SYSTEMIC FRAGILITY IN EUROPEAN CAPITAL MARKET INFRASTRUCTURES: A REVIEW OF FINANCIAL, OPERATIONAL, CYBER, AND GEOPOLITICAL RISKS

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Abstract

This paper reviews the academic and regulatory literature on systemic fragility in European capital market infrastructures (CMIs), focusing on the interaction between financial, operational, cyber, and geopolitical sources of risk. Existing reviews typically examine individual dimensions of systemic risk, such as financial contagion, cyber resilience, or operational risk, in isolation. In contrast, this review integrates these complementary strands of the literature into a unified perspective centred on European capital market infrastructures. The paper synthesises recent theoretical and empirical evidence on the mechanisms through which shocks propagate across European financial markets, highlighting the role of financial interconnectedness, operational dependencies, cyber vulnerabilities, and geopolitical uncertainty in amplifying systemic fragility. The review shows that systemic vulnerability is inherently multidimensional and cannot be adequately assessed through traditional market-based indicators alone. Instead, the resilience of European CMIs depends on the interaction between financial, operational, technological, and geopolitical factors. These findings underscore the need for integrated macroprudential and operational resilience frameworks capable of addressing the evolving sources of systemic vulnerability and strengthening the resilience of European capital market infrastructures.

Keywords: systemic risk, financial stability, operational vulnerabilities, geopolitical shocks

JEL Classification: G01, G10, G20

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1. Introduction

Financial stability and the resilience of European capital market infrastructures (CMIs) play a central role in ensuring the smooth functioning of the financial system and the efficient allocation of resources across the economy. Capital market infrastructures, including trading venues, central counterparties (CCPs), central securities depositories (CSDs), and payment and settlement systems, form the backbone of modern financial markets by facilitating liquidity provision, risk sharing, and price discovery. In addition to financial interconnections, CMIs exhibit operational interdependencies, including reliance on IT systems, third-party services, and cross-border settlement infrastructures, which can amplify vulnerabilities during crises (Holt & Lampke, 2010; Croicu & Călin, 2024).

However, rising financial integration, technological complexity, and heightened geopolitical uncertainty have significantly increased systemic fragility. The literature on financial fragility emphasises that deeply interconnected financial systems are inherently vulnerable to contagion and non-linear shock propagation. Early theoretical contributions highlight how interbank linkages and incomplete markets can amplify localised shocks into systemic crises (Allen & Gale, 2000). Subsequent studies demonstrate that diversification and interconnectedness, while beneficial in normal times, may exacerbate losses under extreme conditions, generating so-called “diversification disasters” (Ibragimov, Jaffee & Walden, 2010).

Early regulatory frameworks largely relied on microprudential approaches focused on the soundness of individual institutions. However, a growing body of literature highlights that such measures are insufficient to address system-wide vulnerabilities arising from interconnectedness and common exposures (Borio, 2003). The global financial crisis reinforced the need for macroprudential policies aimed at preserving financial stability from a systemic perspective (IMF, 2011, Croicu et al., 2023).

More recent network-based approaches show that the stability of financial systems depends critically on their structure. Highly interconnected networks may either absorb or amplify shocks depending on the distribution of exposures and the concentration of key nodes (Acemoglu, Ozdaglar & Tahbaz-Salehi, 2015). These insights are particularly relevant for European CMIs operating in an integrated yet heterogeneous regulatory and economic environment.

Financial stability remains a complex and evolving concept. Rather than representing the absence of crises, stability is increasingly defined as the capacity of the financial system to absorb shocks and continue performing its essential functions (Ballouk et al., 2024). Capital market infrastructures occupy a distinctive position within the financial system, as they combine financial intermediation functions with critical operational and technological processes. Unlike banks or asset managers, CMIs concentrate risk through clearing, settlement, and collateral management mechanisms, making them potential single points of failure in periods of stress (Gofman, 2017).

Systemic fragility in CMIs arises not only from financial exposures but also from operational, cyber, and liquidity shocks, which can amplify instability during crises (Kopp, Kaffenberger & Jenkinson, 2017). From this perspective, systemic fragility reflects latent vulnerabilities that can materialize under stress, driven by structural, operational, and exogenous factors. Empirical research highlights the importance of market infrastructures and sectoral interdependencies in shaping financial stability outcomes (Lupu et al., 2025).

