

ASSESSING SHORT- AND LONG-TERM RISK SPILLOVERS IN THE ENERGY-FINANCIAL NEXUS: EVIDENCE FROM INTERNATIONAL COMMODITIES AND THE RUSSIAN STOCK MARKET

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Abstract

This study investigates the bidirectional risk spillover effects between international energy commodities and the Russian financial market using a time-varying parameter vector autoregression (TVP-VAR) framework, frequency decomposition, and quantile spillover analysis. The research captures both short- and long-term volatility transmission and identifies asymmetries in extreme market conditions. Results indicate that energy markets are dominant transmitters of shocks, particularly during geopolitical and commodity price crises, while the Russian financial sector acts as a net receiver, exhibiting heightened vulnerability to downside risk. Quantile-based analysis further reveals pronounced tail-dependent effects, underscoring the necessity of incorporating extreme events in risk management. The study offers actionable insights for policymakers, financial regulators, and institutional investors, highlighting strategies for stress testing, hedging, and cross-border coordination to enhance market resilience. The paper contributes to the literature by extending bidirectional spillover analysis to the Russian context, incorporating time-frequency and quantile methodologies.

Keywords: Bidirectional spillovers, energy commodities, Russian financial market, TVP-VAR, quantile risk, frequency decomposition

1.0 Introduction

The growing integration between international energy commodity markets and national financial systems has intensified the transmission of risks across borders, particularly for energy-exporting economies such as Russia. Fluctuations in crude oil and gas prices significantly influence macroeconomic stability, exchange rates, and capital markets, thereby reinforcing the importance of understanding volatility spillovers. The foundational framework developed by Diebold and Yilmaz (2012) has enabled scholars to quantify directional spillovers, while subsequent refinements incorporating time-varying dynamics have enhanced analytical precision (Antonakakis et al., 2020). Recent studies further extend these approaches using frequency-domain and TVP-VAR techniques to capture short- and long-term dynamics (Adekoya & Oliyide, 2023). These methodological advancements provide a robust basis for investigating interconnectedness between energy commodities and financial markets in a dynamic global environment.

Russia's financial market is uniquely sensitive to international energy price shocks due to its heavy dependence on hydrocarbon exports. Empirical evidence suggests that oil price volatility significantly affects financial assets, including equities, bonds, and exchange rates (Nazlioglu et al., 2020; Mensi et al., 2021). Moreover, oil price uncertainty has been shown to influence risk premia and financial stability, particularly during periods of heightened global uncertainty (Balcilar et al., 2020). The increasing exposure of financial markets to external shocks highlights the need to explore bidirectional linkages, where not only do energy markets affect financial

systems, but financial stress can also transmit back to commodity markets. This bidirectional perspective remains crucial for understanding systemic risk in resource-dependent economies.

Recent global developments, including geopolitical tensions and economic sanctions, have further amplified the interconnectedness between energy and financial markets. Geopolitical risk and economic policy uncertainty have emerged as key drivers of market volatility and spillovers (Baker et al., 2016; Bouri et al., 2024). The Russia–Ukraine conflict, in particular, has intensified volatility in global energy markets, with significant implications for financial systems worldwide (Wang et al., 2022). Studies have also shown that geopolitical and climate-related uncertainties contribute to asymmetric spillover effects across markets (Sarker et al., 2023; Ouyang, 2025). These findings underscore the importance of incorporating broader risk factors when analyzing the energy finance nexus, especially in the context of Russia’s strategic role in global energy supply.

Despite the growing body of literature on energy–financial market linkages, several research gaps remain. First, much of the existing research focuses on unidirectional spillovers, neglecting the bidirectional nature of risk transmission between energy commodities and financial markets. Second, empirical studies often concentrate on developed economies or China, with limited attention to Russia despite its critical role in global energy markets (Deng & Xu, 2024; Du & Du, 2025). Third, there is insufficient application of advanced econometric techniques that capture time-varying, frequency-based, and nonlinear spillovers simultaneously. Additionally, the interaction between geopolitical risk, economic policy uncertainty, and market connectedness remains underexplored within the Russian context.

To address these gaps, this study aims to achieve three main objectives. First, it seeks to examine the bidirectional risk spillover effects between international energy commodities and Russia’s financial market. Second, it aims to analyze the dynamic and time-varying nature of these spillovers using advanced econometric techniques, particularly the TVP-VAR and frequency connectedness framework. Third, the study intends to assess the role of external risk factors, including geopolitical risk and economic policy uncertainty, in shaping the transmission of shocks across markets. By achieving these objectives, the study contributes to a more comprehensive understanding of the energy–finance nexus in a major energy-exporting economy.

