Risk Propagation and System Resilience in the Global Food Supply Network

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Food system stability is a precondition for social stability. Yet todayâ€™s food supply is increasingly threatened by climate extremes, geopolitical disruptions, and market volatility. Meanwhile, as the global food supply chain grows more interconnected, localized shocks can cascade through trade and production networks, generating systemic risks. Understanding resilience under risk propagation helps locate bottlenecks and leverage points in global food supply chains, informing risk reduction beyond national responses.
However, existing studies remain some limitations. Many focus on a single food item or a limited number of countries, which leaves global vulnerability patterns and multi-step transmission pathways insufficiently characterized. In addition, many risk assessments assume linear pass through, overlooking buffering capacity and conditional threshold responses that determine whether shocks fade out or escalate as they move through trade and production networks.
To address these gaps, we develop a network-based resilience assessment framework that models shock propagation in the global food supply chain. Building on this framework, we focus on three core questions: (1) How does resilience under external shocks vary across countries and food items? and which bottlenecks are most critical for supply stability? (2) Is risk transmission nonlinear and threshold-triggered, and which factors shape propagation pathways and threshold levels? (3) What actionable strategies can reduce systemic risk and strengthen resilience through coordinated approaches?
We build a global food supply multilayer network using the FABIO MRIO dataset from 1990 to 2013, representing trade and production linkages across 192 areas and 123 food items. In the network, nodes are area by item pairs, and directed, weighted links represent MRIO traced supply flows from upstream to downstream. Building on this network, we estimate a risk propagation framework with time, area, and item fixed effects and a piecewise linear function with an estimated resistance threshold, allowing the propagation slope to change once shocks exceed the threshold. We treat relative availability loss at each area item node as the shock input and quantify how it translates into downstream supply losses, measured by reductions in export supply and in supply available for downstream production. Resilience is defined by the estimated threshold and slopes: higher thresholds and weaker below threshold slopes indicate stronger buffering capacity, while larger slope increases above the threshold imply greater cascade amplification risk. We then group nodes by their trade roles and structural positions in the network, food item functions, and country development levels, and compare propagation behavior and resilience across these groups. We further identify vulnerable nodes and high spillover nodes and links, and translate the results into practical indicators for early warning and governance.
Our results indicate that risk propagation is nonlinear and becomes threshold triggered in the global food system, with effects that are concentrated rather than universal. Pronounced cascading effects emerge mainly when shocks exceed critical thresholds, and this amplification is especially visible along major export trade pathways. These threshold effects are not widespread across all countries and food items; instead, they concentrate in globally central exporting countries and in export critical food items within those countries. The implications for risk prediction are largest when shocks are severe and when they hit highly central countries in the trade network; ignoring this conditionality leads to systematic overestimation of food system risks. Building on these results, we characterize how resilience differs across countries and food groups by relating estimated thresholds and propagation slopes to exporter centrality and trade dependence. We further identify a small set of globally central exporting countries, such as the United States, Brazil, Argentina, Canada, and Australia, together with export critical primary crops, such as wheat, maize, and soybeans, that are

highly shock sensitive and generate large downstream spillovers.

By taking a network perspective, this study translates complex global production and trade relationships into an interpretable map of the food supply network. This makes it possible to more clearly identify the roles and positions of countries and food items within the supply chain, and to diagnose where resilience is built and where vulnerabilities emerge. Our risk propagation framework provides a more realistic basis for understanding when disruptions remain localized and when they become systemic. It also supports targeted early warning metrics and coordinated interventions that prioritize key exporters, critical food items, and bottlenecks in global supply chains.