; Imran & Ahad, 2023; Zhang et al., 2023b). However, the current dynamics of the

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green bond market face growing geopolitical tensions and regional conflicts, which create an atmosphere of uncertainty (Lee et al., 2021). This instability can undermine investor confidence and increase the risks associated with investments in the green sector. Indeed, geopolitical risk has become a determining factor that can influence economic slowdowns and cause fluctuations in financial markets, thereby compromising efforts to finance ecological initiatives (Lee et al., 2021; De Wet, 2023; Tang et al., 2023).

Green finance is referred to as a means to direct capital toward environmentally friendly initiatives, thereby supporting sustainable development goals while delivering environmental benefits. With the intensifying effects of climate change, promoting green finance has become crucial for channeling investments into sustainable projects and activities that mitigate these impacts. Recently, the significance of green finance and sustainable development in achieving the goals of the Paris Agreement has been widely acknowledged by both developed and developing countries. As a result, many governments have implemented regulations regarding financial instruments to encourage green development and meet sustainable development goals (Tolliver et al., 2020).

The uncertainty generated by geopolitical risk prompts investors to reassess their strategies in financial markets. As a result, market participants pay close attention to the impact of geopolitical risk on asset prices. Green finance, which involves directing public and private funds toward environmentally friendly projects, plays a crucial role in promoting sustainable development (Zhang et al., 2023a). As a promising financial instrument, it offers both economic and environmental benefits (Long et al., 2022). However, geopolitical risk and uncertainty are complex factors that can hinder the growth of the green bond market (Alsagr et al., 2023; Caramichael & Rapp, 2022). Geopolitical events and conflicts create uncertainties and fluctuations in financial markets (Iyke et al., 2022; Gong & Xu, 2022). Furthermore, geopolitical risk can significantly affect green investments. Fluctuations in oil prices, influenced by geopolitical risks (Bouoiyour et al., 2019; Ivanovski & Hailemariam, 2022), reveal a strong co-movement between oil prices and renewable energy costs (A. Dutta & P. Dutta, 2022). Thus, it is plausible that geopolitical risk has a notable effect on sustainable development.

In this paper, we seek to address a fundamental question: What are the impacts of current geopolitical risks on green finance, financial technologies (FinTech), eco-friendly cryptocurrencies, non-renewable energies, and precious metals? We specifically examine the trade conflict between the United States and China, the COVID-19 pandemic, as well as ongoing conflicts between Russia and Ukraine and between Hamas and Israel.

1. LITERATURE REVIEW

In recent years, scholarly interest in the relationship between geopolitical risk and green finance has intensified considerably, reflecting growing awareness of the profound influence of geopolitical dynamics on sustainable financial systems. Sustainable financial markets operate within a global environment increasingly shaped by political instability, military conflicts, pandemics, trade disputes, and policy uncertainty. These forces affect investor expectations, capital allocation, regulatory stability, and long-term environmental investment decisions, making geopolitical risk a structural determinant of financial and ecological transitions.

A substantial body of literature confirms that geopolitical uncertainty plays a critical role in shaping investor behavior, market volatility, and the long-term viability of green financial instruments, particularly green bonds and renewable energy investments (Zhang et al., 2023b; Wang et al., 2023; Tang et al., 2023; Ahmed et al., 2025). Geopolitical conflicts, diplomatic tensions, and policy disruptions increase perceived investment risk, delay renewable energy projects, and weaken confidence in green financial assets by introducing uncertainty regarding regulatory stability and future cash flows. Empirical evidence demonstrates that this influence is not uniform over time, as temporal heterogeneity characterizes the interaction between geopolitical risk and sustainable finance. Geopolitical shocks exert persistent and pronounced effects on volatility, while return responses remain more moderate, highlighting the dominant role of geopolitical instability in driving market fragility rather than immediate profitability (Zhang et al., 2023c). Nonlinear and asymmetric adjustments further emerge, where increases in policy uncertainty and geopolitical actions depress green bond returns in the short run, whereas geopolitical threats and oil price increases may generate temporary supportive effects; in the long run, however, most geopolitical risk components exert negative pressures on green financial performance (Tang et al., 2023).

Research also emphasizes deep interconnectedness among global financial and energy markets under geopolitical stress. Volatility spillovers from oil markets to green bonds intensify during crisis periods, accompanied by strong bidirectional causality between green bonds and commodity markets (Doğan et al., 2023). At the global level, geopolitical turmoil and financial stress generate long-term negative effects on green finance, whereas oil price volatility and clean energy investment stimulate green investment (Wang et al., 2023). Time-varying causality further reveals that heightened geopolitical tensions reduce investor interest in green bonds, while declining geopolitical risk promotes international cooperation in renewable energy development; however, competition over renewable resources may itself become a new source of geopolitical tension (Wang et al., 2023). The role of green finance in accelerating renewable energy development is particularly evident in emerging economies such as China (Li & Umair, 2023).

Another key research direction concerns safe-haven and hedging characteristics. Green bonds display resistance to geopolitical shocks compared with equities and currencies and show connectivity with traditional safe-haven assets (Będowska-Sójka et al., 2022; Rao et al., 2022). During turbulent periods such as the COVID-19 crisis, green bonds provided hedging benefits for equity investors, though short-term volatility dominated long-run adjustments (Mensi et al., 2023). Safe-haven effectiveness nevertheless varies across market regimes and quantiles, as geopolitical risk can simultaneously function as a source of investor anxiety and a trigger for portfolio rebalancing toward sustainable assets (Liu et al., 2024).

Recent geopolitical conflicts have amplified these dynamics. The Russia–Ukraine war and other conflicts have intensified fluctuations in green bond markets and reinforced the dominant role of geopolitical hazards in transmitting shocks from climate change concerns to sustainable finance and renewable energy markets (Ahmed et al., 2025; Gök, 2023; Lorente et al., 2023). The environmental dimension further strengthens this nexus: geopolitical risk and crude oil prices have been identified as key drivers of global CO_2 emissions, while green bonds exert stronger environmental influence in the long term than in the short term (Kartal et al., 2024). Political tensions also negatively affect green equity markets across quantiles and time horizons, confirming the sensitivity of sustainable assets to political disturbances (Cheikh & Zaied, 2023a, 2023b; Helmi et al., 2024).

Parallel developments in financial technology add further complexity. FinTech positively influences clean energy valuations and financial inclusion, yet FinTech markets are highly sensitive to geopolitical and financial stress (Dong & Huang, 2024; Doostkouei et al., 2024). Technology-oriented financial instruments may act as crisis-time shock transmitters while also providing long-term stabilization (Ha, 2023a; 2023b). Oil price fluctuations driven by geopolitical tensions further reinforce the co-movement between energy markets and sustainable finance (Bouoiyour et al., 2019; Ivanovski & Hailemariam, 2022; A. Dutta & P. Dutta, 2022).

Despite substantial progress, existing studies largely focus on bilateral relationships and specific contexts. Integrated analyses that simultaneously incorporate green bonds, renewable and non-renewable energy markets, FinTech, eco-friendly cryptocurrencies, precious metals, and geopolitical risk within a unified dynamic framework remain limited (Doğan et al., 2023; Wang et al., 2023; Cheikh & Zaied, 2023b; Dong & Huang, 2024). This fragmentation leaves a gap in understanding the joint, nonlinear, and crisis-dependent behavior of these interconnected markets under contemporary geopolitical regimes.

The accumulated evidence demonstrates that geopolitical risk is a fundamental structural force shaping green finance, renewable energy investment, financial stability, and environmental sus-

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tainability. Its effects are nonlinear, asymmetric, time-varying, and crisis-sensitive, while sustainable assets and FinTech provide only partial buffering capacity. Addressing these complexities requires integrated empirical frameworks capable of capturing the full scope of geopolitical–financial–environmental interactions.

This study aims to rigorously assess the extent to which geopolitical risk shocks shape return distributions, volatility spillovers, and safe-haven and hedging dynamics across green finance assets, FinTech instruments, eco-friendly cryptocurrencies, non-renewable energy markets, and precious metals during major global crisis periods. The hypotheses are as follows:

H1: *Geopolitical risk shocks significantly alter return distributions and increase volatility spillovers across green finance, FinTech, eco-friendly cryptocurrencies, non-renewable energy markets, and precious metals.*

H2: *Gold and green finance assets exhibit safe-haven and hedging characteristics during periods of heightened geopolitical risk.*

H3: *Market responses to geopolitical risk are nonlinear, asymmetric, and regime-dependent across the examined financial and energy assets.*

2. METHODS

This study analyzes the impact of major geopolitical and health-related events on green finance, FinTech, green cryptocurrencies, renewable and non-renewable energies, gold, and the geopolitical risk index over the daily period from June 15, 2018, to September 14, 2024. The dataset is divided into three sub-periods: (1) June 15, 2018 – November 30, 2019, covering the China–US trade conflict; (2) December 22, 2019 – February 23, 2023, covering the COVID-19 pandemic; and (3) February 24, 2022 – September 14, 2024, covering the Russia–Ukraine war and Hamas–Israel conflict.