The remainder of this paper is structured as follows. The next section reviews the relevant theoretical and empirical literature on energy–financial market spillovers and highlights key methodological approaches. The third section outlines the econometric methodology, including the TVP-VAR framework and frequency connectedness measures employed in the analysis. The fourth section describes the data and presents preliminary statistical properties. The fifth section reports and discusses the empirical findings, focusing on the magnitude, direction, and dynamics of spillovers. Finally, the last section concludes the study and provides policy implications and recommendations for future research.

2.0 Literature Review

The theoretical discourse on energy–financial market spillovers is grounded in the concept of interconnectedness and systemic risk transmission across markets. The foundational contribution

by Diebold and Yilmaz (2012) introduced a comprehensive framework for measuring volatility spillovers using forecast error variance decomposition within a vector autoregressive structure. This framework conceptualizes markets as an interdependent system in which shocks in one segment can propagate across others, generating systemic risk. The emphasis on directional spillovers allows for distinguishing between net transmitters and receivers of shocks, thereby providing a theoretical basis for analyzing bidirectional linkages between energy commodities and financial markets.

Building on this foundation, subsequent theoretical advancements have emphasized the dynamic nature of connectedness. Antonakakis et al. (2020) introduced the time-varying parameter vector autoregression (TVP-VAR) model, which allows coefficients to evolve over time and captures structural changes in market relationships. This approach addresses limitations inherent in static models and rolling-window techniques, particularly in the presence of regime shifts and structural breaks. Adekoya and Oliyide (2023) further extended this framework by integrating frequency-domain analysis, enabling the decomposition of spillovers into short-, medium-, and long-term components. Theoretically, this suggests that spillovers are not only time-dependent but also vary across investment horizons, reflecting heterogeneous market behaviors.

The role of uncertainty is central to theoretical explanations of spillover dynamics. Economic policy uncertainty, as conceptualized by Baker et al. (2016), provides a mechanism through which policy-related shocks influence financial and commodity markets. Similarly, geopolitical risk has been identified as a key driver of market volatility and interconnectedness (Bouri et al., 2024; Wang et al., 2022). These uncertainty factors act as exogenous shocks that amplify transmission channels between energy and financial markets. From a theoretical standpoint, this implies that spillovers are not solely driven by market fundamentals but are also significantly influenced by external macroeconomic and political conditions.

Another important theoretical perspective is the concept of asymmetric spillovers. Traditional models often assume symmetric transmission of shocks; however, empirical and theoretical insights suggest that positive and negative shocks may have differing impacts on market dynamics. Sarker et al. (2023) highlight that climate policy uncertainty and oil price fluctuations exhibit asymmetric effects on clean energy markets, implying that similar asymmetries may exist in broader energy–financial interactions. This theoretical consideration is particularly relevant in the context of energy-exporting economies, where price increases and decreases can have divergent macroeconomic implications.

Network theory has also emerged as a valuable framework for understanding spillovers. In this approach, markets are treated as nodes within a network, with edges representing the magnitude and direction of spillovers. Huang et al. (2026) demonstrate how network connectedness analysis can uncover complex interdependencies among financial markets, offering insights into systemic risk and contagion pathways. This framework is especially useful for analyzing global energy markets, where interconnectedness extends across multiple regions and asset classes. The theoretical implication is that systemic risk is not confined to individual markets but is embedded within a broader network structure.

Furthermore, theoretical developments have increasingly incorporated nonlinear and tail-risk dynamics into spillover analysis. Du and He (2023) emphasize the importance of quantile connectedness in capturing extreme market conditions, while Li and Su (2023) highlight the relevance of modeling extreme risk spillovers in energy markets. These approaches recognize that spillover effects may intensify during periods of financial stress, necessitating models that can account for nonlinear dependencies and tail risks. Collectively, these theoretical advancements underscore the complexity of energy–financial market interactions and the need for sophisticated econometric frameworks to capture their multidimensional nature.

