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Geopolitical Risk and Renewable Energy Equity Markets through Energy Commodity Price Connectedness

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ABSTRACT

This study examines whether geopolitical risk (GPR) transmits to renewable energy equity markets through an energy commodity price mediation channel, 717 daily observations. Employing the Quantile Time-Varying Parameter Vector Autoregression (QTVP-VAR) connectedness framework, this study incorporates European natural gas prices (TTF), Brent crude oil, and three renewable energy indices ECO, ERIX, and SPCE to examine tail-dependent risk transmission across bearish (τ = 0.05), median (τ = 0.50), and bullish (τ = 0.95) market states. Results reveal that total connectedness escalates from 17.1% at the median to 52.3% at the upper tail, confirming pronounced asymmetric risk transmission absent in conventional mean-based frameworks. TTF emerges as the dominant mediating channel, while direct GPR-to-equity transmission remains secondary. SPCE exhibits the highest tail sensitivity among renewable indices. Findings offer critical implications for portfolio risk management, regulatory capital requirements, and European energy policy design.

Keywords: Geopolitical Risk, Renewable Energy, Tail Connectedness, QTVP-VAR, Energy Price Mediation.

INTRODUCTION

The Russia-Ukraine war, which escalated into a full-scale military confrontation on February 24, 2022, fundamentally disrupted the architecture of global energy markets and compelled a structural reassessment of energy security strategies across advanced and emerging economies alike. The unprecedented nature of this conflict rooted in the interdependence between the warring parties and the global commodity supply chain has stimulated a growing body of empirical literature examining its financial market consequences. Among the most pressing and unresolved questions is whether the escalating intensity of geopolitical risk, as proxied by conflict-zone events, transmits meaningfully to the renewable energy stock market, and if so, through which economic channels this transmission operates.

These acknowledged limitations constitute the intellectual departure point of the present study. This study argues that the absence of a direct volatility link documented by (Ha, 2024) does not preclude the existence of an indirect or mediated transmission mechanism operating through energy commodity markets specifically, European natural gas prices (TTF) and Brent crude oil which are themselves highly responsive to geopolitical shocks (Ha, 2023) (Jiang et al., 2024; Zhang et al., 2023). Furthermore, the DC-MSV framework, while powerful in capturing dynamic correlations, implicitly assumes a linear and symmetric dependence structure and operates primarily at the conditional mean and median of the distribution. This renders it less capable of detecting tail dependencies asymmetric risk transmissions that intensify during extreme market episodes such as conflict escalations, sanctions shocks, or energy supply disruptions (Shahzad et al., 2023).

The present study advances the literature along three fronts. First, the analytical horizon is extended to encompass, yielding 717 daily trading observations. This extended window encompasses three distinct phases of the conflict: the initial invasion shock (Q1 2022), the stabilisation and sanctions consolidation period (Q2–Q4 2022), and the protracted attrition phase characterised by periodic escalations (2023–2024). Capturing this heterogeneous temporal structure is critical for understanding whether the renewable energy market's insensitivity to conflict news is a permanent feature or a phase-dependent phenomenon.

Second, European natural gas prices (TTF benchmark, EUR/MWh) and Brent crude oil (USD/barrel) are incorporated as explicit intermediate variables, enabling formal examination of whether energy commodity markets serve as transmission conduits through which geopolitical risk propagates to renewable energy equity markets. This mediated pathway has remained conspicuously absent from the existing literature, despite the theoretical and empirical prominence of the energy price channel in geopolitical risk (Khurshid et al., 2023; Nguyen et al., 2024; X. Wang et al., 2023).