In recent years, the literature has expanded beyond traditional macroeconomic and microprudential determinants of fragility to include cyber risks and geopolitical shocks. These include digital disruptions, energy market shocks, and pandemics, which propagate through financial and operational channels, affecting both infrastructure functionality and market stability. Cyber incidents and digital disruptions have emerged as potential sources of systemic risk, capable of undermining market confidence and operational continuity (Kopp, Kaffenberger & Jenkinson, 2017; Tosun, 2021). At the same time, geopolitical crises and energy-related shocks have demonstrated their capacity to transmit instability across financial markets and sectors (Konovalova & Abuzov, 2023; Lupu et al., 2021).

Despite these advances, several gaps remain in the existing literature. While a substantial body of research investigates systemic risk through market-based indicators, network structures, and entropy-based methodologies (Billio et al., 2016; Lupu et al., 2020), most studies focus either on financial institutions or on asset price dynamics, with limited attention to the operational and infrastructural dimension of systemic fragility. In particular, the role of capital market infrastructures as amplifiers of financial, cyber, and geopolitical shocks remains underexplored, and sectoral analyses of systemic risk transmission are rarely linked to the operational resilience and functioning of CMIs.

This paper addresses these gaps by integrating the existing literature on financial, operational, cyber, and geopolitical sources of systemic fragility into a unified perspective centered on European capital market infrastructures. By synthesizing recent theoretical and empirical evidence, the review highlights the key transmission channels of systemic risk and identifies the main factors shaping the resilience of European CMIs. In doing so, it provides a conceptual basis for future research and offers policy-relevant insights for strengthening macroprudential supervision and the operational resilience of European capital market infrastructures.

The remainder of the paper is organized as follows. Section 2 describes the data and methodology. Section 3 presents and discusses the empirical results. Section 4 concludes and outlines the main implications of the findings.

2. Data and methodology

This study adopts a narrative literature review approach to examine the main sources and transmission channels of systemic fragility in European capital market infrastructures (CMIs). The review draws on seminal contributions as well as recent academic and regulatory publications covering the period 2000–2025. Relevant studies were identified through searches of major academic databases, including JSTOR, ScienceDirect, Scopus, MDPI, and SpringerLink, complemented by reports published by international institutions such as the International Monetary Fund (IMF) and the Bank for International Settlements (BIS).

The literature search was conducted using combinations of keywords including systemic risk, financial fragility, capital market infrastructures, cyber risk, operational risk, geopolitical risk, and European capital markets. Priority was given to peer-reviewed journal articles, institutional reports, and empirical studies employing quantitative or network-based methodologies.

Rather than providing a statistical meta-analysis, the review synthesises the existing literature from a thematic perspective. The selected studies are organised into four complementary dimensions of systemic fragility—financial, operational, cyber, and geopolitical—to identify the principal transmission channels of systemic risk, the methodological approaches adopted in the literature, and the main research gaps relevant to the resilience of European capital market infrastructures.

3. Results

3.1 Financial fragility and systemic vulnerabilities

Financial fragility describes the susceptibility of financial systems to shocks that can propagate across institutions, markets, and sectors, potentially leading to systemic crises (Acemoglu, Ozdaglar & Tahbaz-Salehi, 2015; Ballouk et al., 2024). Interconnectedness, market concentration, and the complexity of financial instruments are widely recognised as key amplifiers of systemic risk (Ibragimov, Jaffee & Walden, 2010).

Existing research broadly emphasises that systemic risk is largely rooted in the dense network of interconnections among financial institutions. While these linkages facilitate liquidity provision and risk sharing under normal conditions, they also act as powerful transmission channels for shocks (Wang et al., 2018; Gofman, 2017), allowing localised disturbances to cascade rapidly across markets and institutions. Consequently, systemic fragility emerges not only from the weaknesses of individual institutions, but also from the structural characteristics of the financial network, including the distribution of exposures, concentration of critical nodes, and connectivity of systemically important infrastructures.