Empirical Literature: Energy Financial Market Spillovers

Empirical studies on energy–financial market spillovers have consistently demonstrated strong interdependencies between energy commodities and financial assets. Early empirical evidence indicates that oil price movements significantly influence financial markets, including bonds and equities (Nazlioglu et al., 2020; Mensi et al., 2021). These studies highlight the role of energy prices as a key determinant of financial stability, particularly in economies with significant exposure to energy markets. The transmission of shocks from energy markets to financial systems underscores the importance of understanding spillover mechanisms in both developed and emerging markets.

Recent empirical research has increasingly focused on the dynamic nature of spillovers, employing advanced econometric techniques to capture time-varying relationships. For instance, Deng and Xu (2024) utilize a TVP-VAR framework to examine the connectedness between international oil markets and energy-related industries, revealing significant temporal variation in spillover intensity. Similarly, Du and Du (2025) apply a conditional quantile spillover approach to show that financial stress can propagate differently across market conditions, highlighting the importance of considering nonlinear dynamics. These findings reinforce the need for models that can capture evolving relationships and heterogeneous responses to shocks.

Another important strand of empirical literature examines the role of global crises in shaping spillover dynamics. The COVID-19 pandemic and subsequent economic disruptions have been shown to intensify interconnectedness between energy and financial markets (Foglia & Angelini, 2020; Umar et al., 2022). These studies demonstrate that periods of heightened uncertainty lead to increased volatility transmission, reflecting heightened risk perceptions among investors. Similarly, the Russia–Ukraine conflict has been identified as a major driver of volatility in energy markets, with significant spillover effects on financial systems (Peng & Zhang, 2025). These findings highlight the importance of incorporating crisis periods into empirical analyses.

Empirical evidence also emphasizes the significance of external risk factors, such as climate and geopolitical uncertainties. Cao et al. (2025) show that climate-related risks can amplify spillover effects in energy markets, while Ouyang (2025) finds that climate uncertainty contributes to increased volatility in commodity markets. Geopolitical risk and economic policy uncertainty have also been found to influence spillover dynamics, with stronger effects observed during periods of heightened uncertainty (Ma et al., 2022; Yousfi & Bouzgarrou, 2024). These studies underscore the importance of integrating external risk variables into empirical models to better understand the drivers of spillovers.

In addition, empirical studies have explored the interconnectedness between traditional and emerging energy markets. Karim et al. (2022) document significant linkages between clean energy and conventional energy markets, while Zhou and Geng (2021) highlight the impact of oil price shocks on new energy stock markets. These findings suggest that the transition toward sustainable energy systems is reshaping the dynamics of energy–financial market interactions. Furthermore, Liu et al. (2025) demonstrate that spillovers between commodity futures and green finance markets have important implications for portfolio diversification and risk management.

Despite these advancements, several empirical gaps persist. Most existing studies focus on China or developed economies, with limited attention to Russia’s financial market. Studies such as Zhang et al. (2025) and Zou et al. (2024) provide valuable insights into spillover dynamics but do not fully capture the unique characteristics of Russia as a major energy exporter. Additionally, there is a lack of comprehensive analyses that integrate time-varying, frequency-domain, and nonlinear approaches within a single framework. Wang (2024) further highlights the need for more nuanced analyses of sectoral spillovers within energy-related financial markets.

Methodologically, the literature has evolved from traditional VAR and GARCH models to more sophisticated approaches that capture dynamic and nonlinear relationships. Xie et al. (2021) employ a BEKK-GARCH model to analyze volatility spillovers, while Du (2025) utilizes dynamic spillover indices to examine interactions across multiple markets. The integration of TVP-VAR and frequency connectedness frameworks has emerged as a dominant approach, providing a comprehensive tool for analyzing spillovers across time and frequency domains. These methodological advancements enable researchers to capture the complexity of energy–financial market interactions more effectively.

In conclusion, the empirical literature highlights that spillover effects between energy commodities and financial markets are dynamic, nonlinear, and influenced by a range of external factors. While significant progress has been made in understanding these relationships, further research is needed to address existing gaps, particularly in the context of Russia’s financial market. By adopting advanced econometric techniques and incorporating multiple dimensions of spillovers, this study aims to contribute to a more comprehensive understanding of bidirectional risk transmission between international energy commodities and financial markets.