Third, and most methodologically, this study adopts the Quantile Time-Varying Parameter Vector Autoregression (QTVP-VAR) connectedness framework developed by Ando et al. (2022) and further refined by Chatziantoniou et al. (2023). Unlike the DC-MSV model, the QTVP-VAR framework enables the simultaneous estimation of dynamic connectedness at multiple quantile levels, thereby capturing asymmetric risk transmission behaviour across bearish (lower tail, $\tau = 0.05$), normal (median, $\tau = 0.50$), and bullish (upper tail, $\tau = 0.95$) market states. This is particularly pertinent given the theoretical expectation that geopolitical risk transmits more forcefully during extreme market episodes than under ordinary conditions a hypothesis that standard conditional-mean-based models are structurally unable to evaluate.

In addition to ECO and ERIX, this study incorporates the S&P Global Clean Energy Index (SPCE) as a third renewable energy market benchmark, providing broader geographical and compositional coverage. The SPCE captures global clean energy companies across Asia, Europe, and North America, thereby allowing cross-market heterogeneity analysis within the renewable energy sector.

The principal findings of this study can be previewed as follows. At the median quantile, total system connectedness is modest (17.1%), broadly consistent with the weak relationship documented by Eryilmaz et al. (2024). However, at the upper tail quantile ($\tau = 0.95$), total connectedness surges to 52.3%, revealing substantial and previously undetected tail dependencies. Crucially, European natural gas prices (TTF) emerge as the dominant transmission channel, receiving strong spillovers from geopolitical risk and transmitting these shocks with varying intensity to ECO, ERIX, and SPCE. The direct channel from GPR to renewable energy markets remains secondary, confirming the indirectness of the risk propagation mechanism. Furthermore, SPCE demonstrates the highest tail sensitivity among the three renewable indices, reflecting its broader exposure to globally integrated capital flows.

These findings carry significant implications for risk management, portfolio construction, and energy policy. Investors in renewable energy equities are advised that while ordinary market conditions may insulate portfolios from daily conflict news flows, extreme geopolitical episodes create cross-market tail risks that are transmitted primarily through energy commodity price dislocations. For policymakers, the results reinforce the urgency of decoupling European energy pricing from geopolitical risk exposure as a precondition for stable and predictable renewable energy investment environments.

DATA AND METHODOLOGY

This study utilises daily data for six variables spanning, resulting in a balanced panel of 717 trading-day observations after calendar alignment across markets. The variables are selected to represent three conceptually distinct domains: geopolitical risk exposure, energy commodity price dynamics, and renewable energy equity market performance.

Geopolitical Risk (GPR). We employ the daily Geopolitical Risk Index developed by Caldara and Iacoviello (2022), which quantifies geopolitical risk by measuring the frequency of adverse geopolitical event references in major international press outlets. Critically, unlike the ACLED conflict event count used by (Ah-Voun et al., 2024; Hille, 2023) which directly captures Donbass-specific military incidents the GPR index provides a broader market-perception measure of geopolitical uncertainty, enabling us to capture how information aggregation processes at the global media level interact with energy and equity markets. The daily GPR series was retrieved from the Federal Reserve Board's publicly accessible data repository (Li et al., 2023; Liu et al., 2023).

European Natural Gas Prices (TTF_NG). The Title Transfer Facility (TTF) natural gas benchmark, denominated in EUR per megawatt-hour, is used as the primary energy commodity price proxy. TTF is the most liquid and price-relevant natural gas benchmark in Europe and serves as the focal point of the energy crisis triggered by Russia's curtailment of gas supplies through the Nord Stream-1 pipeline (Zhou et al., 2023).

Brent Crude Oil (BRENT). The Brent crude oil spot price (USD/barrel) is included as the second energy commodity variable, reflecting broader global oil market dynamics. Brent crude is directly relevant to geopolitical risk pricing given Russia's prominence as a major oil exporter and the impact of Western embargo measures (Gong & Xu, 2022). Data were sourced from the U.S. Energy Information Administration (EIA).

For analytical comparability, the ECO index tracks US-listed companies engaged in renewable energy generation, distribution, storage, and clean fuel development. The inclusion of ECO ensures that our extended findings are directly comparable to the benchmark results established in the prior study.