Empirical research has proposed a range of indicators to quantify systemic vulnerability, including measures derived from conditional tail risk and network spillovers. Applying CoVaR and MES to the Romanian equity market, Călin and Lupu (2026b) show that carbon-price innovations are associated with heterogeneous systemic-risk responses, with transition risk being concentrated in carbon-exposed non-financial firms rather than financial intermediaries. Similarly, Croicu (2026) combines BSADF-based bubble detection with market-based systemic risk measures to demonstrate that speculative bubbles are a recurrent feature of shadow banking institutions, highlighting the importance of continuous macroprudential monitoring. Extending this evidence, Călin et al. (2026) show that conventional systemic risk measures exhibit a pro-cyclical bias, tending to underestimate the buildup of vulnerabilities during speculative expansions while capturing systemic stress only after bubbles collapse, suggesting that bubble detection provides a valuable complement to traditional systemic risk indicators. Lupu et al. (2026) provide evidence that highly volatile bubble episodes are consistently associated with elevated systemic risk across multiple indicators, with

vulnerabilities remaining significant throughout all phases of the bubble lifecycle rather than being confined to the bursting stage.

Other recent contributions introduce composite fragility indices designed to capture the sensitivity of financial systems to asset price bubbles and speculative dynamics, showing that fragility intensifies during periods of excessive risk-taking (Lupu et al., 2025). Recent studies increasingly employ hybrid indicators combining fragility indices, network metrics, and entropy-based measures to account for financial, operational, and sectoral risks simultaneously.

Within the European context, cross-country empirical analyses provide valuable insights into how national market structures and policy frameworks shape systemic fragility. The literature consistently documents heterogeneous fragility patterns across European financial markets, with Eastern European countries exhibiting significant cross-country variation in systemic vulnerability. Empirical evidence based on dimension-reduction techniques, such as Principal Component Analysis and the Absorption Ratio, shows that individual markets contribute differently to overall systemic risk, with macroeconomic conditions and policy perceptions playing an important role in shaping these dynamics (Lupu et al., 2018). These findings support the case for differentiated and country-specific macroprudential strategies within the European financial system.

At the sectoral level, studies focusing on European stock markets demonstrate that certain industries act as persistent generators of systemic risk. Albu, Lupu and Călin (2017) highlight the role of sectoral interdependencies in amplifying market-wide instability, reinforcing the relevance of network-based monitoring frameworks for European capital market infrastructures. In Eastern European countries, stock market fragility has been closely linked to macroprudential policy effectiveness, market liquidity, and structural characteristics, underscoring the importance of tailored regulatory interventions (Albu et al., 2014; Albu et al., 2015; Lupu et al., 2018; Călin & Lupu, 2026a).

Network effects play a central role in shaping these dynamics. Dense interconnections within and across CMIs can facilitate rapid shock transmission, reinforcing the need for network-based monitoring frameworks that move beyond institution-level indicators (Acemoglu, Ozdaglar & Tahbaz-Salehi, 2015).

3.2 Cyber and operational vulnerabilities

The increasing digitalization of capital market infrastructures has introduced new forms of operational risk. Cyber incidents, including ransomware attacks, distributed denial-of-service (DDoS) events, and data breaches, can disrupt trading, settlement, and clearing processes, with potential systemic consequences (Kopp, Kaffenberger & Jenkinson, 2017; Corbet & Gurdgiev, 2019).

Empirical evidence suggests that cyber-attacks can affect market activity and volatility, particularly when incidents undermine investor confidence or impair critical infrastructure (Tosun, 2021).

From a systemic perspective, cyber risk differs from traditional operational risk due to its potential to simultaneously affect multiple institutions and infrastructures. Moreover, operational interdependencies, including IT service providers and clearing relationships, create channels through which cyber or technical failures can propagate systemically (Corbet & Gurdgiev, 2019).

Chida et al. (2026) provide evidence that cyber shocks affecting banks' intermediation capacity are associated with future systemic fragility, suggesting that incident-based cyber risk indicators can complement traditional tools used for financial stability monitoring. A substantial body of literature has examined systemic risk in the banking sector, focusing on a wide range of transmission channels, including market, credit, liquidity, operational, and more recently cyber-related risks (Aldasoro et al., 2020; Boungou, 2023; Kotidis & Schreft, 2025).

Using a connectedness framework, Gaies et al. (2026) demonstrate that cyber risk contributes to systemic financial instability through asymmetric spillover effects, with market fear amplifying contagion, particularly during bearish market conditions.