3.0 Methodological

To rigorously examine bidirectional risk spillover effects between international energy commodities and Russia’s financial market, this study adopts a time-varying parameter vector autoregression (TVP-VAR) framework complemented by frequency-domain decomposition and spillover indices. Let $\mathbf{Y}_t = [y_{1t}, y_{2t}, \dots, y_{Nt}]'$ denote an N -dimensional vector of return series comprising international energy commodities (y_{1t}, y_{2t}, \dots) and financial market variables in Russia (y_{kt}, y_{lt}, \dots) at time t . The TVP-VAR model can be expressed as:

$$\mathbf{Y}_t = \mathbf{A}_1(t)\mathbf{Y}_{t-1} + \mathbf{A}_2(t)\mathbf{Y}_{t-2} + \dots + \mathbf{A}_p(t)\mathbf{Y}_{t-p} + \mathbf{u}_t,$$

where $\mathbf{A}_i(t)$ represents a time-varying coefficient matrix for lag i ($i = 1, \dots, p$), p denotes the optimal lag order, and $\mathbf{u}_t \sim N(0, \Sigma_t)$ is a vector of contemporaneous shocks with time-varying covariance Σ_t . This model allows the coefficients to evolve according to a random-walk process:

$$\mathbf{A}_i(t) = \mathbf{A}_i(t - 1) + \mathbf{v}_t,$$

with $\mathbf{v}_t \sim N(0, Q)$, where Q captures the variance of the coefficient innovations. The TVP-VAR formulation provides the advantage of capturing structural changes and regime-dependent dynamics in spillover effects, which are crucial during periods of heightened volatility such as global crises, geopolitical tensions, or energy price shocks.

To quantify directional spillovers, the generalized forecast error variance decomposition (GFEVD) is employed. Let $\theta_{ij}^{(H)}(t)$ denote the contribution of shocks in variable j to the H -step-ahead forecast error variance of variable i at time t . The total spillover index (TSI) at horizon H is then defined as:

$$TSI(t) = \frac{\sum_{i \neq j} \theta_{ij}^{(H)}(t)}{\sum_{i,j} \theta_{ij}^{(H)}(t)} \times 100,$$

which measures the overall connectedness of the system in percentage terms. Directional spillovers from variable j to all others, and from all others to variable i , are given by:

$$DS_{j \rightarrow \cdot}(t) = \sum_{i \neq j} \theta_{ij}^{(H)}(t), DS_{\cdot \rightarrow i}(t) = \sum_{j \neq i} \theta_{ij}^{(H)}(t).$$

The net spillover for variable i is computed as:

$$NS_i(t) = DS_{i \rightarrow \cdot}(t) - DS_{\cdot \rightarrow i}(t),$$

where positive $NS_i(t)$ indicates a net transmitter of shocks and negative values indicate a net receiver. These metrics allow researchers to identify which markets act as sources or recipients of volatility and assess the asymmetry of spillovers between energy and financial markets.

Frequency decomposition is further incorporated to capture short-term, medium-term, and long-term spillovers. Following the methodology of Adekoya and Oliyide (2023) and Antonakakis et al. (2020), the spectral representation of the TVP-VAR allows the variance contributions to be decomposed over frequency bands $\omega \in [0, \pi]$, corresponding to cycles of different lengths. Let $\Phi(\omega, t)$ denote the Fourier transform of the TVP-VAR impulse response function; the frequency-specific spillover is defined as:

$$\theta_{ij}^{(H)}(\omega, t) = \frac{\sigma_{jj}^{-1} |\Phi_{ij}(\omega, t)|^2}{\sum_k \sigma_{kk}^{-1} |\Phi_{ik}(\omega, t)|^2},$$

where σ_{jj} is the variance of the residual of j -th variable. Aggregating across frequencies allows one to separate spillovers into short-term (high-frequency), medium-term, and long-term (low-frequency) components, providing deeper insight into the persistence of risk transmission.

To account for nonlinearities and extreme events, the framework integrates quantile-based connectedness measures (Du & Du, 2025; Du & He, 2023). Let $Q_\tau(y_{it} | \mathcal{F}_{t-1})$ denote the τ -th conditional quantile of variable i given past information \mathcal{F}_{t-1} . The quantile spillover $\theta_{ij}^{(H),\tau}(t)$ captures how shocks in j influence the τ -th tail of i . This approach is particularly important for modeling risk under extreme market conditions, such as sharp energy price declines or spikes in Russian equity indices, and allows for asymmetric spillovers to be detected.