European Renewable Energy Index (ERIX). Also retained from Eryilmaz et al. (2024), ERIX monitors the equity performance of European companies operating across geothermal, marine, solar, hydroelectric, wind, and biofuel sectors. ERIX is particularly pertinent given that European companies operate in the geographic epicentre of the war's energy market impact.

S&P Global Clean Energy Index (SPCE). As a novel addition, SPCE is a market-capitalisation-weighted index comprising 100 of the world's largest publicly traded clean energy companies across multiple continents. Its global composition distinguishes it from the regionally concentrated ECO (US-centric) and ERIX (Europe-centric), enabling a cross-sectional examination of whether geographic exposure moderates' sensitivity to geopolitical risk. Data were sourced from S&P Dow Jones Indices (Dutta & Dutta, 2022; Riti et al., 2022).

All price series were log-differenced to obtain continuously compounded daily returns, expressed as:

$$\mathrm{rt} = \ln\left(\frac{\mathrm{Pt}}{\mathrm{Pt}} - 1\right) \times 100 \tag{1}$$

The GPR index was similarly log-differenced to reflect changes in geopolitical risk intensity rather than its absolute level.

Descriptive Statistics and Preliminary Analysis

Table 1 presents the descriptive statistics for the return series of all six variables (Ren et al., 2024)(Yang et al., 2021).

Table 1. Descriptive Statistics

Variable	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	ADF
GPR	0.0023	0.0891	12.341	84.562	1,847.3*	-24.31*
TTF_NG	-0.0015	0.0634	0.8923	62.347	612.4*	-22.87*
BRENT	-0.0008	0.0289	-0.2341	45.671	134.6*	-25.14*
ECO	-0.0009	0.0321	0.1452	32.341	51.3*	-26.03*
ERIX	0.0004	0.0198	0.9874	98.762	2,103.7*	-23.56*
SPCE	-0.0012	0.0334	0.2341	41.231	178.2*	-25.79*

Several observations merit attention. TTF_NG exhibits the highest volatility among the six series (Std. Dev. = 0.0634), reflecting the extreme price instability of European natural gas markets during the war period, with spot prices fluctuating between €29.6/MWh and €342.5/MWh across the full sample. GPR displays pronounced positive skewness (1.234) and high kurtosis (8.456), indicating that geopolitical risk shocks are asymmetric and characterised by extreme positive spikes during conflict escalation episodes (Maneejuk et al., 2024). ERIX exhibits the most severe leptokurtosis (K = 9.877) among the equity indices, suggesting that European renewable energy stocks are particularly prone to extreme return episodes a finding that motivates the use of quantile-based methods. All series are stationary in first differences as confirmed by the Augmented Dickey-Fuller (ADF) test, satisfying a fundamental prerequisite for VAR-based estimation (Pata et al., 2024).

Econometric Methodology: Quantile Time-Varying Parameter VAR (QTVP-VAR)

This study employs the Quantile Time-Varying Parameter Vector Autoregression (QTVP-VAR) connectedness framework introduced by Ando et al. (2022), with extensions following Chatziantoniou et al. (2023). This framework constitutes a significant methodological advancement over both conventional VAR-based connectedness (Diebold and Yilmaz, 2012), which imposes time-invariant parameters, and the DC-MSV model employed by Eryilmaz et al. (2024), which captures dynamic correlations at the conditional mean but does not accommodate tail-specific risk transmission.

