SOCIAL ARCHITECTURE, JUDICIAL PEER EFFECTS AND THE "EVOLUTION" OF THE LAW: TOWARD A POSITIVE THEORY OF JUDICIAL SOCIAL STRUCTURE

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Building upon the themes of this symposium, as well as a growing extant literature demonstrating the common law displays properties of a complex system,[1] we believe existing theories of judicial decision-making and legal change would benefit from the concepts and techniques typically reserved for the study of complexity. Among possible approaches, network analysis offers one manner of representing the interactions between various entities across a

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1. *See, e.g.*, Lawrence A. Cunningham, *From Random Walks to Chaotic Crashes: The Linear Genealogy of the Efficient Capital Market Hypothesis*, 62 GEO. WASH. L. REV. 546 (1994) (discussing chaos theory in the context of capital market regulation); Mark J. Roe, *Chaos and Evolution in Law and Economics*, 109 HARV. L. REV. 641 (1995) (discussing legal evolution and invoking both path dependence and systems theory); Vincent Di Lorenzo, *Complexity and Legislative Signatures: Lending Discrimination Laws as a Test Case*, 12 J.L. & POL. 637 (1996) (employing chaos theory to review legislative responses to alleged lending discrimination); J. B. Ruhl, *The Fitness of Law: Using Complexity Theory to Describe the Evolution of Law and Society and Its Practical Meaning for Democracy*, 49 VAND. L. REV. 1407 (1996) (discussing both complexity and the general evolutionary model); David G. Post & Michael B. Eisen*, How Long is the Coastline of the Law? Thoughts on the Fractal Nature of Legal Systems*, 29 J. LEGAL STUD. 545 (2000) (uncovering the fractal structure of citations to precedent in judicial opinions); Thomas A. Smith, *The Web of Law*, 44 SAN DIEGO L. REV. 309 (2007) (demonstrating the distribution of citations across the roughly four million cases in American law as consistent with the power law distribution); Elizabeth Leicht, Gavin Clarkson, Kerby Shedden & M. E. J. Newman, *Large-Scale Structure of Time Evolving Citation Networks*, 59 EUROPEAN J. OF PHYS. B 75 (2007) (mapping the structure of the United States Reports and detecting temporal communities in case to case citations). *See also* Daniel A. Farber, *Earthquakes and Tremors in Statutory Interpretation: An Empirical Study of the Dynamics of Interpretation*, 89 MINN. L. REV. 848 (2005); Daniel F. Spulber & Christopher S. Yoo, *On the Regulation of Networks as Complex Systems: A Graph Theory Approach*, 99 NW. U. L. REV. 1687 (2005); Bernard Trujillo, *Patterns in a Complex System: An Empirical Study of Valuation in Business Bankruptcy Cases*, 53 UCLA L. REV. 357 (2005). For an extensive list of scholarship compiled by Professor Ruhl, see Society for Evolutionary Analysis in Law, Complex Adaptive Systems in Literature for Law and Social Sciences, http://law.vanderbilt.edu/seal/resources/readingscomplex.htm (last visited Sept. 20, 2008).

complex adaptive landscape.[2] Specifically, as applied to the path of the common law as well as theories of judicial decision-making, the networks paradigm helps evaluate the manner in which individual level judge choice maps to the judiciary's aggregate doctrinal outputs.[3]

Of course, to the extent individual decision-making is driven by factors entirely intrinsic to a given case and a given jurist,[4] the study of interactions is arguably trivial as the description of the aggregate would reflect little more than the summation of individual preferences in a manner consistent with the institution's aggregation rule. It is far more likely, however, that judicial choice is, at least in part, impacted by a combination of jurists who are socially prominent

2. The analysis of social networks is long standing with notable early work conducted by scholars such as Jacob Moreno, Fritz Heider, and Kurt Lewin. *See, e.g.*, JACOB MORENO, WHO SHALL SURVIVE? (1934) (developing the "sociogram," an apparatus that allows social relationships to be drawn using analytic geometry); KURT LEWIN, FIELD THEORY IN SOCIAL SCIENCE (1951) (extending Moreno's work and applying a host of mathematical techniques including graph theory, topology, and set theory). Popular accounts of networks concepts can largely be attributed to the work of Stanley Milgram. *See* Stanley Milgram, *The Small World Problem*, 22 PSYCHOL. TODAY 61 (1967). Milgram is often credited with coining "six degrees of separation." However, many attribute the term to Hungarian author, Frigyes Karinthy, whose volume of short stories invoked such concepts. *See* FRIGYES KARINTHY, MINDEN MÁSKÉPPEN VAN [EVERYTHING IS DIFFERENT] (1929). A host of recent popular literature continues the public's widespread interest in network science. *See generally* FORBES, *Networks*, May 7, 2007 (devoting its Ninetieth Anniversary Issue to the "New" Age of Networks). For a non-exhaustive list of recent popular books in the subject, see also ALBERT-LASZLO BARABÁSI, LINKED: THE NEW SCIENCE OF NETWORKS (2002); MARK BUCHANAN, NEXUS: SMALL WORLDS AND THE GROUNDBREAKING SCIENCE OF NETWORKS (2002); and MALCOLM GLADWELL, THE TIPPING POINT: HOW LITTLE THINGS CAN MAKE A BIG DIFFERENCE (2000). Recent developments within the academy have also driven increased interest in network analysis. Among these developments the work of Watts and Strogatz is of utmost interest. *See* Duncan J. Watts & Stephen H. Strogatz, *Collective Dynamics of 'Small World' Networks*, 393 NATURE 440 (1998). *See also* Laszlo Barabási & Reka Albert, *Emergence of Scaling in Random Networks*, 286 SCIENCE 509 (1999). For instructive texts on the subject see, e.g., THE STRUCTURE AND DYNAMICS OF NETWORKS (Mark Newman, Albert-Laszlo Barabási, & Duncan J. Watts, eds., 2006); STANLEY WASSERMAN & KATHERINE FAUST, SOCIAL NETWORK ANALYSIS (1994).

3. *See generally* THOMAS C. SCHELLING, MIRCOMOTIVES AND MACROBEHAVIOR (1978).