2.1. Procedure

1. Data Collection:
   - Green finance: S&P Green Bond Index (S&PGBI) and S&P Global Clean Energy Index (S&PGCEI) from S&P Global;
   - FinTech: S&P Kensho Alternative Finance (S&PKGAFI), Distributed Ledger (S&PKGDGLI), and Bank Democratization (S&PKGDBI) indices from S&P Global;
   - Green cryptocurrencies: Cardano (ADA) and Tezos (XTZ) from Investing.com;
   - Non-renewable energy: Oil and gas prices from FRED;
   - Precious metals: Gold prices;
   - Geopolitical risk: GPR index.
2. Data Processing: Daily returns calculated
3. Preliminary Analysis: Descriptive statistics (mean, variance, skewness, kurtosis), stationarity tests (ERS, 1992), and autocorrelation tests (Ljung-Box Q(20) and $Q^2(20)$).
4. Interdependence Assessment: Total correlation matrices constructed for each sub-period to identify unconditional relationships among assets.
5. Spillover Analysis: Quantile Vector Auto-Regression (QVAR) at median quantile applied to capture dynamic spillovers and net connectedness among the studied assets, highlighting the influence of extreme market conditions.

This approach ensures a systematic, replicable, and concise framework for analyzing the effects of geopolitical and pandemic shocks on sustainable finance, FinTech, and energy markets.

The descriptive statistics reveal strong deviations from normality across all assets, as confirmed by extremely high Jarque-Bera statistics, driven by pronounced skewness and substantial excess kurtosis, indicating frequent extreme price movements. Volatility, measured by variance, rises sharply during crisis periods. All return series are found to be stationary, as confirmed by the ERS unit root test, supporting the validity of further econometric modeling. The Ljung-Box tests reveal significant serial correlation and volatility clustering, particularly during turbulent periods, confirming persistent risk transmission. Correlation analysis further shows that market interdependence intensifies under stress (Table A1 and Table A2 in Appendix A).

We use the quantile connectivity technique proposed by Ando et al. (2022) to explore the interconnections between green finance, the three FinTech indicators, eco-friendly cryptocurrencies, non-renewable energies, precious metal, and the geopolitical risk index. This technique extends the connectivity approach based on the general VAR model proposed by Diebold and Yilmaz (2012, 2014).

Various measures to assess connectivity have been described in the literature, including VAR, TVP-VAR, and LASSO-VAR. However, the key advantage of the QVAR model lies in its ability to elucidate spillover effects during extreme market conditions. Unlike the general VAR model, which focuses on conditional means and overlooks extreme connectivity, the QVAR captures the dynamic connectivity between variables across different quantiles, providing insights into tail behavior during bull and bear market phases (Long et al., 2022; Mensi et al., 2022).

The quantile spillover matrix and the infinite-order vector moving average representation of the Quantile Vector Auto-regression model QVAR(τ, ρ), where τ is the quantile and ρ denotes the autoregressive order, are defined as follows:

$$
\begin{aligned}
y_t &= \mu(\tau) + \sum_{j=1}^{p} \phi(\tau) y_{t-j} + \mu_i(\tau) \\
&= \mu(\tau) + \sum_{i=0}^{\infty} \Omega_i(\tau) \mu_{t-i},
\end{aligned} \tag{1}
$$

where: y_t is an n×1 vector of endogenous variables. μ(τ) is an n×1 vector of intercepts at quantile τ. *Φ_j(τ)* is an n×n matrix of lag coefficients at quantile τ for j = 1, ..., p. $\mu(\tau)$ is an n×1 vector of error terms at quantile τ. $\Omega_i(\tau)$ is an n×n matrix of moving average lag coefficients at quantile τ.

The Generalized Forecast Error Variance Decomposition (GFEVD), following Koop et al. (1996) and Pesaran and Shin (1998), defines the forecast horizon H as follows:

$$
\Theta_{ij}^{z}(H) = \frac{\Sigma(\tau)_{jj}^{-1} \sum_{h=0}^{H-1} (e_i' \Omega_h(\tau) \Sigma(\tau) e_j)^2}{\sum_{h=0}^{H-1} (e_i' \Omega_h(\tau) \Sigma(\tau) \Omega_n(\tau)' e_i)}, \tag{2}
$$

Here, e_i denotes a zero vector, with unitary value present in the "i" position. In the decomposition matrix, the normalization of the elements is represented as:

$$
\begin{aligned}
\bar{\Theta}_{(i,j)}^{\mathrm{E}}(H) &= \frac{\Theta_{ij}^{g}(H)}{\sum_{j-1}^{k} \Theta_{ij}^{\gamma}(H)}, \\
\text{with } \sum_{j=1}^{k} \bar{\Theta}_{ij}^{s} & \;\; and\, \bar{\Theta}_{ij}^{g}(H) = 1 .
\end{aligned} \tag{3}
$$

Consistent with the observations of Diebold and Yilmaz (2012), the GFEVD based spillover measures are described below.

$$
TO_{j,t} = \sum_{i=1, i \neq j}^{k} \bar{\Theta}_{i,j}^{g}(H), \tag{4}
$$

$$
FROM_{j,t} = \sum_{i=1, i \neq j}^{k} \bar{\Theta}_{j}^{g}(H), \tag{5}
$$

$$
NET_{j,t} = TO_{j,1} - FROM_{j,s}, \tag{6}
$$

$$
TCI_t = \frac{\sum_{i,j=1, j \neq j}^{k} \tilde{\Theta}_{i,j}^{\delta}(H)}{k-1} . \tag{7}
$$

This extended QVAR methodology is particularly advantageous for assessing spillover dynamics during extreme market conditions (both bullish and bearish) and provides a more nuanced understanding of interconnected markets.

The fractional connectivity approach with median quantiles allows for the analysis of how time series interact over the long term while focusing on the median effects of these interactions. This approach is particularly useful in studies that explore the persistence of shocks while remaining robust to extreme variability, as seen in financial market analysis.

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3. RESULTS AND DISCUSSION

This study investigates the statistical behavior and interdependence of green finance, FinTech, renewable and non-renewable energy, green cryptocurrencies, precious metals, and geopolitical risk over the period from June 15, 2018 to September 14, 2024, covering three major global shock episodes: the China–US trade conflict, the COVID-19 pandemic, and the combined Russia–Ukraine war and Hamas–Israel conflict.

The descriptive statistics reveal strong deviations from normality across all assets, as confirmed by extremely high Jarque-Bera statistics (e.g., S&PKGAFI = 99,232, Gold = 1,723, S&PGBI = 8,088 during COVID-19), driven by pronounced skewness and substantial excess kurtosis (e.g., Oil kurtosis = 30.64, S&PKGAFI kurtosis = 54.05, Gold kurtosis = 154.21 during the war period), indicating frequent extreme price movements.

Volatility, measured by variance, rises sharply during crisis periods, particularly for FinTech indices (S&PKGAFI = 25.95, S&PKGDGLI = 8.09 during COVID-19), green cryptocurrencies (ADA = 995.53, XTZ = 1,106.21 during COVID-19; XTZ = 31,556.41 during geopolitical conflicts), and gold (37.63 during the war period).

All return series are found to be stationary, as confirmed by the ERS unit root test with strongly negative statistics (e.g., ERS = −13.52 for S&PKGAFI during the war period), supporting the validity of further econometric modeling.

The Ljung-Box tests reveal significant serial correlation and volatility clustering, particularly during turbulent periods, with $Q^2(20)$ values reaching 293.75 for S&PGBI and 324.29 for S&PKGDBI during COVID-19, and exceeding 216.70 for gold during the war period, confirming persistent risk transmission.

Correlation analysis further shows that market interdependence intensifies under stress: during the trade conflict, clean energy exhibits strong linkages with FinTech (corr(S&PGCEI, S&PKGAFI) = 0.376, corr(S&PGCEI, S&PKGDBI) = 0.403), while during geopolitical conflicts, green bonds become increasingly integrated with sustainable and alternative finance (corr(S&PGBI, S&PKGDBI) = 0.233, corr(S&PGBI, S&PKGAFI) = 0.154).

Moreover, eco-friendly cryptocurrencies display persistent co-movement (corr (ADA, XTZ) = 0.210 during geopolitical conflicts) (Table A1 and Table A2 in Appendix A).

The spillovers of static returns during the conflict between the United States and China show that the S&P Green Bond Index (S&PGBI) captured the majority of incoming spillovers, reaching 84.22%. This indicates that the return of the S&PGBI is relatively stable and seems little influenced by other returns.

Additionally, the S&P Global Clean Energy Index (S&PGCEI) also shows significant spillovers of 50.61%, with notable interactions with other returns such as those from ADA and Gold. Meanwhile, the S&P Kensho Alternative Finance Global Index (S&PKGAFI) presents a notable contribution of 52% from its own returns, highlighting its dominant performance in the alternative finance sector.

The S&P Kensho Distributed Ledger Index (S&PKGDGLI) exhibits stability with 80.69% of its own spillovers, while the S&P Kensho Bank Democratization Index (S&PKGDBI) generates significant spillovers of 41.75%, indicating its influence across different markets.