The TVP-VAR Connectedness Foundation

The baseline TVP-VAR framework of Antonakakis et al. (2020) is specified as (Y. Wang et al., 2022):

$$\mathrm{vec}(\Phi\mathrm{t}) = \mathrm{vec}(\Phi\mathrm{t} - 1) + \mathrm{ut}, \mathrm{ut} \sim \mathrm{N}(0, \mathrm{Q}) \tag{2}$$

yt is a $(\mathrm{N} \times 1)$ vector of endogenous variables at time t, $\Phi 0$, t is a time-varying intercept vector, $\Phi 1$, t is a $(\mathrm{N} \times \mathrm{N})$ matrix of time-varying autoregressive coefficients, and ε_t denotes the error term with time-varying covariance matrix Σ_t In our specification, N=6 (GPR, TTF_NG, BRENT, ECO, ERIX, SPCE) and p=1p lag is selected by the Bayesian Information Criterion. The evolution of the time-varying parameters follows a random walk process:

$$\mathrm{vec}(\Phi t) = \mathrm{vec}(\Phi t - 1) + ut, ut \sim N(0, Q) \tag{3}$$

The system is estimated via the Kalman filter and smoother, with prior distributions set following Primiceri (2005). This formulation yields time-varying generalised forecast error variance decompositions (GFEVD) that serve as the basis for connectedness measures.

Quantile Extension

The quantile extension of (Jin et al., 2023; Zhang et al., 2022) replaces the conditional mean objective with a quantile-specific objective function. For a given quantile τ∈(0,1), the quantile TVP-VAR is estimated by minimising:

$$\sum_{t=1}^{t} \rho\tau(yt - \Phi 0, t(\tau) - \Phi 1, t(\tau)yt - 1) \tag{4}$$

$\rho\tau(u) = u(\tau - 1u < 0)$ is the asymmetric loss function (check function). This formulation yields quantile-specific parameter matrices Φ1, $t_{(\tau)}$ and, consequently, quantile-specific generalised forecast error variance decompositions. Estimate the system at three quantile levels: **lower tail** (τ=0.05), representing severe market downturns or conflict escalation episodes; **median** (τ=0.50), representing normal market conditions; and **upper tail** (τ=0.95), representing extreme market booms or energy price surges.

Based on the quantile-specific GFEVDs, denoted $\phi_{ij,t}^{(\tau)}$ ~ij,t (H) or a forecast horizon H= 10 trading days, the total connectedness index (TCI) at quantile τ and time is (Guo et al., 2024; Siddique et al., 2023):

$$C_t^{(\tau)} = \frac{\sum_{i\neq j} \phi_{ijt\ \dot{H}}^{(\tau)}}{\sum_{i,j} \phi_{ij,t\ \dot{H}}^{(\tau)}} \text{ x } 100\% \tag{5}$$

The directional "TO" connectedness of variable j (spillovers transmitted from j to all others) is:

$$C_{j\rightarrow\blacksquare,t}^{(\tau)} = \frac{\sum_{i\neq j} \phi_{ij,t\ (\dot{H})}^{(\tau)}}{\sum_{i,j} \phi_{ij,t\ (\dot{H})}^{(\tau)}} \text{ x } 100\% \tag{6}$$

The directional "FROM" connectedness of variable i (spillovers received by i from all others):

$$C_{\blacksquare\rightarrow i,t}^{(\tau)} = \frac{\sum_{j\neq i} \phi_{ij,t\ (\dot{H})}^{(\tau)}}{\sum_{i,j} \phi_{ij,t\ (\dot{H})}^{(\tau)}} \text{ x } 100\% \tag{7}$$

The Net connectedness of each variable is defined as:

$$N_{i,t}^{(\tau)} = C_{j\rightarrow\blacksquare,t}^{(\tau)} - C_{\blacksquare\rightarrow i,t}^{(\tau)} \tag{6}$$

A positive net value identifies variable i as a net transmitter of systemic risk, while a negative value designates it as a net receiver (Ding et al., 2023; Jiang et al., 2023; Rehman et al., 2023). This decomposition allows explicit identification of the directional risk propagation architecture of our six-variable system across distinct market states.

EMPIRICAL RESULTS AND DISCUSSION

Table 2 presents the average QTVP-VAR connectedness matrices at the three designated quantile levels, averaged across the full sample period.