4. Early public law scholarship often modeled judicial choice as a function of judge and case level variables. *See, e.g.*, JEFFREY A. SEGAL & HAROLD J. SPAETH, THE SUPREME COURT AND THE ATTITUDINAL MODEL (1993). Later work inspired by New Institutional Economics (NIE) describes how judicial choice is in part conditioned on the institutional environment a given actor faces. *See, e.g.*, LEE EPSTEIN & JACK KNIGHT, THE CHOICES JUSTICES MAKE (1998); FORREST MALTZMAN ET AL., CRAFTING LAW ON THE SUPREME COURT: THE COLLEGIAL GAME (2000). These approaches do not explicitly model social-dynamics.

and socially proximate.[5] While in some forms of network structure such "peer effects" are limited, in many states of the social world, they are supremely consequential. The precursor to evaluating potential doctrinal consequences is a classificatory effort designed to determine the micro implications of a given observed macro landscape.[6]

Section I provides a brief overview of the complex system paradigm while simultaneously reviewing existing theories of judicial decision-making and common law evolution. Section II considers a series of classic network structures. Among the possibilities considered herein are random graphs, clustered graphs, as well as models built upon processes of preferential attachment. Drawing from the larger complexity literature, Section II also describes the processes of self-organization likely responsible for generating each of these network structures.[7]

With an understanding of these possible "states of the world" in mind, Section III concludes with a consideration of judicial decision-making, arguing "the path of the law"[8]—from emergence to convergence—is conditioned, in part, upon the nature of self-organized social architecture that relevant decisional actors confront. In all, we believe "architecture matters." Thus, our broad sweep of the possibility frontier should help identify the conditions under

5. Recent work in the public law literature acknowledges a need for contextual understandings of judicial decision making. *See, e.g.*, Charles M. Cameron & Craig P. Cummings, *Diversity and Judicial Decision-Making: Evidence from Affirmative Action in the Federal Courts of Appeals, 1971–1999*, Paper Presented at the 2003 Meeting of the Midwest Political Science Association (Apr. 3–6, 2003) (manuscript on file with author) (applying a "social economics approach" to the behavior of judges on the U.S. Court of Appeals). Cameron and Cummings cite a number of studies which "cast considerable doubt on what might be called the traditional political science approach to decision-making on collegial courts." *Id. See, e.g.*, Sean Farhang & Gregory Wawro, *Institutional Dynamics on the U.S. Court of Appeals: Minority Representation Under Panel Decision Making*, 20 J. L. ECON. & ORG. 299 (2004); Richard L. Revesz, *Environmental Regulation, Ideology, and the D.C. Circuit*, 83 VA. L. REV. 1717 (1997). Of course, other actors and institutions also impact a given jurist's conception of what constitutes a sound legal rule.

6. *See generally* SCHELLING, *supra* note 3.

7. Of course, since formal institutions "matter," it is certainly fair to assert that not all organization here is "self-organization."

8. *See generally* Oliver Wendell Holmes, Jr., *The Path of the Law*, 10 HARV. L. REV. 457 (1897).

which network effects are present in the development of the common law.

I. COMPLEXITY THEORY INTERSECT JUDICIAL DECISION MAKING AND LEGAL CHANGE

Describing the mechanisms that coalesce to produce change in the common law has been the charge of a diverse set of scholars. From within the legal academy and across allied disciplines such as political science, sociology, anthropology, physics and economics, an extensive set of positive and normative scholarship attempts to characterize global judicial outputs and the interconnected layer of actors and institutions that collectively generate the canon. As a means to introduce complexity theory and network analysis, this section engages the public law literature arguing many theories of judicial decision-making and common law development could be improved through consideration of law as a complex adaptive system.

A. On the "Evolution" of the Law

This symposium reflects the initial organized volume of scholarship applying complexity to enrich legal theory. As it offers an analytical framework to consider the possibility of law's adaptation and potential evolution, the extant complexity literature provides a number of illuminating examples relevant to modeling the common law's stasis and occasional doctrinal changes.

For example, consider existing models of common law development with reference to H_2O, as phase transitions of water are a useful manner for understanding how micro processes of self-organization can generate systemic changes. Specifically, while an analysis of individual water molecules provides information about the transition from solid into liquid or liquid into vapor, such a micro-analysis is not illustrative of broader system-level dynamics. Instead, careful observation from the proper vantage point demonstrates how molecules interact very differently at specific temperatures (i.e. at the freezing and boiling points).[9] Phase transitions in water are emergent—from ice to water and from water to steam. Once a given temperature threshold has been crossed, molecules self-organize in a completely different manner than immediately prior to attaining the critical 32°F and 212°F thresholds.

While physical systems offer interesting insights, social systems are also capable of complex, adaptive behavior. Consider Professor Axelrod's work on the evolution of cooperation.[10] Axelrod explores humanity and governance by pondering the Hobbesian state of nature. Hobbes based many of his conclusions concerning the brutality of the natural state of man based upon interactions between unfamiliar agents operating under a lack of centralized authority. Axelrod argues this initial uncertainty is akin to the risks and rewards contained in a prisoner's dilemma. Accordingly, Axelrod considers the conditions under which one would observe cooperation despite a lack of institutionalized central authority and prior communication. In short, without large discount rates, actors cooperate when the number of interactions between agents is indefinite. These uncertain intervals allow players to adapt their behavior and punish or reward the other actor through the renowned Tit-for-Tat strategy.

Given the introduction of greater numbers of actors with whom interaction is possible, self-sorting of interaction, easy exit strategies, reputation effects and selection based upon fitness, the system will evolve to different ends based upon the critical masses of defectors and cooperators. The adaptive behavior of the individual actors is the key to this evolutionary process. Linking back to the common law, we contend the manner in which doctrine changes cannot be divorced from the manner of self-organized social structure relevant actors confront. The micro-motives of federal jurists and the professional and social interactions between jurists, at least in part, help generate systemic changes in the common law.

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9. *See, e.g.,* PIERRE PAPON, JACQUES LEBLOND, PAUL H. E. MEIJER, THE PHYSICS OF PHASE TRANSITION (1999).

10. *See* ROBERT M. AXELROD, THE EVOLUTION OF COOPERATION (1984).

Under the conditions described here, the "evolution" of the law does not refer to some normative upward ascension to good. It does not necessarily imply efficiency or quality. Rather, our invocation of evolution refers to a dynamic process observed when a characteristic or attribute increases or decreases the probabilities for reproduction or replication, and that trait is passed on with a greater or lesser probability through the reproduction process.[11] When certain factors exist within a system, the trait or characteristic will be selected and greater proportions of the agents within that system will take on that characteristic until that population reaches some ceiling based on the external environment.[12]

This process is often described as fitness landscape hill-climbing. Imagine an agent is standing on some sort of hill that is surrounded by many other hills. While the agent's goal is to reach the hill's highest point, assume it is midnight and thus difficult to determine in which direction to proceed. The agent, however, is not without any guidance as other than the exact top of a hill, the angle of the ground underneath his or her feet indicates the direction of assent. Given this information, an agent can walk until the angle levels whereby the exact top of the given hill is reached. Yet, since the individual cannot see anything, he or she is unable to determine if a given hill peak is the tallest mountain in the known world, or the smallest foothill.[13] Without any additional information, the agent cannot justify any strategy other than remaining at the given hill's peak. Thus, the actor will hold steady until an exogenous force knocks him or her from the peak and carries the agent to another position on the landscape. Once in this new position, the process of hill-climbing begins anew.