Gold, with 63.79% of its own returns, proves to be a safe-haven asset during this period. Regarding eco-friendly cryptocurrencies, notably ADA and XTZ, they show high spillovers, particularly ADA with 76.91%, underscoring their growing importance in international markets.

Finally, non-renewable energies (oil and gas) demonstrate stability, with spillovers primarily concentrated on their own performance.

The spillovers of static returns during the COVID-19 pandemic showed that the S&PGBI experienced a decrease in its spillovers to 77.64%.

The S&PGCEI saw an increase in its own impact to 75.57%. The S&PKGAFI and S&PKGDGLI indicated some stability, but with a relatively lower impact on incoming returns.

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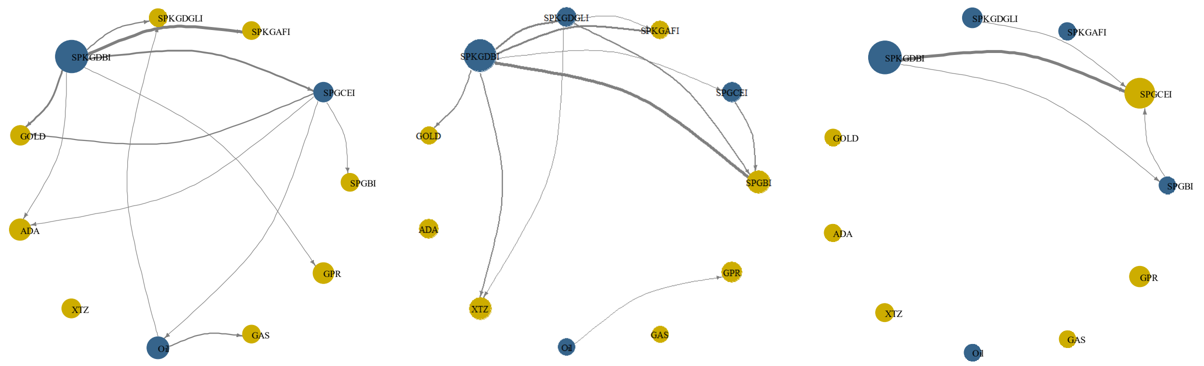

Figure 1. The directional connectivity networks at the median quantile of the three major events referred to in our study

Gold maintained a high level of spillovers (84.24%). ADA and XTZ demonstrated strong resilience, with 76.66% and 74.23% of their own returns, respectively.

The spillovers of static returns during the current geopolitical risks showed that the S&PGBI experienced a reduction in its spillovers to 76.09%.

The S&PGCEI saw a decrease in its impact to 69.93%. The S&PKGAFI maintained strong importance with 81.92%.

Gold remained one of the most stable assets at 81.69%. Eco-friendly cryptocurrencies, ADA and XTZ, also exhibited significant spillovers. Energy assets were dominated by their own performances but had lower incoming spillovers.

Finally, Table A3 shows that asset returns evolved in response to global events.

Following Mensi et al. (2022), Long et al. (2022), and Yousaf et al. (2022), Figure 1 illustrates the directional connectivity network at the median quantile between the returns of green finance, financial technologies, non-renewable energies, as well as precious metal, eco-friendly cryptocurrencies, and the geopolitical risk index.

Figure 1 reveals that during the international trade conflict between China and the United States, only three returns act as risk emitters: the Global Distributed Ledger Index (S&PKGDGLI), Clean Energy (S&PGCEI), and Oil prices.

During the COVID-19 pandemic, the Global Distributed Ledger Index (S&PKGDGLI), the Global Bank Democratization Index (S&PKGDBI), Clean Energy (S&PGCEI), and Oil prices become risk emitters.

The current geopolitical risks show that the Global Distributed Ledger Index (S&PKGDGLI), the Global Alternative Finance Index (S&PKGAFI), the Global Bank Democratization Index (S&PKGDBI), and Gree n Bonds (S&PGBI) act as risk emitters.

We now analyze the median quantile connectivity networks for three indicators of financial technology (FinTech), clean energy, the composite green bond index, non-renewable energies (oil and gas), precious metal (gold), two eco-friendly cryptocurrencies, and the geopolitical risk index.

In the context of the trade war between China and the United States, strong connections are observed between the Global Banking Democratization Index (S&PKGDBI) and the Global Alternative Financing Index (S&PKGAFI), as well as between the S&PKGDBI and the Clean Energy Index (S&PGCEI).

During the COVID-19 pandemic, the networks of connections are very high among the different returns.

During the two ongoing wars, the connection is weak between green cryptocurrencies, while strong dependence exists between the Global Democratic Index and the Global Distributed Ledger Index.

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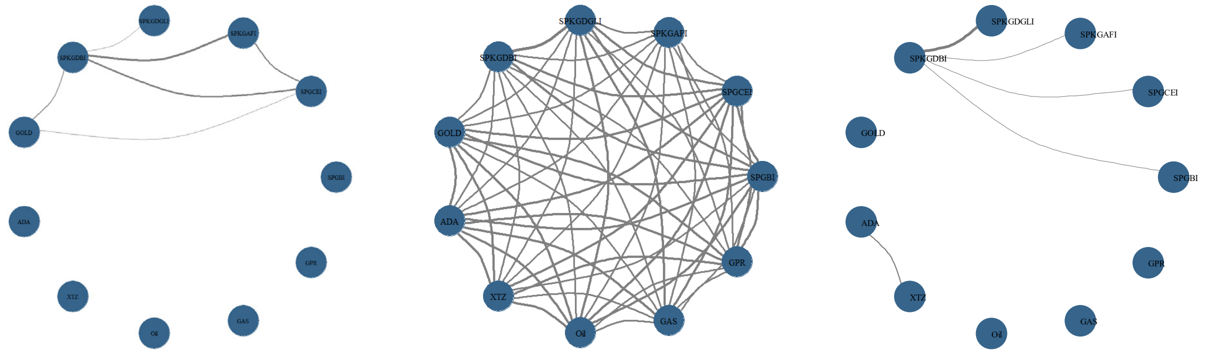

Figure 2. The median quantile connectivity networks of the three major events referred to in our study

The fractional connectivity approach with median quantiles allows for the analysis of how time series interact over the long term (through fractional connectivity) while focusing on the median effects of these interactions (median quantile). This approach is particularly useful in studies aiming to explore the persistence of shocks while remaining robust to extreme variability, as seen in financial market analysis. In analyzing financial returns, using fractional connectivity with quantiles captures not only the relationships between assets over the long term but also shows how these relationships behave for the majority of returns (median quantile) rather than focusing solely on extremes (high or low quantiles). It may reveal that shocks to certain assets propagate slowly, with a persistent impact over time, while for others, this effect is more temporary.

Figure 3.1 represents the fractional spillover effects between the various returns of FinTech, green finance, non-renewable energy, eco-friendly cryptocurrencies, precious metals, and geopolitical risk during the trade conflict between the United States and China. It captures how shocks or information spillovers from one asset market affect other markets. The spillovers can be positive or negative, influencing the connectivity between these markets. Figure 3.1 includes several layers of colors that represent different types of returns or asset classes. The red section occupies a large part of the figure, while the smaller green and blue sections indicate other asset classes. The spillover effects fluctuate slightly over time, suggesting that the overall connectivity remains constant throughout the observed period.

Figure 3.2 illustrates the fractional spillover effects between the returns of FinTech, green finance, non-renewable energy, eco-friendly cryptocurrencies, precious metal (gold), and geopolitical risk (GPR) during the COVID-19 pandemic. The different colored layers represent the respective contributions of these asset classes to the spillover effects between the markets. This pandemic generated increased volatility, thereby intensifying

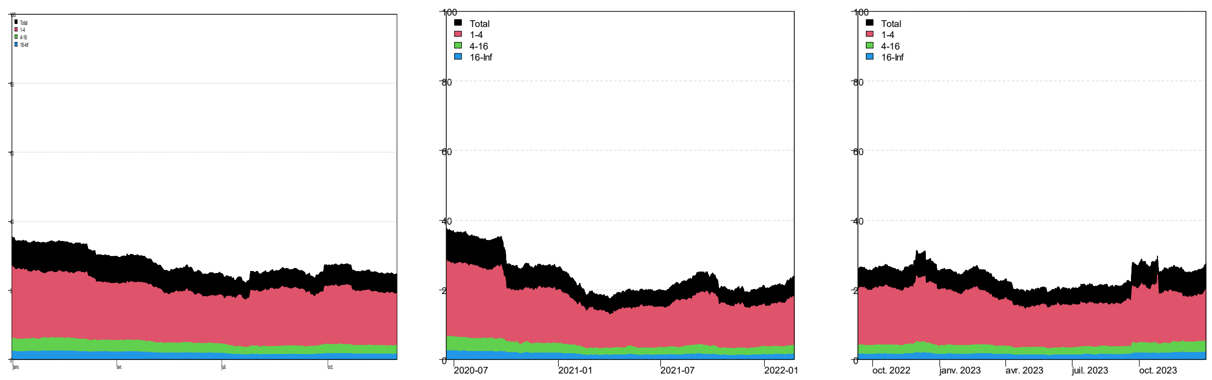

Figure 3. Various fractional spillovers of the three major events referred to in our study

