Complexity theory and financial regulation

Economic policy needs interdisciplinary network analysis and behavioral modeling

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Traditional economic theory could not explain, much less predict, the near collapse of the financial system and its long-lasting effects on the global economy. Since the 2008 crisis, there has been increasing interest in using ideas from complexity theory to make sense of economic and financial markets. Concepts, such as tipping points, networks, contagion, feedback, and resilience have entered the financial and regulatory lexicon, but actual use of complexity models and results remains at an early stage. Recent insights and techniques offer potential for better monitoring and management of highly interconnected economic and financial systems and, thus, may help anticipate and manage future crises.

Tipping points, warning signals. Financial markets have historically exhibited sudden and largely unforeseen collapses, at a systemic scale. Such “phase transitions” may in some cases have been triggered by unpredictable stochastic events. More often, however, there have been endogenous underlying processes at work. Analyses of complex systems ranging from the climate to ecosystems reveal that, before a major transition, there is often a gradual and unnoticed loss of resilience. This makes the system brittle: A small disruption can trigger a domino effect that propagates through the system and propels it into a crisis state.

Recent research has revealed generic empirical quantitative indicators of resilience that may be used across complex systems to detect tipping points. Markers include rising correlation between nodes in a network and rising temporal correlation, variance, and skewness of fluctuation patterns. These indicators were first predicted mathematically and subsequently demonstrated experimentally in real complex systems, including living systems (1). A recent study of the Dutch interbank network (2) showed that standard analysis using a homogeneous network model could only lead to late detection of the 2008 crisis, although a more realistic and heterogeneous network model could identify an early warning signal 3 years before the crisis (see the chart).

Ecologists have developed tools to quantify the stability, robustness, and resilience of food webs and have shown how these depend on the topology of the network and the strengths of interactions (3). Epidemiologists have tools to gauge the potential for events to propagate in systems of interacting entities, to identify superspreaders and core groups relevant to infection persistence, and to design strategies to prevent or limit the spread of contagion (4).

Extrapolating results from the natural sciences to economics and finance presents challenges. For instance, publication of an early warning signal will change behavior and affect future dynamics (the Lucas critique (5)). But this does not affect the case where indicators are known only to regulators or when the goal is to build better network barriers to slow contagion.

Too central to fail. Network effects matter to financial-economic stability because shock amplification may occur via strong cascading effects. For example, the Bank of International Settlements recently developed a framework drawing on data on the interconnectedness between banks to gauge the systemic risk posed to the financial network by Global Systemically Important Banks. Recent research on contagion in financial networks has shown that network topology and positions of banks matter; the global financial network may collapse even when individual banks appear safe (6). Capturing these effects is essential for quantifying stress on individual banks and for looking at systemic risk for the network as a whole. Despite on-going efforts, these effects are unlikely to be routinely considered anytime soon.

Information asymmetry within a network—e.g., where a bank does not know about troubled assets of other banks—can be problematic. The banking network typically displays a core-periphery structure, with a core consisting of a relatively small number of large, densely interconnected banks that are not very diverse in terms of business and risk models. This implies that core banks’ defaults tend to be highly correlated. That, in turn, can generate a collective moral hazard problem (i.e., players take on more risk, because others will bear the costs in case of default), as banks recognize that they are likely to be supported by the authorities in situations of distress, the likelihood amplifies their incentives to herd in the first place.

Estimating systemic risk relies on granular data on the financial network. Unfortunately, business interactions between banks are often hidden because of confidentiality issues. Tools being developed to reconstruct networks from partial information and to estimate systemic risk (7) suggest that publicly available bank information does not allow reliable estimation of systemic risk. The estimate would improve greatly if banks publicly reported the number of connections with other banks, even without disclosing their identity.

In addition to data, understanding the effects of interconnections also relies on integrative quantitative metrics and concepts that reveal important network aspects, such as systemic repercussions of the failure of individual nodes. For example, DebtRank, which measures the systemic importance of individual institutions in a financial network (8), shows that the issue of too-central-to-fail may be even more important than too-big-to-fail.
Laboratory experiments with human subjects can provide empirical validation of individual decision rules of agents, their interactions, and emergent macro behavior. Recent experiments studying behavior of a group of individuals in the laboratory show that economic systems may deviate significantly from rational efficient equilibrium at both individual and aggregate levels (14). This generic feature of positive feedback systems leads to persistent deviations of prices from equilibrium and emergence of speculation-driven bubbles and crashes, strongly amplified by coordination on trend-following and herding behavior (15). There is strong empirical evidence of monetary and fiscal policies and financial regulation designed to weaken positive feedback are successful in stabilizing experimental macroeconomic systems when properly calibrated (16). Complexity theory provides mathematical understanding of these effects.

**POLICY DASHBOARD.** It is an opportune time for academic economists, complexity scientists, social scientists, ecologists, epidemiologists, and researchers at financial institutions to join forces to develop tools from complexity theory, as a complement to existing economic modeling approaches (17). One ambitious option would be an online, financial-economic dashboard that integrates data, methods, and indicators. This might monitor and stress-test the global socioeconomic and financial system in something close to real time, in a way similar to what is done with other complex systems, such as weather systems or social networks. The funding required for essential policy-relevant and fundamental interdisciplinary progress in these areas would be trivial compared with the costs of systemic financial failures or the collapse of the global financial-economic system.

**REFERENCES AND NOTES**


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