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11. Although evolutionary dynamics are widely documented as being non-normative, for a more detailed discussion on evolutionary analysis from the perspective of the complex systems paradigm, see PER BAK, HOW NATURE WORKS (1997) and JOHN MAYNARD SMITH & EÖRS SZATHMÁRY, THE ORIGINS OF LIFE (1999).

12. For a more detailed explanation of these evolutionary dynamics, see Mark Newman, *Self-organized Criticality, Evolution and the Fossil Extinction Record,* 263 PROC. ROYAL SOC'Y LONDON B, 1605 (1996); Mark Newman, *The Power of Design*, 405 NATURE 412 (2000).

13. For a discussion in greater detail on fitness landscapes and hill-climbing in the context of evolution, see MARTIN A. NOWAK, EVOLUTIONARY DYNAMICS: EXPLORING THE EQUATIONS OF LIFE (2006).

While not always agent centric or the byproduct of conscious choices, the evolution of social systems often follow this methodical hill-climbing process. If characteristics considered normatively poor lead to greater reproduction, then those bad traits will be considered fit. Thus, in the phrase "survival of the fittest," fitness simply refers to what reproduces or replicates until some exogenous or endogenous shock resets the basis for reproduction. Of course, it is possible the common law tracks towards efficiency, justice or some other normatively attractive criteria. However, to the extent "evolution" is the causal mechanism, this tendency must be embedded in the relevant fitness landscape.

Legal scholars have long described changes in the common law using Darwinian evolutionary terms.[14] Whether speaking loosely or formally, many existing descriptions of legal change posit that law has a trajectory. Specifically, the literature commonly evaluates the outputs of the legal system and links them to some process of purification[15] or move toward efficiency.[16] Of course, the conditions

14. *See* ALLAN C. HUTCHINSON, EVOLUTION AND THE COMMON LAW (2005). "In championing an evolutionary methodology, common lawyers trade off the established theories of biological development and benefit from its scientific pedigree. . . . Perhaps because of its own insecurities, jurisprudence jumped on the Darwinian bandwagon of the nineteenth century more quickly and more zealously than most other disciplines. Indeed, from the pioneering work of Maine, Holmes, Wigmore, and Corbin through to more recent technical efforts, the evolutionary motif has always loomed large over jurisprudential efforts to explicate the nature of the common law." *Id.* at 12–13. For a further history, see *id.* at 13 (citing E. Donald Elliott, *The Evolutionary Tradition in Jurisprudence*, 85 COLUM. L. REV. 38 (1985); Herbert Hovenkamp, *Evolutionary Models in Jurisprudence*, 64 TEX. L. REV. 645 (1985)).

15. As Professor Hutchinson notes, "[t]he leading so-called purist among the elite of modern jurisprudence is Ronald Dworkin. He has placed the notion that the law works itself pure at the dynamic core of his legal theory." HUTCHINSON, *supra* note 14, at 70–71. It is not clear, however, that the law is working itself pure as the Darwinian program is about selection and adaptation—neither of which is necessarily related to the matters of morality or justice that occupy much of Dworkin's project.

16. *See* RICHARD POSNER, ECONOMIC ANALYSIS OF THE LAW (1973) (arguing that the common law tends toward efficiency in the aggregate because jurists maximize efficiency at the individual level). Subsequent scholars extend these claims. *See* Robert Cooter, Lewis Kornhauser, & David Lane, *Liability Rules, Limited Information, and the Role of Precedent*, 10 BELL J. ECON. 366 (1979); George Priest, *The Common Law Process and the Selection of Efficient Rules*, 6 J. LEGAL STUD. 65 (1977). For a recent attempt to reconcile this puzzle, see Nicola Gennaioli & Andrei Shleifer, *The Evolution of Common Law*, 115 J. POL. ECON. 43 (2007) (arguing that under a set of conditions legal evolution can be beneficial even if policy-motivated judges act in an interested fashion.). However, these scholars acknowledge they "have ignored several institutional features of appellate review that might affect our results." *Id.* at 63. Namely, while these scholars identify panel effects as a source for moderation, their analysis might also engage other factors such as those considered herein.

necessary to conclude the Darwinian mechanism is the driver, is fairly strict. The common law may very well be working itself pure but there is genuine tension between claims of trajectory and the reliance upon evolutionary mechanisms.[17] In so much as scholars assert claims that law's evolution is co-extensive with trajectory, the widespread historical misconceptions embedded in the American constitutional canon[18] should provide pause.

The description of evolution offered by the law as a complex system paradigm makes no such claim of trajectory. Instead, as discussed above, the key evolutionary criterion is fitness, where fitness as defined against a given landscape. In the context of legal doctrine, the burgeoning public law historical institutional scholarship argues fitness in the context of law's evolution does not necessarily imply historical precision. Rather, at least some subset of the common law that persists in the average casebook, and is disseminated from generation to generation, is of dubious truth-value. In other words, rather than embracing efficiency or purification, law's fitness landscape appears to select for reproduction the clean and simplified legal narratives that can be most easily imparted to the next generation.

B. Injecting Emergence into Theories of Judicial Decision Making

Although the definition for a complex system can be elusive,[19] most widely accepted definitions include the concept of emergence.

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17. Again, Professor Hutchinson has articulated this point quite succinctly. "[N]ature and law are simply moving on largely in response to the demands and opportunities of their changing environmental situation. Neither always getting better (or worse) nor advancing in any particular direction, they are simply changing." *See* HUTCHINSON, *supra* note 14, at 238.

18. In particular, it is fruitful to review recent work analyzing a number of canonical Constitutional narratives such as the Supreme Court's alleged abandonment of the freeman, the Court's decision in *Lochner*, the development of modern First Amendment speech doctrine, and the New Deal "Switch in Time." Evaluating the record, historical institutional scholarship place long-standing and dominant accounts under significant scrutiny. *See, e.g.*, Pamela Brandwein, *A Judicial Abandonment of Blacks? Rethinking the "State Action" Cases of the Waite Court*, 41 LAW & SOC'Y REV. 343 (2007); BARRY CUSHMAN, RETHINKING THE NEW DEAL COURT (1998); HOWARD GILLMAN, THE CONSTITUTION BESIEGED: THE RISE AND DEMISE OF LOCHNER ERA POLICE POWERS JURISPRUDENCE (1993); MARK A. GRABER, TRANSFORMING FREE SPEECH: THE AMBIGUOUS LEGACY OF CIVIL LIBERTARIANISM (1991).

