The Fragmentation of Production Amplifies Systemic Risk in Supply Chains

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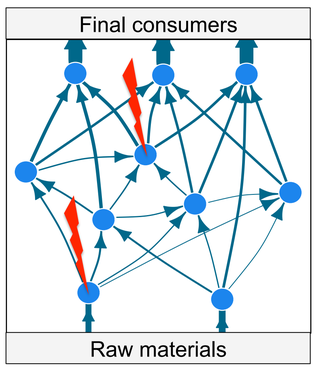
Systemic risk in fragmented supply chains

In a supply chain, production disruptions may **cascade** from one firm to another. Because of this ripple effect, accidents or natural disasters provoke economic losses in distant locations, exemplified by the 2011 flooding in Thailand.

Businesses, insurers, and policy-makers report a rising concern for such **systemic risk**. Through outsourcing and vertical specialization, supply chains are increasingly **fragmented**: the multiple production and delivery stages are run by many independent firms.

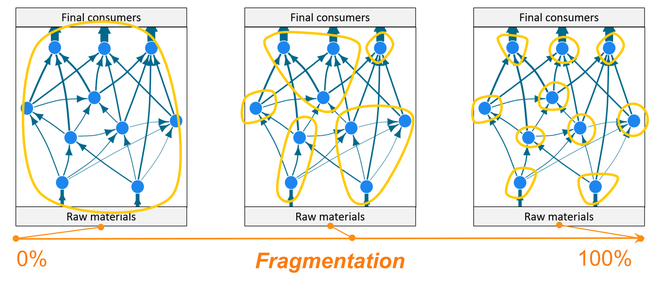
How does this fragmentation affect the management of systemic risk? The way one firm mitigates risk impacts the profit of its supply-chain partners, which may in turn change their mitigating strategy. We study these interactions using evolutionary game theory.

A supply-chain model with external shocks and evolving inventory strategy



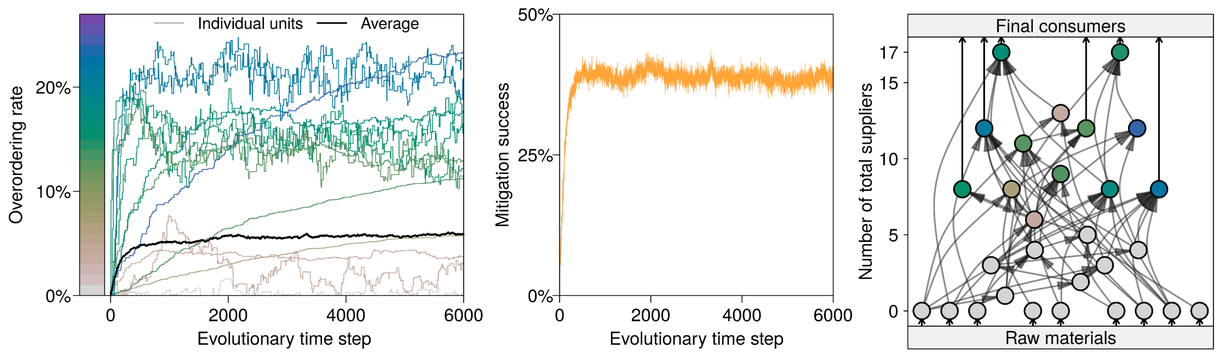
Firms **produce** outputs using inputs from suppliers. **Shocks** occur so that at each time step, firms have a certain probability to lose all their production, inducing potential shortages to clients.

To mitigate this risk, firms **order extra inputs** stored as inventory. These firm-level decisions lead to a reduction of systemic risk.

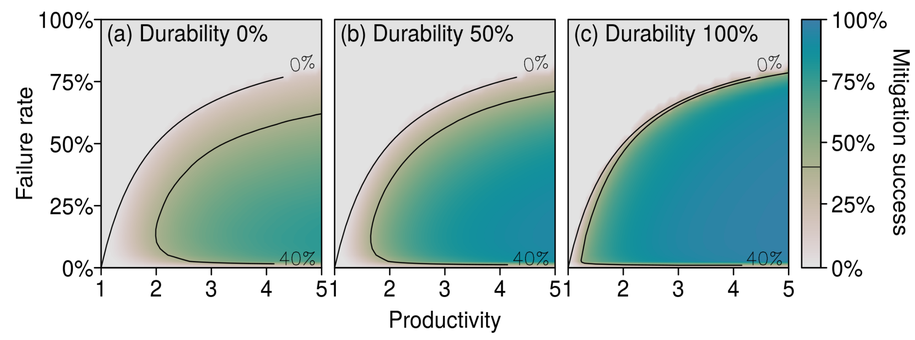


Firms are allocated to form **groups**. The number of groups in a supply chain defines its fragmentation. Firms iteratively **update** their overordering rate to **increase the profit of their group**.