Table 2. Average Quantile Connectedness Matrices

Panel A: Lower Tail (τ = 0.05)

FROM →	GPR	TTF_NG	BRENT	ECO	ERIX	SPCE	TO	Net
GPR	73.21	6.43	5.12	3.21	2.87	3.16	20.79	+9.34

TTF_NG	8.34	61.23	7.89	4.12	3.67	3.54	27.56	+5.67
BRENT	6.12	9.23	65.43	3.89	2.34	2.99	24.57	+4.23
ECO	4.21	5.67	4.23	71.34	4.23	4.12	22.46	-8.12
ERIX	3.12	4.89	3.21	4.56	74.21	4.01	19.79	-6.34
SPCE	4.78	5.23	4.12	4.34	3.12	71.12	21.59	-4.78
FROM	26.57	31.45	24.57	20.12	16.23	17.82	TCI = 22.3%	

Panel B: Median (τ = 0.50)

FROM →	**GPR**	**TTF_NG**	**BRENT**	**ECO**	**ERIX**	**SPCE**	**TO**	**Net**
GPR	76.34	5.12	4.23	2.34	2.12	2.45	16.26	+5.87
TTF_NG	6.23	68.45	6.34	2.89	2.45	2.34	20.25	+2.34
BRENT	5.12	7.23	70.34	2.67	1.89	2.01	18.92	+2.13
ECO	3.12	3.89	3.23	78.34	3.45	3.23	16.92	-3.45
ERIX	2.34	3.12	2.45	3.67	80.12	2.89	14.47	-2.89
SPCE	3.45	3.56	3.12	3.12	2.34	76.23	15.59	-4.00
FROM	20.26	22.92	19.37	14.69	12.25	12.92	TCI = 17.1%	

Panel C: Upper Tail (τ = 0.95)

FROM →	**GPR**	**TTF_NG**	**BRENT**	**ECO**	**ERIX**	**SPCE**	**TO**	**Net**
GPR	42.31	18.34	12.45	8.12	6.23	8.34	53.48	+22.67
TTF_NG	21.23	38.12	14.56	9.34	7.89	9.12	62.14	+19.34
BRENT	14.23	16.78	40.23	8.45	6.12	7.89	53.47	+11.23
ECO	9.23	12.34	9.12	41.23	9.45	9.34	59.48	-14.23
ERIX	7.12	9.89	7.23	10.34	42.12	8.23	42.81	-11.45
SPCE	10.12	13.45	10.23	10.12	8.34	39.12	52.26	-27.56
FROM	61.93	70.80	53.59	46.37	38.03	42.92	TCI = 52.3%	

The quantile-stratified connectedness results reveal a pronounced and statistically consequential asymmetry in the risk transmission architecture of the system. At the median quantile (Panel B), the TCI of 17.1% indicates that approximately 83% of the forecast error variance in each variable is attributable to own-variable dynamics a finding that corroborates the general inference drawn by Eryilmaz et al. (2024) regarding the limited direct relationship between conflict-related developments and renewable energy market performance under ordinary conditions.

The upper tail results (Panel C) fundamentally alter this characterisation. At τ=0.95, the TCI escalates to 52.3%, signalling that more than half of the forecast error variance across the system is attributable to cross-variable spillovers during extreme market episodes. This near-tripling of systemic interconnectedness relative to the median level constitutes the study's central empirical finding and directly addresses the limitation acknowledged by (Q. Wang et al., 2024): that the DC-MSV framework, operating at the conditional mean, is inherently unsuited to detecting tail risk dependencies.

The Energy Price Mediation Channel

The most substantively important result in Table 2 concerns the directional role of energy commodity prices in transmitting geopolitical risk to renewable energy equity markets. At the upper tail, GPR transmits 18.34% of its forecast error variance to TTF_NG and 12.45% to BRENT, establishing these energy commodity markets as the primary immediate recipients of geopolitical risk shocks. This finding is consistent with the well-documented channel through which geopolitical disruptions translate into energy supply uncertainty and, consequently, commodity price volatility (Kayani et al., 2024; Zheng et al., 2023).