19. *See* JOHN H MILLER & SCOTT E. PAGE, COMPLEX ADAPTIVE SYSTEMS 3 (2007).

Systems display emergence when interactions between components, at least in part, structure the outputs of the system.[20] Among other things, emergence offers scientific credence to claims that "the whole" is different from "the sum of its parts."

With ultimate reference to existing theories of judicial decision-making, consider some examples of emergence as described across the complex systems literature. For example, contemplate a photograph composed of thousands of pixels.[21] One could conceivably zoom close enough to the picture to observe each individual pixel, but this information, even if studied discretely for every pixel in the photo, would not necessarily provide insight into the overall image. Rather, in order to understand the image, it is necessary to obtain the proper vantage point and observe the interaction between the pixels. With perspective, a pattern of meaning ultimately emerges.

Consider also the design of traffic systems.[22] When engineering transportation structures so as to prevent gridlock, knowledge about a host of individual level variables including the maximum speed of vehicles, the disposition of particular drivers, average weather conditions as well as other factors, provides only partial insight into the ultimately observed pattern. Instead, it is the interactions between certain drivers with individual decision rules and car capabilities together with other conditions that dictate whether an observed macro pattern of congestion or efficiency will obtain.

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20. Multiple disciplines across a variety of intellectual domains include discussions of emergence. *See generally* David Chalmers, *Strong and Weak Emergence*, in THE RE-EMERGENCE OF EMERGENCE: THE EMERGENTIST HYPOTHESIS FROM SCIENCE TO RELIGION (Philip Clayton & Paul Davies, eds. 2006); Tom De Wolf & Tom Holvoet, *Emergence Versus Self-Organisation: Different Concepts but Promising When Combined*, *in* ENGINEERING SELF-ORGANISING SYSTEMS (Sven A. Brueckner et al., eds. 2005); STEPHEN WOLFRAM, A NEW KIND OF SCIENCE (2002); JOHN H. HOLLAND, EMERGENCE FROM CHAOS TO ORDER (1998).

21. *See* MILLER & PAGE, *supra* note 19, at 48.

22. For a further discussion of cross-disciplinary historical uses of complex systems, see Peter A. Corning, *The Re-Emergence of "Emergence": A Venerable Concept in Search of a Theory*, 7 COMPLEXITY 18 (2002). *See also* BRIAN GOODWIN, HOW THE LEOPARD CHANGED ITS SPOTS: THE EVOLUTION OF COMPLEXITY (2001); STEVEN JOHNSON, EMERGENCE: THE CONNECTED LIVES OF ANTS, BRAINS, CITIES, AND SOFTWARE (2001).

Returning to the consideration of legal institutions, there are a host of social scientific approaches to judicial decision-making that together provide great insight into the relevant individual level variables that inform judge choice. For example, attitudinalists observe that judicial decision-making is the singular pursuit of an individual's partisan policy preferences.[23] "Simply put, Rehnquist votes the way he does because he is extremely conservative; Marshall voted the way he did because he is extremely liberal."[24] In short, the attitudinal model builds individual policy preferences into the core of its approach. The strategic institutionalists, while offering a more nuanced approach to judicial choice, follow a similar individual level strategy, arguing jurists act strategically in the pursuit of their policy preferences.[25] Institutionalist theories, while highlighting how institutional rules sometimes lead constrained actors to deviate from their unbounded policy preferences, do not consider the dynamic interplay between the micro and macro and its consequences for aggregate outputs.[26]

This is troublesome because judicial decision-making is decision-making in a judicial hierarchy. Agents across the institution consistently interact and those interactions undoubtedly consequence aggregate outputs. An important precursor to gaining leverage on the empirical implications of this revelation is an effort to develop a positive theory of judicial social structure. Much like the study of the pixels or the understanding of traffic systems, existing theories could benefit from modeling both direct and indirect interactions between judicial agents. Along with factors identified by behavioral and strategic institutional scholars, we believe that a holistic model of judicial decision-making should account for the institution's self-

23. *See, e.g.*, SEGAL & SPAETH, *supra* note 4.
24. *Id.* at 65.
25. *See, e.g.*, EPSTEIN & KNIGHT, *supra* note 4; MALTZMAN, *supra* note 4.
26. For a discrete applied example of the strategic institutional approach, see Daniel M. Katz, *Institutional Rules, Strategic Behavior, and the Legacy of Chief Justice William Rehnquist: Setting the Record Straight on* Dickerson v. United States, 22 J. L. & POL. 303 (2006) (arguing Justice Rehnquist's decision to support and author the Court's decision in *Dickerson* should be best understood as a strategic effort designed to preserve the very exceptions to *Miranda* the Chief Justice spent roughly three decades working to secure).

organized social topology and its role in structuring the emergent and convergent outputs produced by the aggregate institution.

One manner of quantifying and representing such interactions between jurists is through the use of network analysis.[27] Rooted in graph theory, network analysis allows scholars to condense information about interactions and provide graphical and statistical representations of the broader social landscape. Once operationalized into depictions of the system, network science offers a variety of techniques including node-level statistics as well as characterizations of the network's broader structural properties.[28]

In order to contextualize what a particular observed social structure implies, it is critical to remember that the social landscape need not take any particular form. Scaffolding could indeed assume a variety of flavors and there are causal mechanisms that act at the micro-level to produce the observed macro-architecture. Specifically, macro-system properties are a function of historical processes of positive and negative feedback. Such processes can generate periods of dynamical change followed by periods of relative stasis. However, cascades across a network are far more likely in certain orientations of the social world than in others. Therefore, it is important to characterize the alternative network structures or 'states of the world' and consider what these alternative states imply for the prospects of doctrinal diffusion.

27. Although not the founder of network analysis, Jacob Moreno does deserve credit for the development and modernization of social network analysis. Along with Kurt Lewin and Fritz Heider, the first half of the twentieth century has been a period of dramatic progress for networks scholars. For example, Moreno developed notions of "sociograms." *See* MORENO, *supra* note 2. Kurt Lewin extended Moreno's work arguing the structural properties of social space could be uncovered using a host of mathematical techniques including graph theory, topology, and set theory that link to sociology. *See, e.g.*, LEWIN, *supra* note 2.