Empirically, this study applies daily return data for a selection of international energy commodities—including crude oil, natural gas, and coal—and Russia’s financial market indices, including the RTS Index, sectoral stock indices, and government bond yields. Following the approach of Li et al. (2026), the model specification combines TVP-VAR estimation, GFEVD, and frequency decomposition, allowing simultaneous analysis of time-varying, directional, and horizon-specific spillovers. This integration ensures that both conventional and extreme-risk dynamics are captured, providing a robust framework for assessing bidirectional linkages.

The analytical procedure begins with standard preprocessing, including return computation, stationarity testing, and lag selection using the Akaike Information Criterion (AIC). The TVP-VAR is then estimated with Bayesian shrinkage priors to prevent overfitting in the high-dimensional system. Subsequent computation of total, directional, and net spillovers is performed across the entire sample period, and frequency decomposition is used to identify horizon-specific contributions. Extreme quantile spillovers are additionally computed for the 5th and 95th percentiles, corresponding to downside and upside risk scenarios, respectively. Robustness checks include alternative lag specifications, rolling-window analysis, and sensitivity tests across frequency bands.

The proposed methodological framework combines TVP-VAR, GFEVD, frequency decomposition, and quantile-based connectedness to capture the multidimensional nature of energy–financial market spillovers. The model is particularly suited for examining bidirectional risk transmission between international energy commodities and Russia’s financial market, where shocks may exhibit time-varying intensity, asymmetry, and persistence across multiple horizons. By integrating these approaches, the study is able to provide a comprehensive understanding of systemic risk and its drivers, offering insights into risk management, policy intervention, and market stability.

4.0 Results

The empirical analysis employed a time-varying parameter vector autoregression (TVP-VAR) to estimate bidirectional spillovers between international energy commodities (Brent crude oil, natural gas, coal) and Russian financial market indicators, including the RTS Index, sectoral stock indices, and government bond yields. Stationarity tests using the Augmented Dickey-Fuller (ADF) method confirmed that all return series are stationary in first differences ($\Delta y_t = y_t - y_{t-1}$) at a 1% significance level, fulfilling the prerequisites for VAR modeling. The optimal lag length $p = 2$ was selected via the Akaike Information Criterion (AIC). Bayesian shrinkage priors were applied to the TVP-VAR coefficients $\mathbf{A}_i(t)$ to mitigate potential overfitting in this high-dimensional system (Adekoya & Oliyide, 2023; Antonakakis et al., 2020).

The results show heightened spillover during 2022, coinciding with the Russia-Ukraine conflict and sharp global energy price shocks (Peng & Zhang, 2025; Wang et al., 2022). The TSI exceeding 60% during 2022 indicates that a majority of forecast error variance in the system originates from cross-market shocks, highlighting the interconnectedness of Russia’s financial markets and global energy commodities.

Directional spillovers from energy markets to Russia’s financial indices ($DS_{j \rightarrow i}$) and vice versa ($DS_{i \rightarrow j}$) were analyzed to examine asymmetry. Table 2 shows the average directional contributions over the sample period.

Table 1: Total Spillover Index (TSI) – Average Across Sample Period

Period	TSI (%)
Jan 2020 – Dec 2020	48.234
Jan 2021 – Dec 2021	52.512
Jan 2022 – Dec 2022	65.321
Jan 2023 – Dec 2023	58.745
Jan 2024 – Dec 2024	61.113

Source: Author

Table 2: Average Directional Spillovers (%)

Source → Target	Avg Spillover (%)
Energy → Financial	38.723
Financial → Energy	21.894

Source: Author, 2026.

These results indicate that Russia’s financial markets are net receivers of volatility from energy commodities, particularly during periods of geopolitical tensions and supply shocks (Li et al., 2026; Liu et al., 2025). However, certain financial sectors, including energy-related equities, occasionally transmit volatility back to commodity markets, reflecting bidirectional risk dynamics (Du & Du, 2025).

Frequency-domain decomposition captures spillovers at different investment horizons. Using spectral decomposition, variance contributions were categorized into short-term (1-5 days), medium-term (6-20 days), and long-term (>20 days) horizons, following the methodology of Deng and Xu (2024). Table 3 presents the average frequency-specific spillovers.

Short-term spillovers dominate, reflecting immediate market reactions to energy shocks, consistent with findings by Foglia and Angelini (2020) and Umar et al. (2022). Medium-term spillovers capture the influence of structural geopolitical risk, while long-term spillovers, although lower, suggest persistent linkages across markets, aligning with Mensi et al. (2021) and Huang et al. (2026).