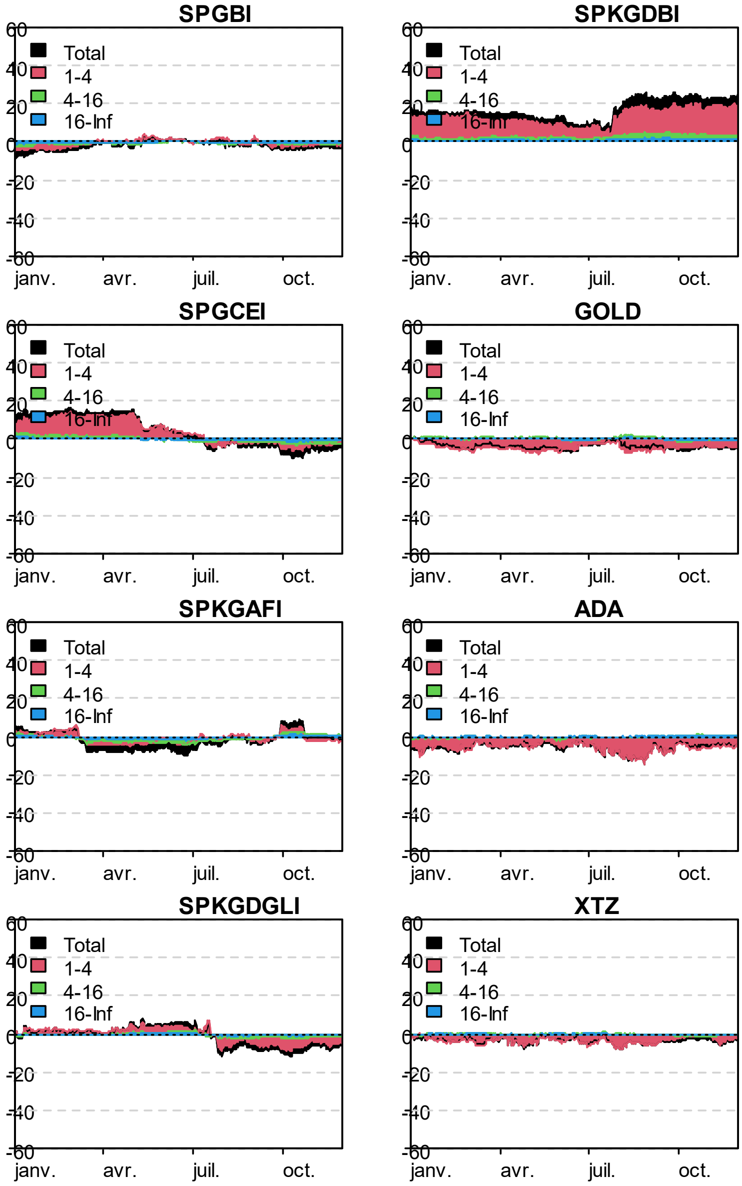

Figure 4. Fractional transmission of the shock caused by the trade conflict between US–China for the different returns referred to in our study

these spillovers. The predominance of one color suggests that certain indicators played a central role in the transmission of shocks and volatility between markets. The other asset classes had a more modest but consistent role.

Figure 3.3 represents the fractional spillover effects between the returns of FinTech, green finance, non-renewable energy, eco-friendly cryptocurrencies, precious metal (gold), and geopolitical risk (GPR) in the context of current geopolitical conflicts. The different colors represent the respective contributions of various asset classes to the spillover effects. The predominant color indicates that certain assets play a central role in transmitting shocks. Increased uncertainty during these conflicts heightens return volatility, leading to more pronounced spillovers between markets. Although fluctuations exist, the shape of the curves indicates a certain stability in the contributions of different assets to the spillover effects.

Figure 4 shows that FinTech returns appear relatively stable, with few significant fluctuations. Green finance is more varied. Returns from non-renewable energy fluctuate. Gold shows stability.

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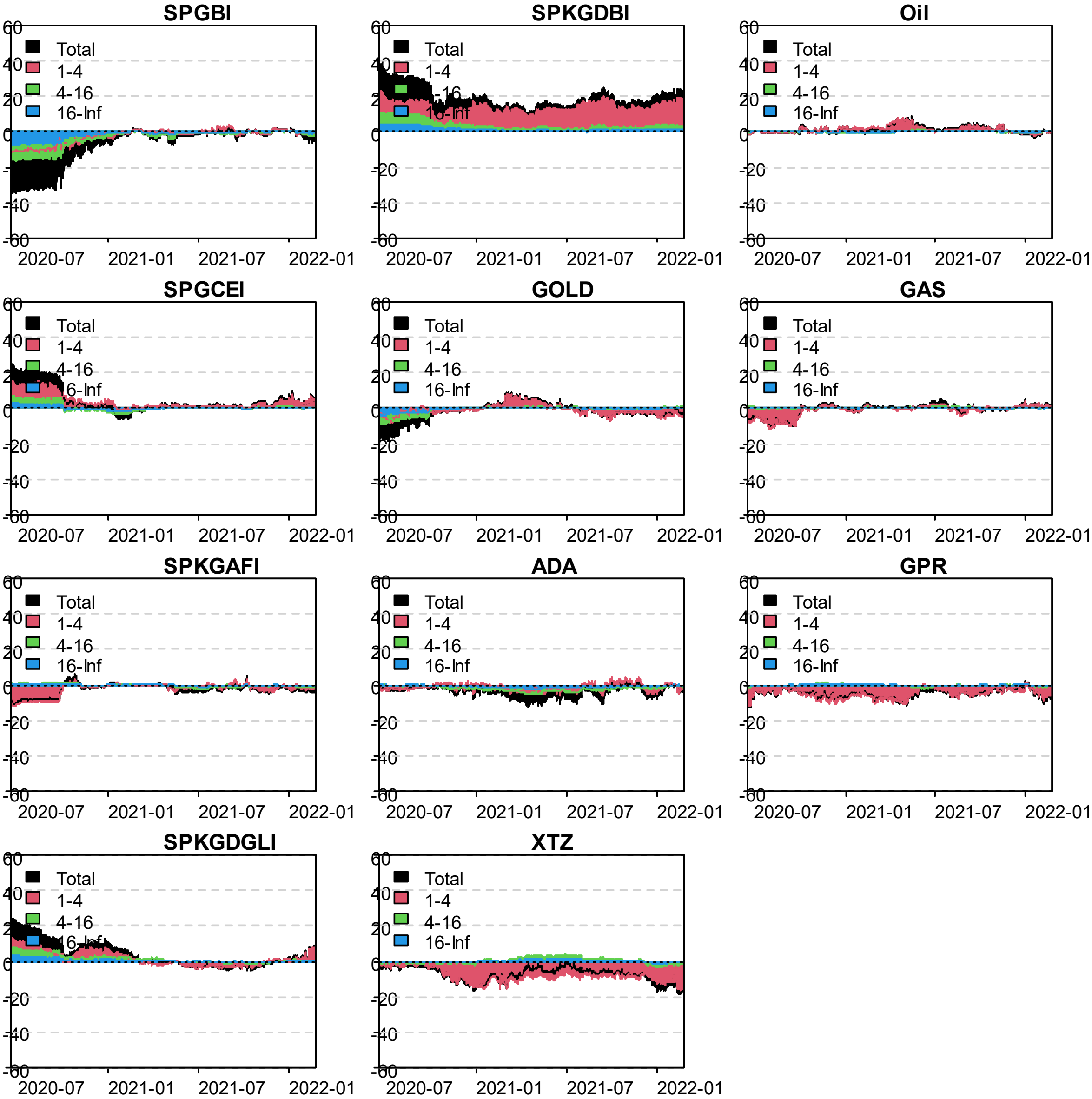

Figure 5. Fractional transmission of the shock caused by COVID19 pandemic for the different returns referred to in our study

Green cryptocurrencies are highly volatile. The geopolitical risk index shows spikes during major events.

Figure 5 represents the total fractional spillover during the COVID-19 pandemic. The three FinTech indicators show relatively stable spillovers. Green finance exhibits pronounced fluctuations. Non-renewable energies fluctuate. Gold shows stability or a slight increase. Green cryptocurrencies show stable transmissions. The geopolitical risk index displays spikes during major events.

Figure 6 corresponds the total fractional transmission during the two ongoing wars for the various indicators of FinTech, green finance, eco-friendly cryptocurrencies, non-renewable energy, gold, and the geopolitical risk index.

