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Evolution and determinants of firm-level systemic risk in local production networks

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Extended Abstract

Production networks, built on the exchange of goods and services between firms, are central to modern economies as they connect suppliers, manufacturers, and consumers across industries and regions. While these interdependencies foster growth, globalization and the pursuit of efficiency have made production networks increasingly fragile. Indeed the propagation of local disruptions—due to either natural disasters, geopolitical shocks, or the COVID-19 pandemic—through supply chains has occurred several times recently. This has sparked growing interest in assessing systemic risk, i.e., the economy-wide effects of such disruptions.

Traditional approaches to systemic risk relied on aggregated Input-Output tables, but recent access to large-scale firm-level data has shifted attention toward production networks at the micro level. Firm-level analyses overcome aggregation bias and allow more accurate estimates of systemic risk, accounting for heterogeneity in firms' processes, positions, and network connections. However, most existing frameworks treat networks as static, overlooking the adaptive responses of firms during crises. In reality, firms reconfigure supply chains by finding alternative suppliers, changing logistics, or reallocating production—actions that can reduce or, in some cases, amplify systemic risk.

This work examines the Hungarian production network between 2015 and 2022, covering the COVID-19 pandemic, using firm-level value-added tax (VAT) data. We compute time-dependent values of the Economic Systemic Risk Index (ESRI) [1] for every firm, hence we can assess how the resilience of the economy evolves and which firms emerge as new key players during crises. We also benchmark our empirical findings to a null network model that preserves firms' sector-level supply and demand: the *stripe-corrected gravity model* (s-GM) [2]. This heuristic maximum entropy formulation [3] provides a thermodynamic construction of networks at the Walrasian economic equilibrium [4] and thus enables us to isolate deviations caused by crisis-driven adaptations.

Our results reveal a structural transformation at the onset of COVID-19: firms facilitating economic exchanges become central sources of systemic risk, a shift not reproduced by the null model. While empirical systemic risk closely matches null predictions before the pandemic, it diverges significantly afterward, reflecting adaptive network reconfigurations that enhance resilience both absolutely and relative to equilibrium expectations. Regression analysis further shows that international trade volume becomes a strong predictor of systemic risk, though imports and exports exert opposite effects through supply and demand channels.

In summary, systemic risk is not a static property of production networks but evolves dynamically through firms' adaptive responses to crises. By integrating firm-level data with a principled null model, this study highlights how resilience emerges from structural reconfigurations of the production network.

References

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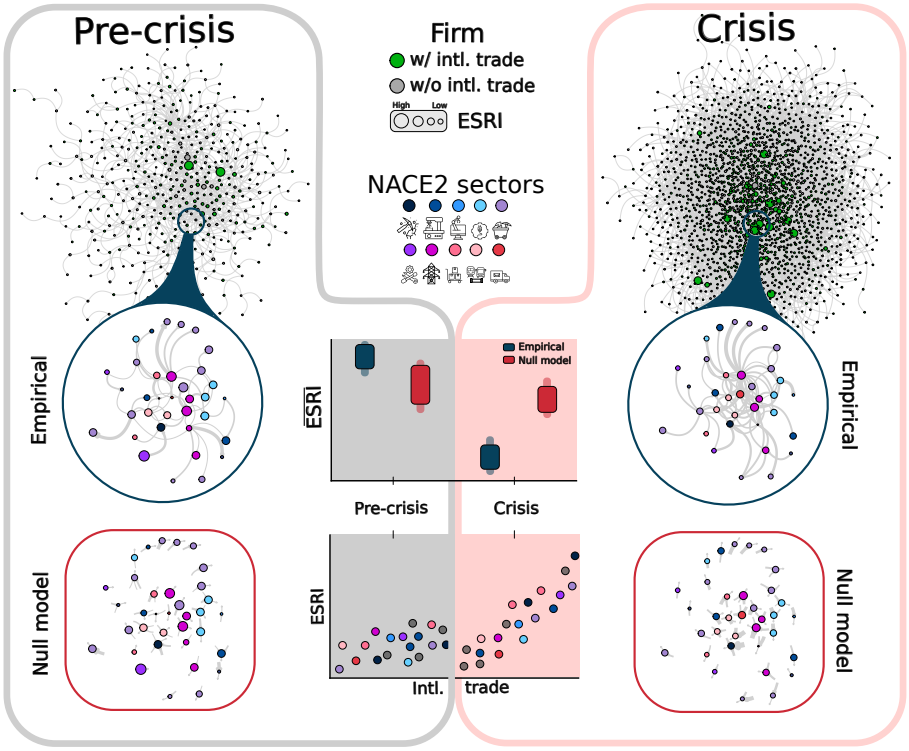

Figure 1: **Empirical and null model networks are compared before and during the COVID-19 crisis, to study the evolution of economic systemic risk and understand the role of international trade.** We start with temporal snapshots of the empirical production network. The top of the figure shows the network of a sample of the same 1000 nodes, before and during the crisis. Firms are colored according to the presence (green) or absence (gray) of international trade ties, while nodes' size is proportional to firms' ESRI value. We then focus on firms with the highest systemic risk values, highlighted with a circular magnification from the empirical networks, where the nodes' color represents the firms' industrial (NACE2) sector. Finally, the squares in the third row represent the null models for the same set of risky firms, where we show only the constrained quantities (for each firm, its supplies from different sectors and total sales). Our framework thus allows studying the temporal evolution of systemic risk, how it deviates from the predictions of the null model, and which characteristics of the firms, such as the presence of international trade, are linked to their risk value (as shown by the sample analysis plots in the middle of the figure).