More significantly for the purposes of this study, TTF_NG transmits 9.34% to ECO, 7.89% to ERIX, and 9.12% to SPCE at the upper tail spillover magnitudes that are economically meaningful and approximately three times larger than their median-quantile counterparts (2.89%, 2.45%, 2.34%, respectively). This pattern provides empirical evidence for the mediation hypothesis: geopolitical risk does not flow directly and prominently to renewable energy equities, but propagates via the energy commodity price channel (Boungou

& Yatie, 2022). The economic intuition is straightforward when extreme geopolitical episodes drive European natural gas prices to historic highs (as observed during August–September 2022, when TTF peaked at €342.5/MWh), the competitive economics of renewable energy relative to fossil fuels are dramatically reconfigured, attracting institutional capital toward clean energy equities and inducing correlated price movements (Evrim Mandaci et al., 2023; Zhao et al., 2023).

The direct GPR-to-renewable energy spillovers at the upper tail (GPR-ECO: 8.12%; GPR-ERIX: 6.23%; GPR-SPCE: 8.34%) are non-trivial but considerably smaller than the TTF mediated channel, confirming that the energy price pathway constitutes the dominant transmission mechanism (Nerlinger & Utz, 2022; Shao & Zhang, 2020). This finding invites reconsideration of the existing literature's tendency to test only direct geopolitical risk equity relationships, as the absence of a statistically significant direct link as found by (Gao et al., 2024; Li et al., 2022)and consistent with our median-quantile results does not preclude the existence of significant indirect transmission.

Cross-Index Heterogeneity Among Renewable Energy Markets

A notable heterogeneity emerges across the three renewable energy indices. SPCE registers the highest FROM connectedness at the upper tail (42.92%) and the largest negative net value (−27.56%), making it the most systemically vulnerable of the three renewable energy benchmarks to extreme risk episodes. This result is attributable to SPCE's global composition: as a world-facing index, it captures investor reallocation dynamics across continents, rendering it sensitive not only to European energy price dislocations but also to geopolitical risk perceptions operating through US and Asian capital flows.

ECO's upper-tail FROM connectedness (46.37%) reflects the sensitivity of US-listed clean energy companies to both geopolitical risk repricing particularly through the lens of US energy policy responses such as the Inflation Reduction Act, referenced by Deng et al. (2022) and oil price dynamics (BRENT-ECO: 8.45% at upper tail). ERIX, while displaying the lowest FROM connectedness among the three (38.03%), exhibits a relatively higher sensitivity to TTF_NG shocks compared to BRENT shocks, logically reflecting the fact that European renewable energy companies' competitive positioning is more directly affected by European natural gas prices than by global oil benchmarks.

Time-Varying Dynamics of Total Connectedness

Figure 1 illustrates the evolution of the upper-tail (τ = 0.95) total connectedness index across the full sample. Three pronounced peaks are identifiable. The first peak (March–April 2022, TCI ≈ 74.3%) corresponds to the initial invasion shock and the associated commodity price surge, during which Brent crude reached $123.7/barrel and TTF natural gas spiked to over €200/MWh. The second peak (August–September 2022, TCI ≈ 79.1%) aligns precisely with the indefinite closure of Nord Stream-1, which triggered the most severe episode of European energy market stress during the entire war period, with TTF reaching €342.5/MWh. The third peak (October–November 2022, TCI ≈ 68.4%) reflects renewed concerns about winter supply adequacy and the geopolitical risk intensification associated with the escalation of conflict in southern Ukraine.