Figure 6 illustrates that the three FinTech indices show relatively stable transmissions. Green finance

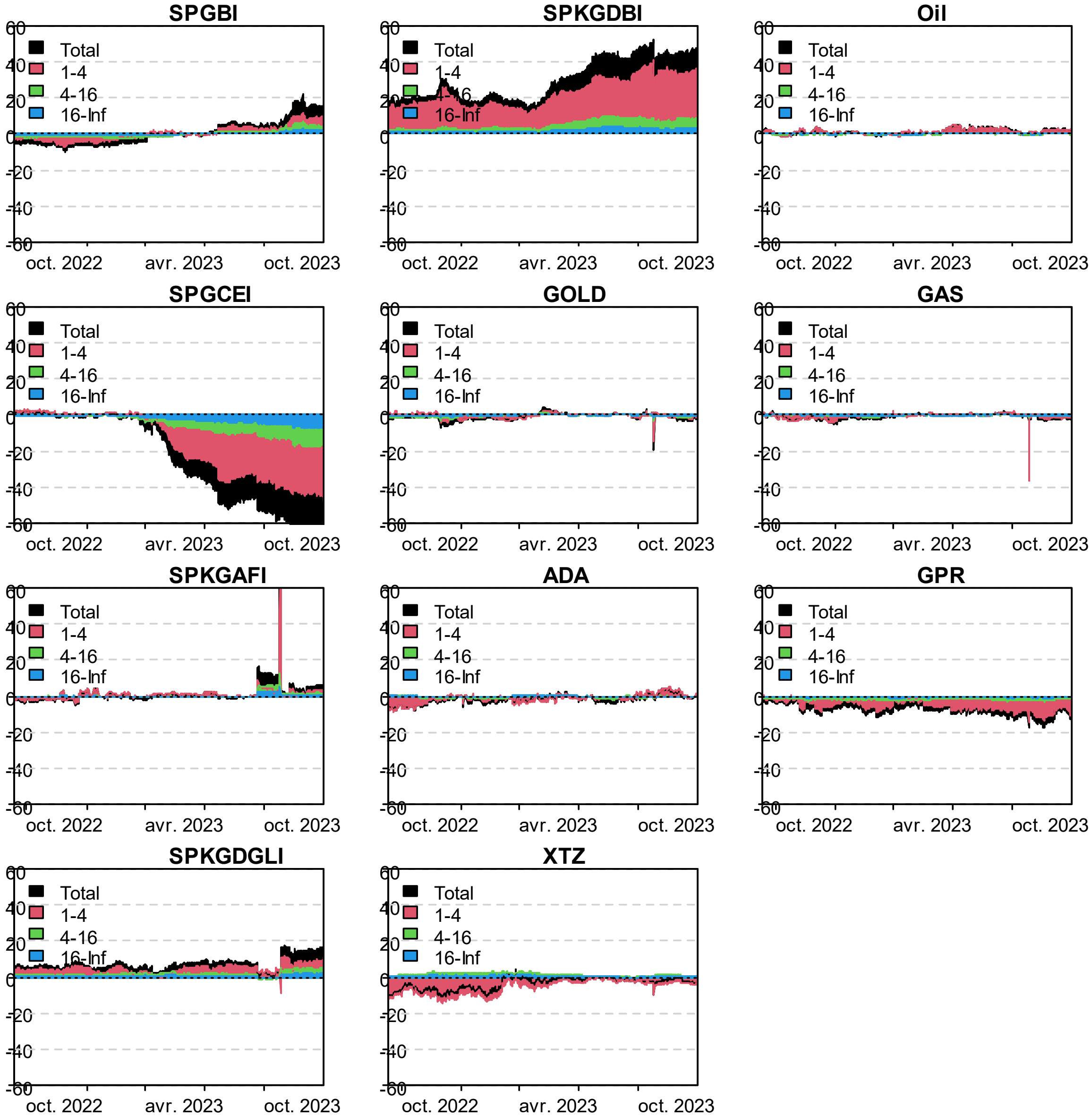

Figure 6. Fractional transmission of the shock during the two ongoing wars for the different returns referred to in our study

exhibits pronounced fluctuations. Non-renewable energies fluctuate. Gold shows stability or a slight increase. The geopolitical risk index reveals spikes during major events. The two eco-friendly cryptocurrencies display relatively low total fractional spillovers.

3.1. Hypotheses testing

Descriptive statistics show extreme deviations from normality, strong volatility clustering, and high Ljung-Box Q^2 values during geopolitical conflicts. Quantile VAR (QVAR) analyses further indicate that FinTech indices and green cryptocurrencies act as major shock transmitters, with elevated spillovers across all examined markets. Therefore, H1 is supported.

The evidence shows that gold maintains high own-return spillovers and limited outgoing spillovers. Similarly, the S&P Green Bond Index remains stable with reduced outgoing shocks. Therefore, H2 is supported.

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The evidence reveals that QVAR and fractional connectivity analyses show strong nonlinear and asymmetric spillovers across quantiles and regimes. In addition, directional connectivity networks show regime-dependent behavior. Therefore, H3 is supported.

3.2. Discussion

The findings demonstrate that global crises significantly amplify volatility, tail risk, and interconnectedness across sustainable, digital, and traditional financial markets, underscoring the evolving structure of financial risk in the era of geopolitical and systemic uncertainty.

The analysis shows that green finance, FinTech, eco-friendly cryptocurrencies, energy, and gold exhibit significant volatility and heavy tails during major global shocks (US–China trade conflict, COVID-19, Russia–Ukraine and Hamas–Israel wars). FinTech and green cryptocurrencies act as primary transmitters of shocks, while gold and green bonds serve as stable receivers. Connectivity and spillovers intensify under crises, with strong interdependence among sustainable, digital, and traditional markets.

Fractional QVAR confirms the persistence of shocks, highlighting FinTech and green crypto dominance, the moderate impact of energy, and the safe-haven role of gold. These results are consistent with the findings of Mensi et al. (2022), Long et al. (2022), and Yousaf et al. (2022), who emphasize that digital finance and cryptocurrency markets tend to dominate shock transmission during periods of heightened uncertainty, while traditional safe-haven assets such as gold retain their stabilizing role.

The directional and median quantile connectivity networks further indicate that market behavior is regime-dependent. Different assets act as risk emitters or receivers depending on the nature of the shock, whether related to trade tensions, health crises, or geopolitical conflicts. During extreme conditions, FinTech indices and green cryptocurrencies dominate risk transmission, whereas green bonds and gold absorb shocks, confirming their hedging and diversification properties.

The findings also suggest that geopolitical risks reshape the structure of financial interconnectedness by strengthening the links between sustainable finance, digital assets, and traditional markets. This increased integration implies that diversification benefits may diminish during crises, as correlations and spillovers rise simultaneously across asset classes.

Overall, the results highlight that global shocks not only increase volatility and tail risk but also alter the transmission mechanisms across markets. Sustainable finance and digital assets play an increasingly central role in the global financial system, while gold and green bonds continue to function as stabilizing assets under conditions of heightened geopolitical and systemic uncertainty.

CONCLUSION

The aim of this study was to evaluate how geopolitical risk shocks influence return behavior, volatility transmission, and hedging dynamics across green finance, FinTech, eco-friendly cryptocurrencies, non-renewable energy markets, and precious metals during major global crisis episodes.

The results indicate that geopolitical disturbances substantially reshape return distributions and amplify volatility spillovers across these interconnected markets, with effects that vary across asset classes and crisis regimes. The analysis shows that green bonds and gold maintain comparatively stable profiles under geopolitical stress, while FinTech demonstrates structural robustness, whereas eco-friendly cryptocurrencies and non-renewable energy markets exhibit heightened sensitivity and pronounced vulnerability. Furthermore, the observed interactions are nonlinear and regime-dependent, reflecting asymmetric responses to different geopolitical shocks.

These findings lead to the conclusion that geopolitical risks play a central role in redefining financial interconnectedness and risk transmission, reducing diversification benefits during crises while reinforcing the stabilizing function of traditional and sustainable safe-haven assets. At the same time, the results highlight the growing systemic relevance of digital finance and green assets within global financial markets. Future research should extend this framework by incorporating longer time horizons, broader geopolitical scenarios, and additional structural factors in order to better capture the long-term implications of geopolitical instability for sustainable finance, energy transitions, and digital financial ecosystems.

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Writing – review & editing: Nadjib Allah Hakmi, Nidhal Mgadmi, Souhila Imansouren.