28. Graph theory is the mathematical foundation for network analysis. In attempting to solve the Konigsberg Bridge Problem, Leonhard Euler asked whether it is possible to traverse the seven bridges of Konigsberg only once and close the circuit by returning to the point of origin. Euler demonstrated this was not possible. With reference to the Konigsberg Bridge Problem, mathematicians ask whether "there exists any *Eulerian path* on the network." *See* THE STRUCTURE AND DYNAMICS OF NETWORKS, *supra* note 2, at 2. For more on the life and work of Leonhard Euler, see C. EDWARD SANDIFER, THE EARLY MATHEMATICS OF LEONHARD EULER (2007). For more information on graph theory see, e.g., GARY CHARTRAND, INTRODUCTORY GRAPH THEORY (1985); FRANK HARARY, GRAPH THEORY (1969).

II. STATES OF THE WORLD: THE CONSEQUENCES OF NETWORK ORGANIZATION FOR SYSTEMIC CHANGE

The emergence of internal order is ubiquitous in the formation of both natural and artificial systems.[29] Prior scholarship, drawn from a variety of disciplines, observes how different processes of self-organization can generate alternative structures, distributions of authority, and levels of diffusion.[30] Although attempts to measure and describe self-organization are frequent, in considering the social landscape judicial actors embrace, our analysis is limited to network structures, their characteristics, and frequency distributions. Given the same processes which generates the structure also produces the characteristic or output distributions, the network structures and frequency distributions feature an endogenous relationship. In order to fully contemplate judicial decision-making and law's evolution, we consider a variety of possible network structures, the characteristics of these networks, and their likely generating processes.

A. *The Federal Judiciary and Dependence Networks*

Dependence networks are graph theoretical representations of processes that generate connections between nodes.[31] These

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29. MARK BUCHANAN, UBIQUITY: WHY CATASTROPHES HAPPEN (2002).

30. In one of the seminal works of network diffusion, James G. Anderson and Stephen J. Jay track the dissemination of medical technology across different communities of doctors. James G. Anderson & Stephen J. Jay, *The Diffusion of Medical Technology: Social Network Analysis and Policy Research,* 26 SOC. Q. 49 (1985). Though important, this work is by no means comprehensive. The relationship between diffusion and network structure has been used to study a variety of issues including but not limited to municipal reform, civil service reform, organizational structure, the poison pill dilemma in business, and social epidemiology. For more detailed information, *see* Lawton R. Burns & Douglas R. Wholey, *Adoption and Abandonment of Matrix Management Programs: Effects of Organizational Characteristics and Interorganizational Networks*, 36 ACAD. MGMT. J., 106 (1993), Gerald F. Davis, *Agents without Principles? The Spread of the Poison Pill through the Intercorporate Network*, 36 ADMIN. SCI. Q. 583 (1991), David Knoke, *The Spread of Municipal Reform: Temporal, Spatial, and Social Dynamics*, 87 AM. J. SOC., 1314 (1982), and E. O. Laumann, J. H. Gagnon, S. Michaels, R. T. Michael, & J. S. Coleman, *Monitoring the AIDS Epidemic in the United States: A Network Approach*, 244 SCIENCE 1186 (1989).

31. *See* MODELS AND METHODS IN SOCIAL NETWORK ANALYSIS 166 (Peter J. Carrington, John Scott, & Stanley Wasserman, eds., 2005).

processes are normally related to proximity of nodes or the already existing distribution of connections. Given the dynamic nature of social systems, specific network structures emerge as the direct by-product of micro-level generating processes. For analytical ease, the foregoing analysis will focus primarily upon characterizing networks using their clustering and/or degree frequency distribution. If one assumes that embedded in each directed connection is some degree of influence from one actor to another, then the observed aggregate network can offer insight into the prospect for change in subsequent periods. As considered herein, network induced judge-level change occurs when the probability of a judge supporting a particular policy position is impacted by the policy positions taken by the community of individuals with whom he or she shares social or professional connections.

The variety of network structures, displayed *infra*, represent a cursory overview of the possibility frontier for the self-organization of the federal judiciary—where the nodes are the jurists and the connections are a measure of influence, loosely defined as a social and/or professional relationship between given jurists. Thus, if the connections between actors connote influence between the agents, then the actor to whom a connection is allotted would be the recipient of that original person's esteem. All else equal, the higher the indegree[32] for a node, the greater the influence enjoyed by that node.[33] With respect to diffusion, information passes through a given dyad and is tagged by the recipient as positive or negative.[34] That

32. Indegree is a network analysis statistic that represents the aggregation of all connections to a given node, where the arrows point to that node. *See* WOUTER DE NOOY, ANDREJ MRVAR, & VLADIMIR BATAGELJ, EXPLORATORY SOCIAL NETWORK ANALYSIS WITH PAJEK 321 (2005).

33. David Strang and Sarah A. Soule use other centrality measures as a possible measure of power or influence in their dynamic model, but unfortunately they do not examine these effects and how they interact with network structure, which is the basis of our analysis. *See* David Strang & Sarah A. Soule, *Diffusion in Organizations and Social Movements: From Hybrid Corn to Poison Pills*, 24 ANN. REV. SOC. 265 (1998).

34. In other simulation models, the commodity being diffused is not the positive or the negative tag, but rather the people within the network who are in opposition to one another. In this model, the actors have agency over the acceptance of information. *See* Devi R. Gnyawali & Ravindranath Madhavan, *Cooperative Networks and Competitive Dynamics: A Structural Embeddedness Perspective*, 26 ACAD. MGMT. REV. 431 (2001).

receiver can either resist the information with increased probability when the tag is negative or probabilistically accept the information when the tag is positive.[35] As this is a dynamic process, such probabilities increase and decrease over time based upon the influence differential between the actors as well as larger exogenous forces not explicitly modeled herein.

Such an ebb and flow of influence within a social system is consistent with intuitive understanding. Actors of higher influence, as determined by indegree, should be better able to resist new ideas than their less prestigious counterparts. At the same time, such prominent actors are also more likely to disseminate ideas. Specifically, although connections are often directed, the communication flow between actors is bidirectional. The likelihood of the acceptance or denial of the information is likely a function of the power dynamic between agents. Yet, these power dynamics are not static as positive and negative feedback loops abound. For example, the acceptance or denial of a given idea at t=0 can impact the relative standing of that individual in subsequent periods. In order to consider the "evolution" of the law, one must thus consider how a given network of judicial actors adapts to temporal and spatial attempts at doctrinal change.