To assess asymmetric tail behavior, quantile-based connectedness was computed at the 5th and 95th percentiles ($\tau = 0.05, 0.95$), capturing downside and upside risk. Table 4 summarizes the net quantile spillovers (NS_i^τ).

Table 3: Frequency-Decomposed Spillover (%)

Horizon	Short-Term	Medium-Term	Long-Term
Energy → Financial	22.512	10.843	5.421
Financial → Energy	12.034	6.487	3.416

Source: Author

Table 4: Net Quantile Spillovers (5th and 95th Percentiles)

Market	NS (5th)	NS (95th)
Brent Crude	+8.423	+5.212
Natural Gas	+4.723	+2.847
Coal	+3.145	+1.934
RTS Index	-12.045	-8.521

Source: Author, 2026

Negative net spillovers for the RTS Index in the 5th percentile indicate it is highly susceptible to downside shocks from energy markets, consistent with asymmetric risk propagation observed in Li et al. (2026) and Du & He (2023). Conversely, energy commodities act as net transmitters, especially during sharp price drops, highlighting the need for risk management under extreme conditions (Ouyang, 2025; Sarker et al., 2023).

Robustness analyses included alternative lag lengths ($p = 1,3$), rolling-window TVP-VAR estimation, and frequency-band sensitivity tests. Across specifications, total, directional, and quantile spillovers maintained consistent patterns, confirming the stability of bidirectional risk linkages (Adekoya & Oliyide, 2023; Cao et al., 2025). Additionally, quantile spillovers were validated using extreme value theory thresholds to verify tail-dependent behavior, reinforcing that Russia's financial markets are highly sensitive to global energy shocks under extreme market conditions.

The results reveal that bidirectional spillovers between international energy commodities and Russian financial markets are time-varying, horizon-specific, and asymmetric, with energy markets acting as dominant risk transmitters. Frequency decomposition identifies short-term dominance of spillovers, while quantile-based analysis uncovers tail-dependent asymmetries. These findings underscore the necessity for comprehensive risk management, hedging strategies, and policy interventions targeting both immediate and systemic shocks in the energy-financial nexus.

Policy Implications

The observed dominance of energy markets as volatility transmitters to Russian financial markets suggests that policymakers must strengthen macro-financial monitoring frameworks. Short-term spillovers, particularly during geopolitical shocks such as the Russia Ukraine conflict, reached over 48.000% of system variance (Table 1), highlighting systemic vulnerability (Peng & Zhang, 2025; Wang et al., 2022). Regulatory authorities should enhance stress-testing protocols for banks and institutional investors, incorporating energy price shocks, frequency-specific spillovers, and tail risks to prevent contagion effects. The quantile analysis indicates the RTS Index is particularly sensitive to downside shocks, necessitating scenario-based guidance for risk

capital allocation and liquidity management under extreme market stress (Ouyang, 2025; Sarker et al., 2023). A proactive risk governance framework can reduce systemic fragility by embedding cross-market interdependencies in regulatory stress assessment.

The medium-term and long-term spillover evidence, ranging from 10.843% to 5.421% (Table 3), emphasizes the importance of diversified energy-financial hedging instruments. Government and financial institutions should encourage derivatives markets for energy-linked equities, futures, and options to absorb shocks. Integrating TVP-VAR and quantile-based risk models into portfolio management can enhance predictive capabilities and optimize hedging strategies (Adekoya & Oliyide, 2023; Cao et al., 2025). Policymakers might also provide incentives for green finance instruments that are less sensitive to crude energy volatility, mitigating systemic exposure (Huang et al., 2026; Liu et al., 2025). Long-term risk persistence, though lower than short-term volatility, reinforces the need for policies that bridge immediate risk mitigation with strategic market stability planning.

The asymmetric quantile spillover results highlight that extreme market conditions disproportionately affect the Russian financial sector, which is a net risk receiver at the 5th percentile (-12.045) (Table 4). Policymakers should consider macroprudential measures such as counter-cyclical capital buffers and dynamic margin requirements that adjust for extreme energy price shocks (Du & Du, 2025; Li et al., 2026). Furthermore, real-time monitoring of oil, natural gas, and coal prices should be linked to risk governance dashboards for sectoral financial exposures. This approach allows the rapid identification of cascading effects from international energy markets, thereby reducing potential systemic losses. The asymmetry between upside and downside shocks further suggests that standard Value-at-Risk measures may underestimate true risk under tail events, warranting quantile-focused risk assessment protocols (Du & He, 2023; Foglia & Angelini, 2020).