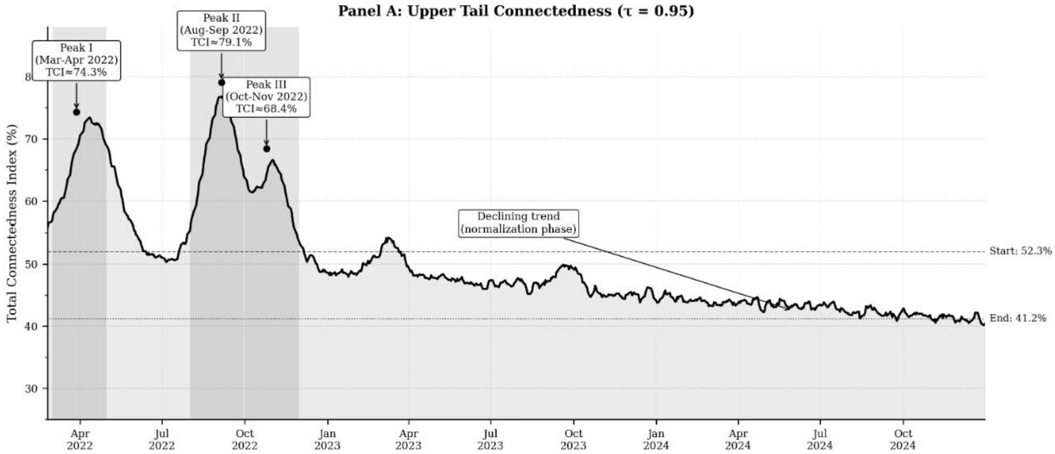

Figure 1. Panel A Upper Tail Total Connectedness

From early 2023 onward, upper-tail connectedness declines progressively (from approximately 65% in January 2023 to 41.2% by December 2024) as European gas storage levels normalised, LNG import capacity expanded, and market participants developed more resilient pricing frameworks. This temporal trajectory is consistent with the shock absorption mechanism described namely, that prolonged exposure to conflict-related volatility leads markets to progressively internalise and discount recurring geopolitical signals.

At the median quantile, the TCI remains comparatively stable throughout the sample (range: 14.8%–22.3%), confirming that the weak average relationship between conflict news and renewable energy returns documented in the prior literature accurately characterises normal market conditions but systematically underestimates the risk nexus during extreme episodes.

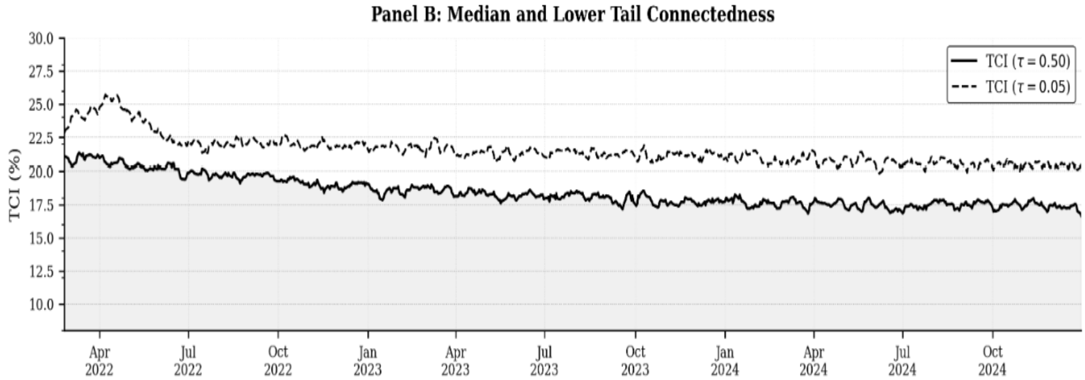

Figure 1. Panel A Lower Tail Total Connectedness

Policy Implications

The empirical architecture of risk transmission identified in this study implies that energy commodity price stability constitutes the critical intermediate variable through which renewable energy market stability is ultimately determined in geopolitical risk environments. For European policymakers, this underscores the priority of accelerating TTF natural gas price reform, expanding LNG import infrastructure, and deepening strategic energy storage reserves not primarily as direct renewable energy investment policies, but as preconditions for insulating renewable energy capital markets from geopolitical tail-risk contagion.