REFERENCES

1. Ahmed, F., Islam, M. M., & Abbas, S. (2025). Assessing the impact of Russian–Ukrainian geopolitical risks on global green finance: A quantile dependency analysis. *Environmental Economics and Policy Studies, 27*(4), 615-641. https://doi.org/10.1007/s10018-024-00395-3
2. Alsagr, N., Cumming, D. J., Davis, J. G., & Sewaid, A. (2023). Geopolitical risk and crowdfunding performance. *Journal of International Financial Markets, Institutions and Money, 85,* Article 101766. https://doi.org/10.1016/j.intfin.2023.101766
3. Ando, T., Greenwood-Nimmo, M., & Shin, Y. (2022). Quantile connectedness: Modeling tail behavior in the topology of financial networks. *Management Science, 68*(4), 2401-2431. https://doi.org/10.1287/mnsc.2021.3984
4. Arif, M., Naeem, M. A., Farid, S., Nepal, R., & Jamasb, T. (2022). Diversifier or more? Hedge and safe haven properties of green bonds during COVID19. *Energy Policy, 168*, Article 113102. https://doi.org/10.1016/j.enpol.2022.113102
5. BędowskaSójka, B., Demir, E., & Zaremba, A. (2022). Hedging geopolitical risks with different asset classes: A focus on the Russian invasion of Ukraine. *Finance Research Letters, 50,* Article 103192. https://doi.org/10.1016/j.frl.2022.103192
6. Bouoiyour, J., Selmi, R., Hammoudeh, S., & Wohar, M. E. (2019). What are the categories of geopolitical risks that could drive oil prices higher? Acts or threats? *Energy Economics, 84,* Article 104523. https://doi.org/10.1016/j.eneco.2019.104523
7. Caramichael, J., & Rapp, A. (2022). *The green corporate bond issuance premium* (International Finance Discussion Papers No. 1346). Board of Governors of the Federal Reserve System. https://doi.org/10.17016/IFDP.2022.1346
8. Cheikh, N. B., & Zaied, Y. B. (2023a). Investigating the dynamics of crude oil and clean energy markets in times of geopolitical tensions. *Energy Economics, 124,* Article 106861. https://doi.org/10.1016/j.eneco.2023.106861
9. Cheikh, N. B., & Zaied, Y. B. (2023b). Renewable energy deployment and geopolitical conflicts. *Journal of Environmental Management, 344,* Article 118561. https://doi.org/10.1016/j.jenvman.2023.118561
10. De Wet, M. C. (2023). Geopolitical risks and yield dynamics in the Australian sovereign bond market. *Journal of Risk and Financial Management, 16*(3), Article 144. https://doi.org/10.3390/jrfm16030144
11. Diebold, F. X., & Yilmaz, K. (2012). Better to give than to receive: Predictive directional measurement of volatility spillovers. *International Journal of Forecasting, 28*(1), 57-66. https://doi.org/10.1016/j.ijforecast.2011.02.006

https://doi.org/10.21511/gg.07(1).2026.02

12. Diebold, F. X., & Yılmaz, K. (2014). On the network topology of variance decompositions: Measuring the connectedness of financial firms. *Journal of Econometrics, 182*(1), 119-134. https://doi.org/10.1016/j.jeconom.2014.04.012

13. Doğan, B., Trabelsi, N., Tiwari, A. K., & Ghosh, S. (2023). Dynamic dependence and causality between crude oil, green bonds, commodities, geopolitical risks, and policy uncertainty. *The Quarterly Review of Economics and Finance, 89,* 36-62. https://doi.org/10.1016/j.qref.2023.02.006

14. Dong, X., & Huang, L. (2024). Exploring ripple effect of oil price, FinTech, and financial stress on clean energy stocks: A global perspective. *Resources Policy, 89,* Article 104582. https://doi.org/10.1016/j.resourpol.2023.104582

15. Doostkouei, S. G, Mousavi, M. H, & Karimi, M. S. (2024). Do oil sanctions reduce Dutch disease phenomenon? A quasi-experimental approach evidence from Iran. *IDEAS, International Economics and Economic Policy, 21*(2), 385-410. Retrieved from https://ideas.repec.org/a/kap/iecepo/v21y2024i2d10.1007_s10368-024-00584-1.html

16. Dutta, A., & Dutta, P. (2022). Geopolitical risk and renewable energy asset prices: Implications for sustainable development. *Renewable Energy, 196*, 518-525. https://doi.org/10.1016/j.renene.2022.07.029

17. Gök, R. (2023). Frequency domain causal effects of geopolitical risk and economic uncertainty on green bond market around the invasion of Ukraine. In B.K. Altınkeski & M.F. Buğan (Eds.), *Finansal Piyasaların Evrimi: Bankacılık, Risk Yönetimi, Piyasa ve Kurumlar* (pp. 179-196). Retrieved from https://www.ceeol.com/search/chapter-detail?id=1170715

18. Gong, X., & Xu, J. (2022). Geopolitical risk and dynamic connectedness between commodity markets. *Energy Economics, 110,* Article 106028. https://doi.org/10.1016/j.eneco.2022.106028

19. Ha, L. T. (2023a). Dynamic connectedness between FinTech innovation and energy volatility during the war in time of pandemic. *Environmental Science and Pollution Research, 30,* 83530-83544. https://doi.org/10.1007/s11356-023-28089-5

20. Ha, L. T. (2023b). Fat tails, serial dependence, and interlinkages of the geopolitical risk and food market during the COVID-19 pandemic and war crisis: An application of Bayesian vector heterogeneous autoregressions. *Environmental Science and Pollution Research, 30*. https://doi.org/10.1007/s11356-023-29565-8

21. Helmi, M. H., Elsayed, A. H., & Khalfaoui, R. (2024). The impact of geopolitical risk on sustainable markets: A quantile-time-frequency analysis. *Finance Research Letters, 64,* Article 105380. https://doi.org/10.1016/j.frl.2024.105380

22. Imran, Z. A., & Ahad, M. (2023). Safe-haven properties of green bonds for industrial sectors (GICS) in the United States: Evidence from COVID-19 pandemic and Global Financial Crisis. *Renewable Energy, 210,* 408-423. https://doi.org/10.1016/j.renene.2023.04.033

23. Ivanovski, K., & Hailemariam, A. (2022). Time-varying geopolitical risk and oil prices. *International Review of Economics & Finance, 77,* 206-221. https://doi.org/10.1016/j.iref.2021.10.001

24. Iyke, B. N., Phan, D. H. B., & Narayan, P. K. (2022). Exchange rate return predictability in times of geopolitical risk. *International Review of Financial Analysis, 81,* Article 102099. https://doi.org/10.1016/j.irfa.2022.102099

25. Kartal, M. T., Taşkın, D., & Kılıç Depren, S. (2024). Dynamic relationship between green bonds, energy prices, geopolitical risk, and disaggregated level CO2 emissions: Evidence from the globe by novel WLMC approach. *Air Quality, Atmosphere & Health, 17,* 1763-1775. https://doi.org/10.1007/s11869-024-01544-z

26. Koop, G., Pesaran, M. H., & Potter, S. M. (1996). Impulse response analysis in nonlinear multivariate models. *Journal of Econometrics, 74*(1), 119-147. https://doi.org/10.1016/0304-4076(95)01753-4

27. Lee, C. C., Lee, C. C., & Li, Y. Y. (2021). Oil price shocks, geopolitical risks, and green bond market dynamics. *The North American Journal of Economics and Finance, 55,* Article 101309. https://doi.org/10.1016/j.najef.2020.101309

28. Li, C., & Umair, M. (2023). Does green finance development goals affect renewable energy in China. *Renewable Energy, 203,* 898-905. https://doi.org/10.1016/j.renene.2022.12.066

29. Liu, F., Qin, C., Qin, M., Stefea, P., & Norena-Chavez, D. (2024). Geopolitical risk: An opportunity or a threat to the green bond market? *Energy Economics, 131,* Article 107391. https://doi.org/10.1016/j.eneco.2024.107391

30. Long, F., Liu, J., & Zheng, L. (2022). The effects of public environmental concern on urban-rural environmental inequality: Evidence from Chinese industrial enterprises. *Sustainable Cities and Society, 80,* Article 103787. https://doi.org/10.1016/j.scs.2022.103787

31. Lorente, D. B., Mohammed, K. S., Cifuentes-Faura, J., & Shahzad, U. (2023). Dynamic connectedness among climate change index, green financial assets and renewable energy markets: Novel evidence from sustainable development perspective. *Renewable Energy, 204,* 94-105. https://doi.org/10.1016/j.renene.2022.12.085

32. Mensi, W., Shafiullah, M., Vo, X. V., & Kang, S. H. (2022). Spillovers and connectedness between green bond and stock markets in bearish and bullish market scenarios. *Finance Research Letters, 49,* Article 103120. https://doi.org/10.1016/j.frl.2022.103120

33. Mensi, W., Vo, X. V., Ko, H. U., & Kang, S. H. (2023). Frequency spillovers between green bonds, global factors and stock market before and during COVID-19 crisis. *Economic Analysis and*

