SCIENCE AND LAW

Harnessing legal complexity

Bring tools of complexity science to bear on improving law

By **J. B. Ruhl,[1] Daniel Martin Katz,[2,3] Michael J. Bommarito II[2,3]**

Complexity science has spread from its origins in the physical sciences into biological and social sciences (*1*). Increasingly, the social sciences frame policy problems from the financial system to the food system as complex adaptive systems (CAS) and urge policymakers to design legal solutions with CAS properties in mind. What is often poorly recognized in these initiatives is that legal systems are also complex adaptive systems (*2*). Just as it seems unwise to pursue regulatory measures while ignoring known CAS properties of the systems targeted for regulation, so too might failure to appreciate CAS qualities of legal systems yield policies founded upon unrealistic assumptions. Despite a long empirical studies tradition in law, there has been little use of complexity science. With few robust empirical studies of legal systems as CAS, researchers are left to gesture at seemingly evident assertions, with limited scientific support. We outline a research agenda to help fill this knowledge gap and advance practical applications.

Legal systems exhibit what complexity scientists identify as hallmark elements of CAS (*1*). The diverse institutions (e.g., legislatures, agencies, and courts); norms (e.g., due process, equality, and fairness); actors (e.g., legislators, bureaucrats, and judges); and instruments (e.g., regulations, injunctions, and taxes) are interconnected through stochastic processes (e.g., trials, negotiations, and rulemakings) with feedback mechanisms (e.g., appeals to higher courts and judicial review of legislation). These are all embedded in hierarchical and nonhierarchical network architectures (e.g., cross-references between statute provisions and judicial opinions, as well as hierarchies of federal, state, and local governance institutions) that frequently produce self-organizing properties (e.g., emergence of common-law doctrines or codified statutory law). Agents typically exercise bounded rationality, have only partial information, and are able to exercise only varying degrees of control on overall system behavior (*2*).

Efforts to integrate CAS approaches to regulated systems may flounder if complex adaptive characteristics of the legal system itself are not taken into account. For example, although natural-resources policy theorists have advocated for a new field of adaptive management based on an understanding that ecosystems are CAS, agencies, courts, and other components of the legal system have reacted in unexpected ways that can frustrate adaptive management (*3*).

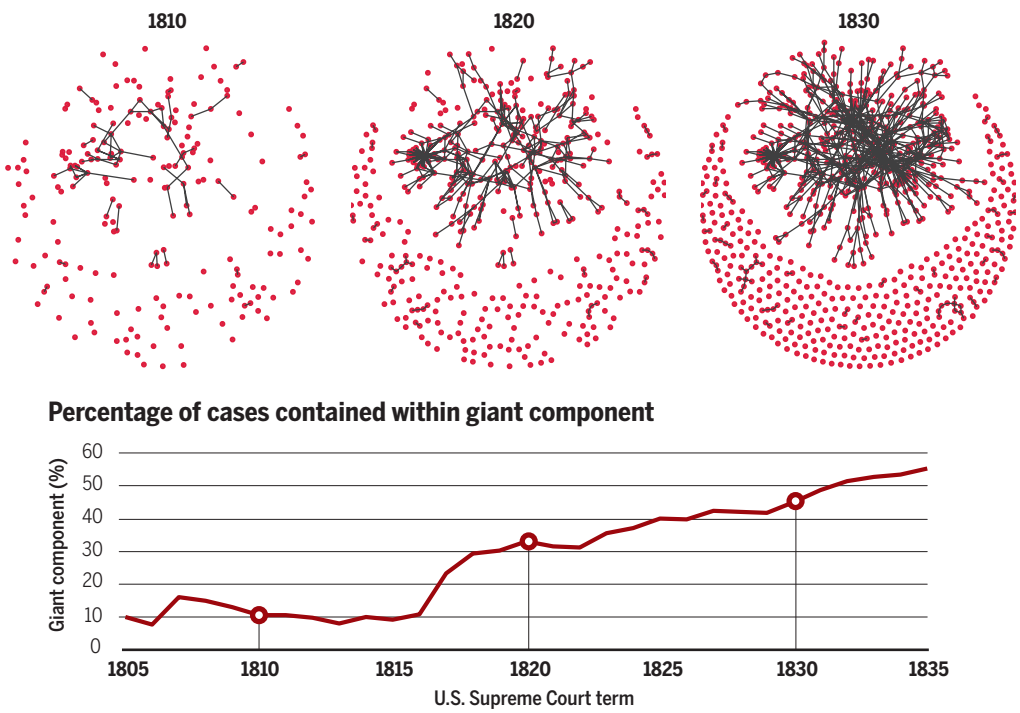
Legal systems are locked in perpetual coevolution with their regulatory targets. Coadaptive dynamics have driven growth in structure and size, punctuated with stages of nonlinear expansion of the U.S. statutory and judicial systems (*4*). CAS approaches can allow modeling of interconnections in this system of systems that can be difficult to capture in simple models (*1*). Minor changes in network structure may lead to cascade effects throughout the systems. By leveraging traditional methods, it is difficult to isolate instability and systemic risk in other social systems from instability and systemic risk in the legal system. Regulatory system failure was a factor in the 2008 financial crisis (*5*) and the Deepwater Horizon oil spill (*6*).

THEORY, ANALYSIS, APPLICATION

Application of informatics and big-data–styled research to law offers many potential benefits for conventional empirical legal studies. The CAS framework is neither an extension of nor a replacement for that approach but a different way of envisioning systems in which agent strategies and system structures evolve, with outcomes standard game theory and equilibrium analyses would not predict (*7*). Although well behind CAS research in other social sciences, researchers have begun to map CAS concepts onto the legal system (*2*). Researchers are applying empirical tools of complexity science to understand how to measure, monitor, and manage the legal system as a CAS.