While certainly not exhaustive, the network structures discussed *infra* represent several possible "states of the world." Each hypothetical state offers different prospects for law's evolution—where system level change is a function of variation in network structure, degree distribution, and clustering.[36] With consideration of

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35. The dynamic proposed in this model is similar to the SIS model described in the social epidemiology literature, except the commodity being diffused in this case can be positive or negative and the varying levels of acceptance or denial depend upon indegree. This extension is in part the value of the study. For more on the SIS model, *see* Frank Ball, *Stochastic and Deterministic Models for SIS Epidemics Among a Population Partitioned into Households*, 156 MATHEMATICAL BIOSCIENCES 41 (1999).

36. Economist and network scientist Matthew O. Jackson summarizes several of the epidemiological models for disease diffusion including the SIR model and previously mentioned SIS model. Jackson explains how diffusion varies as network structure and degree distributions vary. Degree variance is important because the probability of infection is directly impacted by the probability of interacting with diverse nodes. For a detailed description, *see generally* MATTHEW O. JACKSON, SOCIAL AND ECONOMIC NETWORKS (2008). This model incorporates indegree as a measure of power as well, which increases the ability to resist the infection, which in our case is referring to information and not a virus. Thus the

the possibilities outlined herein, subsequent empirical research should seek to identify which network structure, generating mechanism, and corresponding dynamics best characterizes the federal judiciary.

1. Erdos-Renyi Random Graphs

Figure 1 is a random graph initially pictured in a ring lattice, where the nodes are generated in a circular arrangement and the probability of any node being connected to any other node is independent. This structure is often called an Erdos-Renyi graph.[37] Figure 1 contains an alternative visualization of the network after the Kamada-Kawai energizing algorithm has been applied.[38] The Erdos-Renyi form of network structure is sometimes referred to as a Bernoulli Dependence Graph,[39] because the ties assigned are a product of the independently assigned probabilities associated with the network. The probability of a connection between any two nodes is independent of other connections and/or the proximity of the two nodes. In repeated randomly generated networks or with a large enough network, the degree frequency converges upon the Poisson distribution.[40]

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rate of transmission depends upon the aforementioned specification of the information as negative or positive.

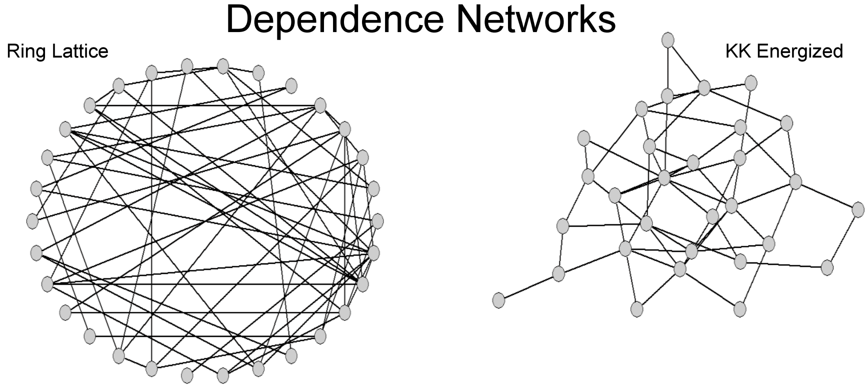
37. In 1959, Paul Erdos and Alfred Renyi designed these random networks, which are also referred to as G_{np} or G_{nm} models. Although these networks are unlikely in the real world, they did launch investigations into network structures and their properties. For more detailed information on these graphs and their properties, see Paul Erdos, *On Random Graphs*, 6 PUBLICATIONES MATHEMATICAE 290 (1959); Paul Erdos & Alfred Renyi, *The Evolution of Random Graphs*, 5 MAGYAR TUD. AKAD. MAT. KUTATÓ INT. KÖZL 17 (1960).

38. *See* Tomishia Kamada & Satoru Kawai, *An Algorithm for Drawing General Undirected Graphs*, 31 Information Processing Letters 7 (1989).

39. "Bernoulli multigraphs assume conditional independence for all pairs of random variables representing distinct pairs of individuals." MODELS AND METHODS IN SOCIAL NETWORK ANALYSIS, *supra* note 31, at 166.

40. These dynamics mathematically follow from the generating mechanisms described in the original Erdos and Renyi graph, *supra* note 37, and further developed by Réka Albert and Albert-László Barabási, *in* STATISTICAL MECHANICS OF COMPLEX SYSTEMS (2002).

Figure 1: Erdos-Renyi Random Dependence Networks



If the federal judiciary organized itself as an Erdos-Renyi directed network, very few jurists would have either great influence or very little influence. However, time would have an appreciable effect on the prestige of judges because the longer a given jurist remained in the network the more exposure the agent would have to the probabilistic attachment of connections. Given the random generating mechanism, it is certainly possible the network would have some localized clustering, but that clustering would not be systematic. If one were to repeatedly simulate the generative process, clustering should appear in random amounts and in random locations.[41]

With respect to diffusion in this hypothetical state of the world, new doctrinal approaches would spread across the network quickly, but such cascades would be unlikely to occur because of the relative equality in influence of the jurists. Additionally, although the diffusion would occur quickly across most of the network, complete consensus would lag because clustering is low. In evolutionary terms, over a long period of time, a hypothetical judiciary organized under such conditions would, on average, be resistant to change or adaptation.[42] In all, the Erdos-Renyi graph is an unlikely depiction of

41. *See* Albert & Barabási, *supra* note 40.

42. *See generally* DUNCAN J. WATTS, SMALL WORLDS: THE DYNAMICS OF NETWORKS BETWEEN ORDER AND RANDOMNESS (1999).

the judicial social world. Specifically, influence relationships are unlikely to form independently.

2. *Neighborhood Clustered Networks*

There are two simple ways to conceptualize highly clustered networks and both are pictured in Figure 2. Network A is a ring lattice, in which every node is connected to their immediate neighbor, and their neighbors' neighbor.[43] This is useful to conceptualize clustering, but obviously is a rather narrow restriction that makes difficult generalizations about substantive contexts. Accordingly, for a more pragmatic illustration, consider Network B, in which nodes are highly clustered and everyone within a community knows everyone else in the given community. Network B is a clustered network in which the probability increases for connections based upon proximity, or degree separation between actors.[44] These types of networks are consistent with balance theory,[45] which states that if person A is connected to person B, and person B is connected to person C, then it is likely that either person A will connect to person C, or one of person B's bonds will break.

