Response

In our Policy Forum, we argued for the development of a policy dashboard to manage complex financial-economic systems based on an interdisciplinary network analysis and behavioral modeling approach.

Ruhl's first point is that legal expertise should be included in the research design. We agree that this may be useful for developing models. In fact, behavioral agent-based models should incorporate legal regulation and market institutional details.

Ruhl's second point is that the regulatory system itself should be part of the research and model building. We also agree that the regulatory system and the financial system are co-evolving and that ideas from complex systems can be useful to think about this relationship. This is reminiscent of the Lucas critique: Regulation itself affects human behavior through mutual adaptive feedback between individual behavior and regulation (*1*).

However, incorporating the evolution of the regulatory system is more difficult than managing the economic-financial system alone. Research on these co-evolving complex systems so far has been mainly qualitative. Haldane's "microscopes and telescopes" (*2*) stresses that the financial-economic system is a complex adaptive "system of systems," including a policy architecture with a layer of national financial systems and economies, a layer of monetary policy, and a layer of global financial architecture.

Even if we do not understand how the regulatory system will evolve, we can test its possible effects and assess plausible alternatives that might improve it. What we advocate should contribute to making evolution of the regulatory system more effective in relation to systemic risk. We can do this even without understanding the long-term evolutionary dynamics of regulation. Complex system models will be not only useful, but essential to gauge effects of regulations.

Finally, Ruhl argues that effective reform measures can already be taken before model building. This may be true, but the point of complexity modeling is to identify possible unintended consequences of regulations. A realistic complexity-based policy dashboard can help to empirically assess reforms before implementing them in real markets. The policy dashboard we propose provides a test bed for such potentially stabilizing regulatory policies.

Witzling argues that fraud played an important role in the financial crisis of 2008. Of course, society has to fight fraud, but removing fraud would not solve the problem. The threat exists already within what is legally possible at the moment. Witzling refers to James Galbraith when he says that "the existence of a bubble in a stable, regulated market like housing is prima facie evidence of fraud." However, one of the essential insights from complex systems is that the bubble and crisis would have occurred without any fraud at all. For example, simple agent-based models of the housing markets, calibrated to U.S. data, generate housing bubbles as soon as leverage levels are turned up to levels that were actually used, and were perfectly legal (*3*, *4*). Furthermore, bubbles and crashes have been frequently observed in controlled laboratory experimental asset markets as the emergent outcome of positive feedback environments (*5*–*7*). The problems that caused the financial crisis of 2008 came from the legal use of excessively high leverage, which generated systemic risk. A model of the reforms developed by the Basel Committee on Bank Supervision illustrates this dramatically (*8*). As soon as the banking sector grows to a certain size, and as soon as it exceeds a leverage threshold that is considerably smaller than that actually used, 10- to 15-year oscillations arise that resemble the Great Moderation (reduction in economic volatility that began in the 1980s) and subsequent crisis, both in magnitude and time scale. Fraud may of course amplify these instabilities or may push the system beyond a tipping point, but it is not the primary driving force, as these instabilities are an emergent outcome of complex financial networks (*9*).

The argument about fraud is not one against models or our complexity approach, and economic theory offers ways to investigate what fraud and breaching of trust would do to a system. For example, methods and insight from the theory of evolutionary biology and evolutionary game theory can be used to include agents that "cheat" the system by not following accepted sets of rules in their behavior (*10*–*12*).

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