Entropy-based methodologies have been increasingly adopted in the literature as effective tools for capturing the non-linear and time-varying nature of systemic risk transmission across sectors, by quantifying uncertainty and information dispersion within interconnected financial and operational networks. Recent contributions using Bayesian entropy frameworks model information flows and uncertainty propagation within financial systems, enabling the identification of dominant risk-transmitting sectors over time (Lupu et al., 2020). Empirical evidence suggests that financial, industrial, and energy sectors frequently emerge as systemic risk hubs, particularly during periods of heightened stress, thereby highlighting the limitations of traditional linear correlation-based measures.

From the perspective of capital market infrastructures, entropy-based approaches are particularly relevant, as they capture abrupt regime shifts and amplification mechanisms that may arise from operational disruptions or cyber incidents. By focusing on uncertainty spillovers rather than price co-movements alone, such frameworks provide valuable insights into how operational shocks can evolve into system-wide fragility (Lupu et al., 2020), reinforcing the need for monitoring tools that integrate financial and operational dimensions of risk. Scenario-based stress tests complement these approaches by simulating compound shocks, including operational, cyber, and financial disturbances, to assess system-wide resilience.

3.3 Geopolitical risks

Geopolitical shocks have emerged as significant drivers of financial instability in Europe. Events such as the COVID-19 pandemic and the Russia–Ukraine conflict triggered sharp increases in volatility, disrupted energy markets, and altered cross-market correlations (Konovalova & Abuzov, 2023; Nimani & Spahija, 2023; Hu et al., 2025).

Growing evidence suggests that geopolitical risk represents an important driver of systemic risk across a wide range of financial markets and institutions. In cryptocurrency markets, Lau et al. (2026) demonstrate that US–China tensions exert a stronger influence on systemic interconnectedness than broader geopolitical risk measures. Similar evidence is reported for traditional financial markets, where Zhong et al. (2026) show that domestic geopolitical shocks amplify systemic tail risk spillovers across major Chinese financial sub-markets. The banking sector appears equally vulnerable. Gabbiadini et al. (2025) find that greater exposure to foreign geopolitical risk significantly increases European banks' systemic risk, while Wang et al. (2025) provide cross-country evidence that geopolitical uncertainty raises systemic risk through higher individual bank risk, deteriorating asset quality, and the bursting of asset price bubbles, although stronger regulatory frameworks mitigate these effects. Beyond financial institutions, geopolitical risk also intensifies systemic spillovers in the real economy. Liu et al. (2024) show that geopolitical shocks amplify systemic risk spillovers among global energy firms through both direct and indirect channels, with contagion propagating across countries via geographic proximity and energy trade linkages. Sectoral analyses highlight the strategic role of the energy sector in transmitting geopolitical risk to financial markets. Empirical studies

show that energy-related shocks generate systemic spillovers, affecting equity markets and broader financial stability in Europe (Lupu et al., 2021). These spillovers complicate traditional risk-monitoring frameworks, which often fail to account for non-linear and delayed transmission channels.

Existing literature has highlighted the energy sector as a key transmitter of systemic risk in European markets. Nevrla (2020) uses a dynamic factor copula approach to quantify the spillovers between European energy and financial sectors, highlighting the prominent role of energy companies during crisis periods. Tiwari et al. (2020) and Wu et al. (2021) provide empirical evidence that shocks in energy prices propagate to equity and derivative markets, affecting both sectoral and infrastructure stability. Entropy-based approaches, as discussed by Lupu et al. (2020) and Billio et al. (2016), further allow for modelling non-linear and time-varying spillovers, underscoring the importance of integrating energy sector dynamics in systemic risk assessments.

The literature also points to methodological challenges in measuring geopolitical risk, as standard financial indicators may not fully capture political uncertainty or its interaction with market expectations (Petrov, Hentov & Zumbo, 2018). Scenario-based approaches and stress-testing exercises are therefore increasingly advocated as tools for assessing resilience under geopolitical stress.

For European capital market infrastructures, such shocks imply heightened operational and liquidity risks, as energy-driven disturbances affect clearing margins, collateral values, and settlement processes, amplifying systemic fragility beyond asset price volatility. Operational dependencies related to collateral management, settlement cycles, and margining mechanisms are particularly sensitive to energy price volatility and geopolitical uncertainty. In this context, scenario-based stress testing and entropy-based models provide valuable tools for quantifying spillovers across sectors and infrastructures under extreme geopolitical conditions, reinforcing the systemic relevance of CMIs during periods of heightened geopolitical stress (Lupu et al., 2021; Nevrla, 2020).