United States Supreme Court citation network (1805–1835)

Cases are represented as nodes, citations between cases as edges. Emergence of a giant [connected] component after 1815, a hallmark phenomenon in complex systems, represents a transition from jurisprudential reliance on foreign to domestic law following the War of 1812 (*4*). We include all cases that had been cited at least once over the Court's history (1791–2015). For figure code and data, see https://github.com/mjbommar/legal-complexity-science.



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They are modeling vast statutory codes as networks and tracing their evolution (*8*), as well as probing self-organized and self-similar structure of components, such as the common law (*9*, *10*).

Public and private demand for legal data in digital form has fueled creation of data sets useful for studying legal systems. Analysis of the dynamic network structure and content of the entire U.S. Code and Code of Federal Regulations can show evolution of text within and cross-references between provisions. This network of legislative and executive rules can be linked with case citations and language in judicial opinions, creating a macro-network model to trace the evolution of legal-system structure and language.

In addition to historical analysis, there are predictive applications. It is likely possible to identify highly cross-referenced "hub" nodes that could be agents of cascading failure. A legislative amendment to an important, highly referenced statutory provision or an agency or judicial opinion narrowing its application could affect the operation and viability of other statutes, agency regulations, and judicial opinions that cite the provision. Actors and institutions throughout that network would need to adapt, and unanticipated effects could abound, e.g., responses of businesses and individuals to changes in regulatory burdens (*11*). A CAS model could investigate how the legal system and its regulatory targets coevolve and share systemic risk (*12*).

Many day-to-day legal tasks can be informed by improved understanding of legal systems as CAS. Sophisticated lawyering is an exercise in helping clients navigate complex legal environments (*13*). In response to increasing legal complexity, the legal industry is increasing its use of technology (*14*), process improvement (*15*), and design-thinking methodologies (*16*). Many of these complexity mitigation efforts can both contribute to and learn from macro-level CAS models of legal systems.

Such models can provide practical value to policy-makers, legal educators, practicing lawyers, and others. For example, a perennial theme of U.S. politics is that the tax system is too complex, in need of "simplification." Tax laws are a highly interconnected network of cross-citations between and across statutory and regulatory provisions. Through tax-based incentives and policy measures, the tax law system creates many dependencies in seemingly unrelated policy realms. This makes the impact of tax reforms difficult for policy offices such as the Congressional Research Service and the Congressional Budget Office to predict. This cascading dependency could be captured in a CAS macro-model to focus policy analysis.

HARNESS DATA, BUILD FOUNDATIONS

Building a CAS model for legal systems will require four major thrusts of research.

Data. Legal systems provide a rich and unique combination of data. For example, the written record of U.S. law can be studied as quantities and rates (e.g., bills per year as a function of Congress); as natural language (e.g., usage of analogical reasoning in case-law opinions); and as a network of dependencies (e.g., degree distribution of tax law). But the U.S. legal "DNA" has been scattered across agencies, departments, and courts at federal, state, and local levels. The universe of available data must be aggregated into an open-source repository to provide a solid, sustainable, and reproducible foundation. Corpora, such as the U.S. Code, Code of Federal Regulations, Congressional Record, executive orders, state and federal judicial decisions, public and private contracts, and docketing systems need to be collected and curated for machine-readable consumption. Additional metadata could support research, such as voting record tables in Congress and citation networks between judicial opinions, which could be published continuously through semiautomated processes.

> ***"Legal systems are locked in perpetual coevolution with their regulatory targets."***

Foundations. As data are made available, structured, and updated, theoretical and empirical researchers can advance our understanding of legal systems as CAS. The first step would be construction of a macro-model, perhaps of several fields of law at first, and tying it to data. Empiricists can pursue descriptive and inferential studies by aligning legal measures with external social, political, and economic observations linked to the macro-model. Theorists can iterate and improve on extant agendas, as well as pose new ones. For example, whereas game theorists have speculated on interactions within a small set of forums like Congress, development and testing of new theories have been limited by available data. With an open-data repository and network models with dependency trees, large-scale experiments could investigate appellate jurisprudence or delegation to technocratic agencies.

Applications. With a solid empirical and theoretical basis, work can focus on practical public and commercial endeavors. For example, a public project to model tax reform can be developed and published for reproduction and analysis by researchers and policy stakeholders. Commercial innovation will be increasingly possible. For example, corporations with access to a real-time model of legal system complexity could develop more effective compliance strategies, including autonomous embedded compliance protocols that adjust as the law adjusts. These initiatives would seek to develop user interface systems to manage and mitigate the size and complexity of the legal system for users across many domains (*2*).

Learning. Such a research agenda should be undertaken with the view of facilitating adaptive learning over time. For example, policy offices could track and evaluate results of legal reforms and train the model as to which reforms produce desirable and undesirable outcomes. Techniques to identify patterns and conditions associated with reforms and their outcomes could help the model improve its ability to provide predictive evaluations of proposed reforms.

Research questions are largely limited in their ambition by the capacity of existing theoretical and empirical approaches. A complexity science agenda in legal research may open new horizons of important research questions. So long as complex and coevolving legal systems are exogenized from social systems research, our understanding and management of human societies will remain incomplete and policy-making will fall short. ■

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10.1126/science.aag3013

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Science **355** (6332), 1377-1378.
DOI: 10.1126/science.aag3013