Policy, 77, 558-580. https://doi.org/10.1016/j.eap.2022.12.010

34. Pesaran, H. H., & Shin, Y. (1998). Generalized impulse response analysis in linear multivariate models. *Economics Letters, 58*(1), 17-29. https://doi.org/10.1016/S0165-1765(97)00214-0
35. Rao, A., Gupta, M., Sharma, G. D., Mahendru, M., & Agrawal, A. (2022). Revisiting the financial market interdependence during COVID-19 times: A study of green bonds, cryptocurrency, commodities and other financial markets. *International Journal of Managerial Finance, 18*(4), 725-755. https://doi.org/10.1108/IJMF-04-2022-0165
36. Rasoulinezhad, E., Taghizadeh-Hesary, F., Sung, J., & Panthamit, N. (2020). Geopolitical risk and energy transition in Russia: Evidence from ARDL bounds testing method. *Sustainability, 12*(7), Article 2689. https://doi.org/10.3390/su12072689
37. Su, C.-W., Umar, M., & Gao, R. (2022). Save the environment, get financing! How China is protecting the environment with green credit policies? *Journal of Environmental Management, 323,* Article 116178. https://doi.org/10.1016/j.jenvman.2022.116178
38. Tang, Y., Chen, X. H., Sarker, P. K., & Baroudi, S. (2023). Asymmetric effects of geopolitical risks and uncertainties on green bond markets. *Technological Forecasting and Social Change, 189*, Article 122348. https://doi.org/10.1016/j.techfore.2023.122348
39. Tolliver, C., Keeley, A. R., & Managi, S. (2020). Policy targets behind green bonds for renewable energy: Do climate commitments matter? *Technological Forecasting and Social Change, 157,* Article 120051. https://doi.org/10.1016/j.techfore.2020.120051
40. Wang, K. H., Wen, C. P., Liu, H. W., & Liu, L. (2023). Promotion or hindrance? Exploring the bidirectional causality between geopolitical risk and green bonds from an energy perspective. *Resources Policy, 85,* Article 103966. https://doi.org/10.1016/j.resourpol.2023.103966
41. Yousaf, I., Nekhili, R., & Umar, M. (2022). Extreme connectedness between renewable energy tokens and fossil fuel markets. *Energy Economics, 114,* Article 106305. https://doi.org/10.1016/j.eneco.2022.106305
42. Zhang, D., Chen, X. H., Lau, C. K. M., & Cai, Y. (2023a). The causal relationship between green finance and geopolitical risk: Implications for environmental management. *Journal of Environmental Management, 327,* Article 116949. https://doi.org/10.1016/j.jenvman.2022.116949
43. Zhang, H., Gong, Z., Yang, Y., & Chen, F. (2023b). Dynamic connectedness between China green bond, carbon market and traditional financial markets: Evidence from quantile connectedness approach. *Finance Research Letters, 58,* Article 104473. https://doi.org/10.1016/j.frl.2023.104473
44. Zhang, Z., Hao, L., Linghu, Y., & Yi, H. (2023c). Research on the energy poverty reduction effects of green finance in the context of economic policy uncertainty. *Journal of Cleaner Production, 410,* Article 137287. https://doi.org/10.1016/j.jclepro.2023.137287

https://doi.org/10.21511/gg.07(1).2026.02

APPENDIX A

Table A1. Descriptive statistics

Variable	Mean	Variance	Skewness	Kurtosis	JB	ERS	Q(20)	$Q^2(20)$
During the China and US trade conflict								
S&PGBI	0.008	0.037***	−0.385***	9.902***	2190.532***	−9.157***	19.926**	46.063***
S&PGCEI	0.035	0.564***	0.097	2.056***	94.709***	−10.049***	13.032	40.368***
S&PKGAFI	−0.040	2.115***	−0.986***	15.559***	5462.793***	−9.924***	13.261	45.786***
S&PKGDGLI	−0.014	5.320***	2.048***	63.105***	88811.256***	−12.773***	48.540***	85.465***
S&PKGDBI	−0.008	0.857***	−0.532***	3.402***	282.188***	−9.667***	10.977	49.112***
GOLD	0.002	17.360***	0.970***	5.334***	715.321***	−11.190***	24.203***	47.860***
ADA	−0.027	1354.159***	0.330***	0.433*	13.815***	−2.635***	36.543***	33.270***
XTZ	0.578	1516.532***	0.236**	2.908***	192.736***	−3.644***	59.675***	67.800***
Oil	−0.030	3.048***	0.063	10.133***	2280.808***	−10.586***	15.302	14.091
GAS	−0.053	6.537***	−0.012	12.112***	3258.223***	−9.479***	25.161***	110.272***
GPR	0.007	4085.157***	0.051	1.830***	74.615***	−3.812***	138.665***	69.798***
During the COVID-19 pandemic								
S&PGBI	0.001	0.085***	−1.271***	15.222***	8087.796***	−9.301***	88.342***	293.751***
S&PGCEI	0.062	3.728***	−1.077***	12.324***	5314.839***	−11.808***	27.174***	141.877***
S&PKGAFI	−0.023	25.948***	0.342***	54.053***	99232.355***	−9.070***	38.476***	82.399***
S&PKGDGLI	0.032	8.087***	−0.037	4.562***	707.007***	−7.885***	22.069***	219.556***
S&PKGDBI	0.020	2.148***	−1.399***	14.325***	7234.378***	−5.721***	41.634***	324.285***
GOLD	0.061	20.157***	0.657***	7.002***	1723.535***	−13.228***	12.391	338.977***
ADA	0.420	995.532***	0.443***	0.516***	35.701***	−4.570***	59.030***	18.761**
XTZ	0.221	1106.205***	0.489***	1.417***	100.731***	−10.649***	59.042***	105.559***
Oil	0.058	7.711***	−2.126***	30.643***	32500.754***	−12.059***	16.827*	77.306***
GAS	0.086	12.537***	0.642***	7.954***	2204.398***	−7.275***	16.260*	104.015***
GPR	0.243	3811.070***	0.001	1.296***	57.004***	−9.411***	182.756***	29.735***
During Russia-Ukraine war and Hamas-Israel conflict								
S&PGBI	−0.004	0.193	0.280***	3.167***	402.089***	−3.320***	17.600**	39.329***
S&PGCEI	−0.024	2.821	−2.520***	69.149***	186873.641***	−5.714***	38.522***	83.444***
S&PKGAFI	0.025	88.259	−0.274***	56.494***	124082.774***	−13.524***	102.010***	99.017***
S&PKGDGLI	−0.001	16.088	1.270***	15.586***	9694.631***	−13.127***	10.181	52.705***
S&PKGDBI	0.009	1.976	0.169**	1.714***	118.652***	−3.936***	14.764	47.144***
ADA	−0.219	1686.612	0.504***	0.924***	72.705***	−2.614***	118.606***	26.949***
XTZ	0.408	31556.407	0.061	8.470***	2789.532***	−9.975***	201.480***	327.082***
Oil	−0.032	3.832	−0.755***	5.610***	1312.255***	−14.767***	24.954***	117.990***
GAZ	−0.078	27.87	−0.131	8.550***	2844.298***	−8.352***	18.192**	58.976***
GOLD	−0.008	37.626	0.415***	154.213***	924535.383***	−13.368***	94.709***	216.699***
GPR	−0.081	2171.021	0.499***	2.385***	259.857***	−6.793***	332.460***	160.945***

Note: *p < 0.1, **p < 0.05, and ***p < 0.01.

Table A2. Matrix of correlation, total

Variable	S&PGBI	S&PGCEI	S&PKGAFI	S&PKGDGLI	S&PKGDBI	GOLD	ADA	XTZ	Oil	GAS	GPR
During the China and US trade conflict											
S&PGBI	1.000***	0.055	−0.029	−0.030	−0.012	0.062**	−0.012	0.015	0.049	−0.063**	−0.036
S&PGCEI	0.055	1.000***	0.376***	0.159***	0.403***	−0.210***	−0.034	−0.032	0.115***	0.013	0.009
S&PKGAFI	−0.029	0.376***	1.000***	0.340***	0.643***	−0.205***	0.027	0.017	0.064**	0.078**	0.016
S&PKGDGLI	−0.030	0.159***	0.340***	1.000***	0.503***	−0.159***	−0.020	0.057	0.055	−0.004	0.032
S&PKGDBI	−0.012	0.403***	0.643***	0.503***	1.000***	−0.240***	0.019	0.005	0.093***	0.041	0.011
GOLD	0.062**	−0.210***	−0.205***	−0.159***	−0.240***	1.000***	0.030	0.049	−0.025	−0.012	−0.015
ADA	−0.012	−0.034	0.027	−0.020	0.019	0.030	1.000***	0.193***	−0.061**	−0.012	0.110***
XTZ	0.015	−0.032	0.017	0.057	0.005	0.049	0.193***	1.000***	0.012	0.002	0.082***
Oil	0.049	0.115***	0.064**	0.055	0.093***	−0.025	−0.061**	0.012	1.000***	−0.012	0.024
GAS	−0.063**	0.013	0.078**	−0.004	0.041	−0.012	−0.012	0.002	−0.012	1.000***	−0.021
GPR	−0.036	0.009	0.016	0.032	0.011	−0.015	0.110***	0.082***	0.024	−0.021	1.000***
During the COVID-19 pandemic											
S&PGBI	1.000***	0.047	0.041	0.036	0.114***	−0.023	0.003	0.010	0.000	−0.025	−0.006
S&PGCEI	0.047	1.000***	0.128***	0.194***	0.241***	−0.080***	0.001	−0.028	0.007	0.039	0.008
S&PKGAFI	0.041	0.128***	1.000***	0.370***	0.518***	−0.152***	−0.034	−0.050**	0.040	0.064**	0.011
S&PKGDGLI	0.036	0.194***	0.370***	1.000***	0.632***	−0.147***	−0.056**	−0.034	0.035	0.014	−0.013
S&PKGDBI	0.114***	0.241***	0.518***	0.632***	1.000***	−0.185***	−0.035	−0.023	0.035	0.009	0.012
GOLD	−0.023	−0.080***	−0.152***	−0.147***	−0.185***	1.000***	0.018	0.039	0.024	−0.018	0.028
ADA	0.003	0.001	−0.034	−0.056**	−0.035	0.018	1.000***	0.266***	0.015	−0.008	0.100***
XTZ	0.010	−0.028	−0.050**	−0.034	−0.023	0.039	0.266***	1.000***	0.019	0.024	0.069***
Oil	0.000	0.007	0.040	0.035	0.035	0.024	0.015	0.019	1.000***	0.001	0.001
GAS	−0.025	0.039	0.064**	0.014	0.009	−0.018	−0.008	0.024	0.001	1.000***	0.026
GPR	−0.006	0.008	0.011	−0.013	0.012	0.028	0.100***	0.069***	0.001	0.026	1.000***
During Russia–Ukraine war and Hamas–Israel conflict											
S&PGBI	1.000***	0.116***	0.154***	0.159***	0.233***	−0.005	0.022	−0.026	−0.003	0.007	−0.034
S&PGCEI	0.116***	1.000***	0.098***	0.055**	0.108***	−0.007	−0.018	0.002	0.017	−0.031	−0.006
S&PKGAFI	0.154***	0.098***	1.000***	0.483***	0.697***	−0.011	−0.021	0.033	−0.009	−0.122***	−0.028
S&PKGDGLI	0.159***	0.055**	0.483***	1.000***	0.648***	−0.027	−0.040	0.005	−0.026	−0.089***	−0.057**
S&PKGDBI	0.233***	0.108***	0.697***	0.648***	1.000***	−0.009	−0.027	0.020	0.011	−0.111***	−0.038
ADA	−0.005	−0.007	−0.011	−0.027	−0.009	1.000***	0.210***	−0.014	−0.009	0.044	0.124***
XTZ	0.022	−0.018	−0.021	−0.040	−0.027	0.210***	1.000***	−0.017	0.030	0.034	0.084***
Oïl	−0.026	0.002	0.033	0.005	0.020	−0.014	−0.017	1.000***	0.025	−0.027	0.003
GAZ	−0.003	0.017	−0.009	−0.026	0.011	−0.009	0.030	0.025	1.000***	−0.026	0.038
GOLD	0.007	−0.031	−0.122***	−0.089***	−0.111***	0.044	0.034	−0.027	−0.026	1.000***	0.040
GPR	−0.034	−0.006	−0.028	−0.057**	−0.038	0.124***	0.084***	0.003	0.038	0.040	1.000***