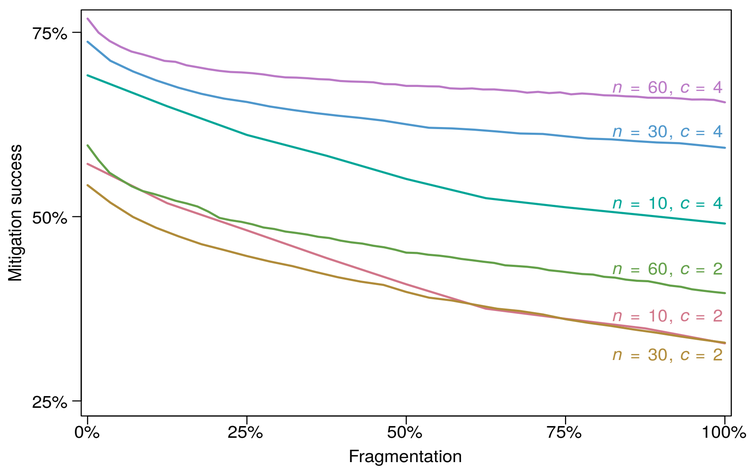
Durable inventories reduce systemic risk, but firms make unbalanced efforts



The profit-driven evolution of overordering rates leads to lower systemic risk, but also to unbalanced efforts, illustrated for a fragmented supply chain.



Systemic risk is more robustly mitigated when goods are durable.



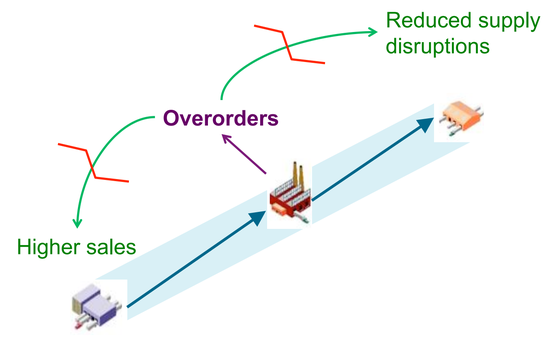
Supply chain fragmentation disincentivizes inventories

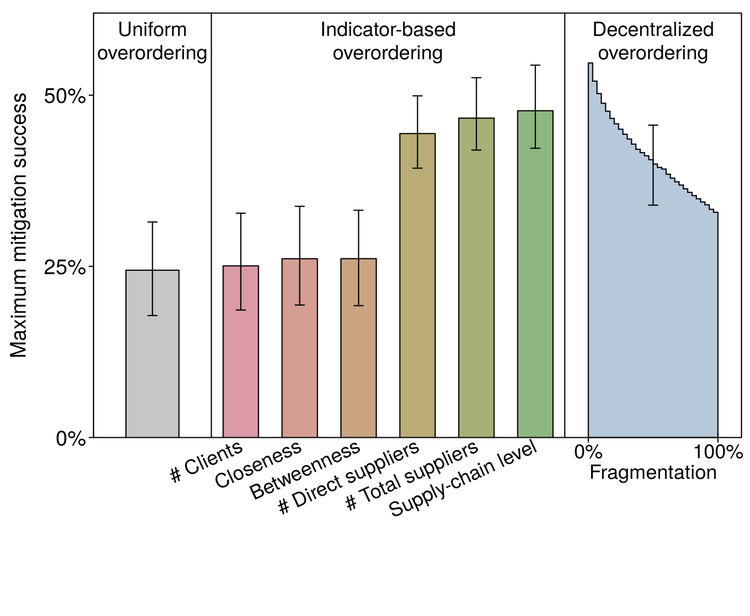
When a firm overorders

- its clients benefit from reduced supply disruptions, and
- its suppliers benefit from higher sales.

If the supply chain is fragmented, these benefits are no longer taken into account; they become **externalities**.

Fragmentation thus **disincentivizes** inventories and elevates systemic risk.





Network indicators help identify mitigation benchmarks

How can this fragmentation-induced systemic risk be alleviated? A central decision-maker may use **network indicators** to allocate the overordering rate of each firm.

We find that "**supply-chain level**" is the best performing indicator. It is defined by the average number of links between a firm and primary producers, and is equivalent to a species' trophic level in ecological systems.

Such an indicator could help policy-makers regulate the supply chains of public services (e.g., disaster relief), or help insurers cover supply-chain disruptions.