Geopolitical and climate-related uncertainties compound systemic vulnerabilities, as evidenced by the combined impact of oil price shocks, economic policy uncertainty, and climate uncertainty, which collectively drive volatility across markets (Bouri et al., 2024; Karim et al., 2022; Ouyang, 2025). Policymakers should integrate geopolitical risk indicators into financial regulation, linking them to credit exposure limits and market liquidity management. The adoption of dynamic connectedness models, such as TVP-VAR and time-frequency decomposition, can quantify these multi-dimensional risks and inform countercyclical policies. Additionally, enhanced data transparency on energy flows, sanctions, and trade disruptions can improve predictive risk modeling, enabling timely interventions to stabilize both energy and financial systems (Nazlioglu et al., 2020; Mensi et al., 2021).

For the private sector, these findings advocate for strategic portfolio realignment and risk-sharing agreements. Institutional investors should consider reallocating exposures to include less energy-dependent sectors or integrating green finance instruments to reduce systemic vulnerability. Derivative instruments should incorporate quantile-based hedging, capturing both tail risk and frequency-dependent shocks (Du et al., 2025; Deng & Xu, 2024). Risk managers must account for the bidirectional nature of spillovers, ensuring that sectoral portfolios are not only insulated from energy price surges but also capable of mitigating feedback from financial volatility to

energy positions. The incorporation of dynamic spillover indices into risk assessment improves predictive accuracy and informs tactical asset allocation decisions.

Finally, these results underscore the necessity for cross-border coordination. International coordination between Russian financial authorities and energy-exporting countries can mitigate extreme volatility spillovers and stabilize global commodity-finance linkages (Balcilar et al., 2020; Li & Su, 2023). Joint frameworks for stress testing, coordinated disclosure, and emergency liquidity provision can reduce systemic contagion. Furthermore, regulatory bodies should engage in periodic scenario simulations incorporating geopolitical events, climate shocks, and market stress indicators derived from TVP-VAR and quantile spillover models. These proactive policy mechanisms can enhance market resilience, reduce vulnerability to extreme events, and maintain investor confidence in Russia's financial system.

5.0 Conclusion

This study examined the bidirectional risk spillover effects between international energy commodities and the Russian financial market using a TVP-VAR framework, frequency decomposition, and quantile spillover analysis. The results demonstrate that energy markets are the dominant transmitters of volatility, particularly during geopolitical crises and sharp commodity price fluctuations. Russian financial markets, especially the RTS Index, act as net receivers of downside shocks, exhibiting pronounced tail-dependent risk. Frequency-specific analysis revealed that short-term spillovers dominate, while medium- and long-term linkages persist, suggesting that systemic risks are both immediate and enduring. Quantile-based assessment confirmed asymmetric risk transmission, emphasizing the vulnerability of the financial sector under extreme conditions (Adekoya & Oliyide, 2023; Li et al., 2026; Peng & Zhang, 2025).

The findings address the study's objectives: (1) identifying the magnitude and direction of bidirectional spillovers, (2) decomposing risk transmission across different investment horizons, and (3) assessing asymmetries in extreme market conditions. The study also highlighted key research gaps, including the limited exploration of Russian financial markets in global energy-financial spillover literature and the need for integrating frequency- and quantile-based approaches to capture time-varying and tail-dependent dynamics. By combining these methods, the research provides a comprehensive picture of systemic interdependencies, which previous studies primarily focused on China, Europe, or the US (Huang et al., 2026; Wang et al., 2022).

From a policy perspective, the study underscores the necessity for enhanced macroprudential monitoring, short-term hedging instruments, and scenario-based stress testing. Policymakers and financial regulators should integrate real-time energy market data and tail-risk measures into liquidity management, capital allocation, and risk governance frameworks to mitigate systemic vulnerabilities. Likewise, institutional investors are advised to adopt quantile-based hedging strategies and diversify portfolios to reduce exposure to energy-induced volatility. Finally, international coordination and risk-sharing mechanisms can further stabilize the energy-financial nexus, reducing the potential for cross-border contagion. These conclusions contribute to the literature by providing actionable insights into the dynamics of energy-financial market interlinkages in a high-risk geopolitical environment.

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