Note: *p < 0.1, **p < 0.05, and ***p < 0.01.

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Table A3. Static return spillovers

Variable	S&PGBI	S&PGCEI	S&PKGAFI	S&PKGDGLI	S&PKGDBI	GOLD	ADA	XTZ	Oil	GAS	GPR	FROM
During the China and US Trade Conflict												
S&PGBI	84.22	3.11	0.88	0.98	1.26	5.99	0.31	0.25	1.20	1.07	0.72	15.78
S&PGCEI	1.56	50.61	12.45	2.13	22.69	5.75	0.96	0.12	3.22	0.38	0.14	49.39
S&PKGAFI	0.52	12.92	52.00	2.52	25.51	3.59	0.40	0.06	1.87	0.34	0.25	48.00
S&PKGDGLI	0.79	1.39	2.63	80.69	7.93	0.70	0.22	3.15	2.10	0.26	0.13	19.31
S&PKGDBI	0.63	19.18	20.98	5.59	41.75	6.79	0.86	0.16	3.50	0.34	0.21	58.25
GOLD	5.19	7.63	4.46	0.61	10.06	63.79	1.78	0.17	5.56	0.56	0.18	36.21
ADA	0.75	2.14	1.17	0.81	2.30	2.52	76.91	6.73	1.91	1.67	3.09	23.09
XTZ	0.73	0.87	0.23	3.58	0.66	0.48	7.06	81.78	0.72	0.95	2.94	18.22
Oil	0.69	4.81	1.25	0.65	2.79	4.69	1.71	0.21	82.71	0.14	0.36	17.29
GAS	1.15	0.58	0.71	0.43	0.45	0.92	1.29	0.54	2.34	91.43	0.16	8.57
GPR	1.57	0.80	1.06	0.58	1.43	1.01	2.55	3.22	1.03	0.38	86.37	13.63
TO	13.57	53.43	45.83	17.89	75.09	32.43	17.14	14.61	23.47	6.10	8.18	307.74
Inc.Own	97.79	104.04	97.83	98.58	116.84	96.22	94.06	96.39	106.18	97.53	94.55	cTCI/TCI
NET	–2.21	4.04	–2.17	–1.42	16.84	–3.78	–5.94	–3.61	6.18	–2.47	–5.45	30.77/27.98
NPT	4.00	8.00	7.00	6.00	9.00	6.00	1.00	1.00	9.00	3.00	1.00	–
During the COVID-19 pandemic												
SPGBI	77.64	4.38	1.14	4.17	8.28	2.22	0.14	0.21	0.15	1.37	0.31	22.36
SPGCEI	2.11	75.57	0.74	7.70	10.80	0.94	0.29	0.21	0.26	0.81	0.56	24.43
SPKGAFI	0.79	1.35	76.25	5.62	11.66	2.19	0.24	0.32	0.18	1.17	0.23	23.75
SPKGDGLI	1.65	7.51	4.31	49.21	34.08	1.05	0.49	0.41	0.34	0.84	0.10	50.79
SPKGDBI	3.54	9.52	8.00	30.57	44.18	2.32	0.34	0.18	0.30	0.75	0.30	55.82
GOLD	2.31	1.73	2.67	1.92	4.66	84.24	0.28	0.63	0.24	0.59	0.72	15.76
ADA	0.95	1.13	0.90	0.94	0.87	1.33	76.66	12.68	1.16	0.70	2.69	23.34
XTZ	1.09	1.06	0.90	1.82	2.15	0.81	13.37	74.23	0.89	1.14	2.55	25.77
Oil	0.15	0.54	0.21	0.64	0.64	0.25	0.60	0.56	95.90	0.17	0.34	4.10
GAS	1.17	1.03	1.82	0.98	1.38	0.80	0.30	0.83	0.18	91.27	0.26	8.73
GPR	0.70	0.95	0.50	0.69	0.87	1.70	3.21	2.37	1.78	0.51	86.72	13.28
TO	14.47	29.20	21.19	55.04	75.38	13.61	19.26	18.41	5.48	8.04	8.06	268.14
Inc.Own	92.11	104.77	97.44	104.26	119.57	97.85	95.92	92.64	101.38	99.31	94.77	cTCI/TCI
NET	–7.89	4.77	–2.56	4.26	19.57	–2.15	–4.08	–7.36	1.38	–0.69	–5.23	26.81/24.38
NPT	4.00	8.00	7.00	9.00	10.00	5.00	2.00	0.00	5.00	4.00	1.00	–

Table A3 (cont.). Static return spillovers

Variable	S&PGBI	S&PGCEI	S&PKGAFI	S&PKGDGLI	S&PKGDBI	GOLD	ADA	XTZ	Oil	GAS	GPR	FROM
During Russia-Ukraine war and Hamas-Israel conflict												
S&PGBI	76.09	0.48	1.34	5.08	11.47	3.65	0.41	0.19	0.11	0.39	0.80	23.91
S&PGCEI	4.78	69.93	2.07	4.69	14.60	1.67	0.59	0.43	0.78	0.25	0.23	30.07
S&PKGAFI	1.27	0.20	81.92	5.04	9.24	1.40	0.21	0.09	0.04	0.48	0.12	18.08
S&PKGDGLI	3.63	0.11	3.81	56.33	32.50	1.73	0.79	0.24	0.10	0.29	0.47	43.67
S&PKGDBI	7.54	0.26	6.51	29.29	50.40	3.89	0.85	0.42	0.13	0.45	0.25	49.60
GOLD	3.73	0.63	1.89	2.71	5.95	81.69	0.24	0.63	0.35	1.45	0.74	18.31
ADA	1.04	1.06	1.29	1.28	1.57	0.43	74.18	13.31	1.26	0.54	4.03	25.82
XTZ	0.35	0.57	0.69	1.07	2.07	1.39	13.99	74.77	0.78	0.82	3.51	25.23
Oil	0.15	0.85	0.15	0.19	0.25	0.48	0.56	0.49	95.85	0.09	0.95	4.15
GAS	0.43	0.13	1.07	0.61	0.91	1.76	0.17	0.38	0.11	92.63	1.80	7.37
GPR	1.44	0.68	0.66	1.05	1.05	0.89	6.14	5.63	1.70	1.56	79.21	20.79
TO	24.36	4.97	19.48	50.99	79.60	17.29	23.93	21.80	5.36	6.31	12.90	267.01
Inc.Own	100.45	74.90	101.41	107.32	130.00	98.98	98.11	96.57	101.20	98.94	92.11	cTCI/TCI
NET	0.45	–25.10	1.41	7.32	30.00	–1.02	–1.89	–3.43	1.20	–1.06	–7.89	26.70/24.27
NPT	7.00	4.00	8.00	9.00	10.00	6.00	2.00	1.00	4.00	3.00	1.00	–

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