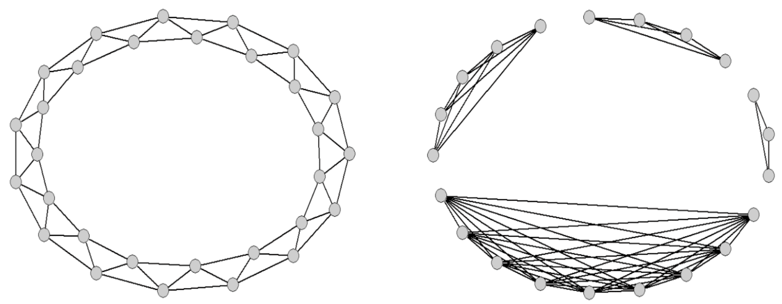
43. The visualization and operationalization of these graph theoretic models can be found in Watts & Strogatz, *supra* note 2. However, the theoretical justification for the process that underlies and generates these graphs has its roots in Mark S. Granovetter, *The Strength of Weak Ties*, 78 AM. J. SOC. 1360 (1973), and *see* Milgram, *supra* note 2.

44. *See* MODELS AND METHODS IN SOCIAL NETWORK ANALYSIS, *supra* note 31. Although several different Markov graphs exist, we are specifically referencing the Markov star networks.

45. *See* D. Cartwright & Frank Harary, *Structural Balance: A Generalization of Heider's Theory*, PSYCHOL. REV. 63, 277–92 (1956). The structural balance considered by these authors is essentially a graph theoretic operationalization of Fritz Heider's theory about minimizing social psychological discomfort in social relationships. *See* Fritz Heider, *Attitudes and Cognitive Organization*, J. PSYCHOL. 21, 107–12 (1946).

Figure 2: Highly Clustered Networks

Network A Network B



In Network A, the generated connections are completely dependent upon proximity, and the degree frequency distributions are uniform, meaning that all nodes have the same degree. Network B will have a conditionally uniform distribution with the average degree dependent upon the size of the community to which the node is connected. Accordingly, in such a highly clustered dependence network, diffusion of new ideas would not occur quickly, but it would happen predictably provided the connections are consistent with our prior influence assumptions.[46] In the ring lattice, information would spread methodically through proximity, while in the other clustered graph, it would spread uniformly conditioned upon it reaching a given community. It is worth noting that given the relatively equal levels of influence, change could be stopped at any interval, by any individual or community. Furthermore, information would likely not permeate communities that initially resisted the change. With respect to law's evolution, if the federal judiciary self-organized as a clustered network, the network would likely display insular communities that evolve differently from one another, with intra-community consensus, and inter-community divergence. Also, greater degrees of clustering and influence equality would produce the greater number

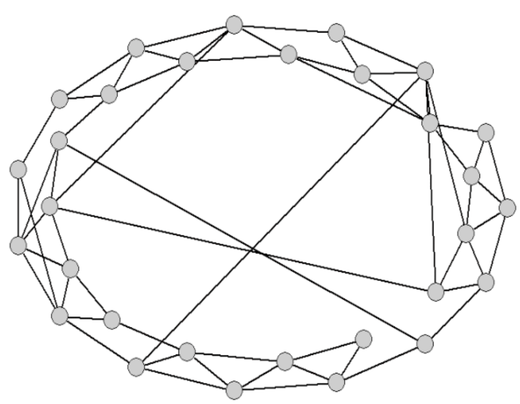
46. This is the logical extrapolation of the generating process. If each node in each separate community is interconnected, we can assume that change will quickly take hold in that community. However, transfer to alternative communities would be unlikely. *See* JACKSON, *supra* note 36.

of communities.[47] Finally, if clusters or neighbors are further characterized by homophily,[48] which implies sameness across nodes, it is likely that greater consensus would follow when those characteristics correlate with opinions or predispositions. In practical terms, possible communities within the federal judiciary could generate along a variety of social, ideological, geographic and institutional dimensions.

3. Watts and Strogatz Small World Networks

In many ways, small world networks are the amalgam of clustered networks and Erdos-Renyi dependent graphs. Watts and Strogatz hypothesized that highly clustered networks could have small world properties if only few of the connections throughout the network were randomly rewired.[49] Their simulation model allowed the network to maintain its clustered nature while lessening the number of links needed to reach any individual node from any other node.

Figure 3: Small World Network



47. These outcomes follow from the generating processes described in MODELS AND METHODS IN SOCIAL NETWORK ANALYSIS, *supra* note 31, and Albert & Barabási, *supra* note 40.
48. *See* NOOY et al., *supra* note 32, at 320.
49. *See* Watts & Strogatz, *supra* note 2.

All else being equal, if the federal judiciary self-organized as a Watts-Strogatz small world network, the diffusion of new doctrinal approaches would occur rapidly. The randomly rewired connections would prevent any individual's attempt to halt dissemination, as the bridges that span across communities provide alternative pathways to the blocked communities.[50] At the same time, the network would not be completely egalitarian as the bridge nodes serve in structurally important positions. Specifically, such actors would be disproportionately important in generating a collective conception.[51] If a critical mass of such bridge jurists simultaneously resisted a given change, the dynamics of this system would mimic the properties associated with the highly clustered neighborhood ring lattice. Accordingly, change would occur quickly if adopted by large proportions of the jurists who are largely equal in influence, but consensus would be rare given the size of the network.[52]

4. *Barabási and Albert Preferential Attachment (Scale-Free)*[53]

Barabási and Albert networks generate from a micro-level preferential attachment mechanism. In the model, a given node prefers to connect to other nodes that already display high indegree.[54] As the number of connections a given agent displays is a function of the number the agent possessed in earlier time periods, the distribution of connections is highly susceptible to the initial starting conditions. For instance, consider a network that has four nodes A, B, C and D where A is connected to B and C is connected to D. If node E enters the network, assume the initial probability of attachment to

50. The small world network as defined by Watts and Strogatz is a graph theoretic explanation for the rapid spanning of a network. *See* Watts & Strogatz, *supra* note 2, at 440–42.

51. The uniform influence of which the model speaks is a product of the assumption of the model that relates indegree to influence.

52. Namely, a mapping of the aggregate federal judiciary would contain in excess of one thousand nodes.

53. Although popularized and extended by Albert-Lazlo Barabási, the scale-free networks were originally described by Derek J. de Solla Price, over 30 years earlier, which he termed cumulative advantage. *See* Derek J. de Solla Price, *Networks of Scientific Papers*, 149 SCIENCE 510 (1965).

54. *See* BARABÁSI, *supra* note 2; THE STRUCTURE AND DYNAMICS OF NETWORKS, *supra* note *2*.