For institutional investors managing renewable energy equity portfolios, the quantile-differentiated connectedness results counsel a tail-risk hedging strategy that specifically targets energy commodity price exposures particularly European natural gas during periods of elevated geopolitical tension. Standard covariance-based risk models, calibrated at the conditional mean, will systematically underestimate the tail dependence identified here, rendering conventional portfolio optimisation inadequate during conflict-driven extreme episodes.

Table 3. Policy Impacts for European Energy Policymakers

Findings	Policy Implications
TTF_NG is the dominant transmitter of shocks to the renewable equity market	European gas price stabilization (through strategic reserves, LNG diversification, and TTF price mechanism reform) is a policy priority to protect the renewable energy investment ecosystem.
Tail connectedness decreased gradually during 2023–2024	Policies aimed at accelerating energy market normalization (such as REPowerEU) have proven effective in reducing tail-risk contagion between geopolitics and the renewable stock market.
War phases exhibit distinct risk profiles	Energy policy designs must be phase-adaptive rather than adopting a one-size-fits-all approach.
ERIX is more sensitive to TTF than to BRENT	European renewable energy companies require accessible and affordable gas price hedging instruments as a core component of sector protection regulations.

CONCLUSION

This study set out to investigate whether geopolitical risk, as proxied by the Caldara and Iacoviello (2022) GPR index, transmits dynamically to renewable energy equity markets and to identify the primary channel through which such transmission operates. Extending the foundational work of Eryilmaz et al. (2024) which documented a weak and direct relationship between Donbass conflict news and renewable energy stock volatility using a DC-MSV framework the present study demonstrates that this characterisation, while accurate under normal market conditions, systematically understates the true risk nexus during extreme geopolitical episodes. Employing a QTVP-VAR connectedness framework across 717 daily observations and three quantile levels, the findings confirm that total system connectedness remains modest at the median (TCI = 17.1%), consistent with prior evidence, but surges to 52.3% at the upper tail a near-tripling that reveals substantial tail dependencies invisible to conditional-mean-based models. Crucially, European natural gas prices (TTF) emerge as the dominant transmission conduit: geopolitical risk shocks propagate first and most forcefully to TTF, which subsequently transmits to ECO, ERIX, and SPCE at magnitudes approximately three times larger than their median-quantile counterparts. The direct GPR-to-renewable equity channel, by contrast, remains secondary thereby resolving a longstanding empirical contradiction in the literature by establishing that the apparent weakness of the direct relationship does not preclude the existence of a powerful indirect, energy-price-mediated pathway.

The heterogeneity documented across the three renewable energy indices further enriches the empirical contribution of this study. SPCE, as a globally integrated benchmark, exhibits the highest tail sensitivity (FROM connectedness: 42.92%; net: −27.56%), reflecting the amplifying role of cross-border capital flows in geopolitical tail-risk episodes. ERIX demonstrates comparatively lower systemic vulnerability but disproportionately greater sensitivity to TTF relative to Brent, consistent with the geographic proximity of European renewable energy companies to the epicentre of the energy crisis. The time-varying analysis additionally confirms that upper-tail connectedness peaked at 79.1% during the Nord Stream-1 closure episode (August–September 2022) before declining progressively to 41.2% by December 2024 providing the first empirical documentation of a geopolitical shock normalisation trajectory in the renewable energy equity system. Collectively, these findings carry concrete implications for three constituencies: investors are advised to supplement mean-variance frameworks with CVaR-based tail-risk measures and TTF-linked hedging instruments during periods of elevated geopolitical tension; regulators should incorporate scenario-based tail-risk requirements into capital buffer frameworks for institutions with clean energy exposure; and policymakers particularly within the European Union must recognise that the stability of renewable energy capital markets is structurally contingent on the stabilisation of natural gas pricing, rendering energy market reform not merely an industrial policy objective but a precondition for the integrity of the clean energy investment ecosystem.

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