3.4 Measurement frameworks and indices

Beyond identifying individual sources of fragility, current research has increasingly focused on developing integrated measurement frameworks capable of capturing the joint dynamics of financial, operational, and macroeconomic risks (Iancu, 2026).

The measurement of systemic fragility has increasingly relied on multivariate and dimension-reduction techniques designed to capture common risk factors. Indicators such as the Absorption Ratio, derived from principal component analysis, have been shown to provide valuable insights into the degree of systemic interconnectedness and vulnerability (Kritzman et al., 2011; Lupu et al., 2018).

Beyond cyber and geopolitical dimensions, macroeconomic fundamentals continue to influence systemic fragility. Volatility dynamics, market capitalization, and macroeconomic indicators such as GDP growth and inflation shape vulnerability patterns across European markets (Lupu et al., 2025).

Comparative studies reveal that Eastern European markets tend to exhibit higher sensitivity to global shocks and policy changes, reflecting differences in market depth, liquidity, and investor behavior (Albu, Lupu & Călin, 2017). These findings reinforce the need for differentiated macroprudential strategies within the European financial architecture.

Recent advances increasingly combine network metrics, entropy-based measures, Bayesian techniques, and scenario analysis to provide a comprehensive assessment of systemic fragility under compound financial, operational, and geopolitical shocks. Such integrated frameworks are particularly suited for evaluating the resilience of capital market infrastructures, where financial, operational, and geopolitical risks interact non-linearly (Lupu et al., 2021).

Despite these advances, the literature points to a persistent gap between market-based systemic risk indicators and the operational realities of CMIs. Traditional measures often focus on price-based co-movements and tail dependencies, while underestimating the role of operational disruptions, liquidity constraints, and institutional design. Composite frameworks integrating network analysis, entropy-based measures, and stress-testing exercises address these limitations, offering a holistic perspective on systemic fragility (Billio et al., 2016).

These limitations are particularly relevant for capital market infrastructures, where systemic fragility emerges not only from financial interconnectedness, but also from operational dependencies and external shocks, reinforcing the need for integrated analytical perspectives such as the one proposed in this review.

4. Conclusions

European capital market infrastructures are inherently exposed to multiple, interacting sources of systemic fragility. Financial interconnections, market concentration, and the complexity of instruments create vulnerabilities that can propagate quickly across institutions and borders. Cyber threats have emerged as a structural component of these vulnerabilities, capable of generating significant disruptions to liquidity, volatility, and investor confidence. Operational interdependencies and sectoral linkages further amplify the systemic impact of both cyber and geopolitical shocks. Geopolitical shocks, such as pandemics, armed conflicts, and energy market disturbances, further exacerbate fragility and underscore the limitations of conventional stress-testing and risk-monitoring frameworks.

From a policy perspective, these findings suggest that the resilience of European capital market infrastructures cannot be ensured through siloed risk assessments. Financial, operational, cyber, and geopolitical risks interact in a non-linear manner, calling for integrated supervisory frameworks that combine quantitative systemic risk indicators with operational resilience testing.

Empirical and theoretical studies indicate that fragility is multidimensional and context-dependent, requiring integrated approaches that combine financial, operational, cyber, and geopolitical risk assessments. The development of fragility indices, entropy-based models, and scenario analyses provides valuable tools for understanding systemic risk, while cross-country comparisons highlight the importance of tailored macroprudential measures. Policy interventions must prioritise cyber resilience, robust stress-testing, and adaptive regulation to enhance the stability and resilience of European capital market infrastructures. Incorporating scenario-based and entropy-based modelling into supervisory frameworks allows policymakers to anticipate compound shocks and design integrated risk mitigation strategies. Overall, safeguarding market stability in this complex environment requires an integrated, forward-looking perspective that accounts for the evolving nature of both traditional and emerging risks.

For managers and regulators of European CMIs, these findings highlight the importance of integrated risk management frameworks, proactive cyber resilience strategies, and scenario-based contingency planning to mitigate potential systemic disruptions.

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