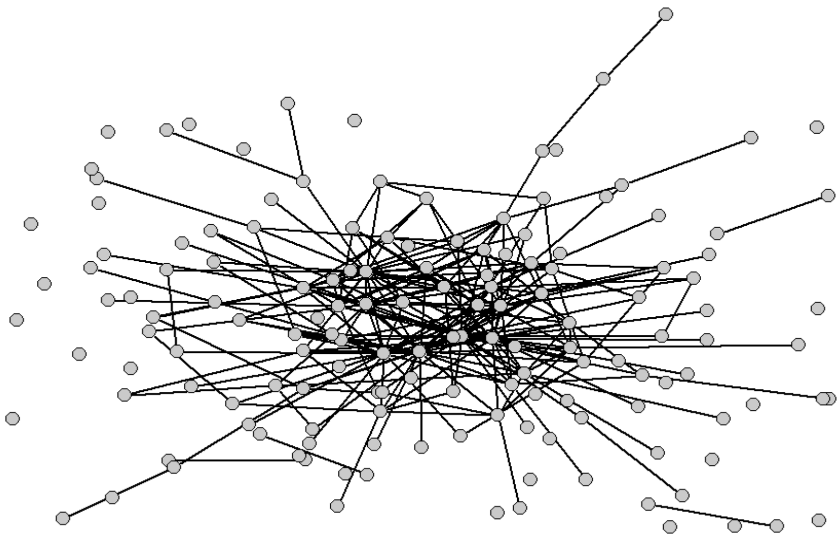
the AB community is equal to that of the CD community. Once E connects to either the AB or CD community, subsequent entrants such as node F, G and beyond are more likely to connect with the community selected by E.[55] Complexity scholars have described a number of phenomena that display this micro-process. Consider the distribution of city size. If individuals are continuously moving and in part choosing the city to which they move based upon the number of people already in the city, then like the Barabási and Albert network, the frequency distribution of city size will soon begin to mimic the power law distribution.[56] In the preferential attachment model, nodes become clustered around centrally located nodes with influence that is greatly disproportionate to the average degree of the network. Preferential attachment models are also known as scale-free or scale-invariant networks as their degree frequency distributions tend to display power law properties.[57]

55. For further information on this generative process and the ubiquity of scale-free networks, *see* Albert-László Barabási & Eric Bonabeau, *Scale-Free Networks*, 288 SCI. AM. 60 (2003); L.A.N. Amaral, A. Scala, M. Barthélémy, & H.E. Stanley, *Classes of Small-World Networks*, 97 PROC. NAT'L ACAD. SCI. 11149 (2000); Chavdar Dangalchev, *Generation Models for Scale-free Networks*, 338 PHYSICA A 659 (2004); M. E. J. Newman, *The Structure and Function of Complex Networks*, 45 SOC'Y INDUS. & APPLIED MATHEMATICS REV. 167 (2003); S. N. Dorogovtsev, J. F. F. Mendes, & A. N. Samukhin, *Structure of Growing Networks: Exact Solution of the Barabási—Albert's Model*, 85 PHYSICS REV. LETTERS 4633 (2000).

56. Xavier Gabaix, *Zipf's Law for Cities: An Explanation*, 114 Q. J. ECON. 739 (1999). Zipfian distributions fall under the larger class of power law distributions.

57. *See* BARABÁSI & ALBERT *supra* note 2.

Figure 4: Scale-Free Networks



The presence of a power law distribution is evidence of a system self-organized at a position of criticality. Self-organized criticality describes a discrete process through which the agent-level micro-motives yield a structure where small components of the system organize in pockets and where small disturbances can have unpredictable critical systemic impacts.[58] Self-organized criticality is normally seen when history builds upon itself implying actions at present build pyramidally on the past. In other words, if bricks from the base of the pyramid are simultaneously removed, large portions of the pyramid will fall.

If the federal judiciary were self-organized at a position of criticality, one would expect to observe long periods of time where the network and perhaps its outputs where resistant to change. These periods of stasis could be followed by relatively unpredictable dramatic change initiated by jurists close to the central actors or by the most central actors themselves. If the network had multiple hubs,

58. *See* MILLER & PAGE, *supra* note 19, at 165. *See also* Per Bak, Chao Tang & Kurt Wiesenfeld, *Self-Organized Criticality: An Explanation of 1 / f Noise*, 59 Phys. Rev. Ltrs. 381 (1987); BAK *supra* note 11.

jurists would cluster and create a small number of separate communities that would resist change from the opposing community because of the disproportionate power certain influence leaders have in each community. As time moved forward, the dynamic system would evolve such that the community would have sub-pockets and the entire system could generate great change through a relatively small disturbance in a structurally important pocket.

If the federal judiciary self-organized at criticality, then a case considered salient to a fairly small subset of the network could induce widespread emergent agreement by large portions of the network. Additionally, the institution would be resistant to random failures. Thus, should several jurists be resistant to a given emergent doctrinal interpretation that change would continue regardless of their resistance unless those resistant judges were central hubs. In other words, this structure is simultaneously conducive to stasis and to a doctrinal phase transition—if the right shock, struck the right pocket, then systemic legal change would obtain, perhaps followed by a hill-climbing like process on the new fitness landscape.

B. Social Influence and Yule's Law

The exploration of possible dependence networks motivates the exploration of the nature of influence and prestige, and how these attributes accumulate. In order to understand social influence, consider first the temporal accumulation of wealth. Yule's Law helps explain a dynamic process of wealth generation[59] where the greater amount of money person x_1 possesses at an initial starting condition t_0 the greater percent interest a person will receive on that quantity of money when measured at the conclusion of the first time interval t_1. The principle and the accrued interest from t_1 provides relative increases in the interest earned in the subsequent time period t_2. Thus, as $t \Rightarrow \infty$, Yule's Law describes the process of rapid growth, where the percentage return on a commodity is dependent upon the

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59. Mark Newman, *Power Laws, Pareto Distributions and Zipf's Law*, 46 CONTEMP. PHYSICS 323 (2005).

initial size of that commodity. Even small initial differences in resources among agents in the system can produce large disparities in wealth because the process is highly sensitive to initial conditions. In other words, for two different quantities of money (x_1 and x_2), the amount of money at a given time interval t_n is dependent upon the amount n of intervals elapsed and the difference between the two starting conditions (x_1 and x_2).

In a dynamic system with a relatively large population, after multiple iterations, the resulting distribution typically follows a power law, where a small number of individuals possess a widely disproportionate percentage of the overall wealth. Observing a highly skewed distribution begs a question: what function generated such a distribution? In a dynamic system, with a large population size, a process similar to Yule's Law or the previously described preferential attachment processes are likely hypotheses.

III. TOWARD A POSITIVE THEORY OF JUDICIAL SOCIAL STRUCTURE

The process of legal change and aggregate judicial decision-making is undoubtedly impacted by actors, institutions, and social forces exogenous to the judicial branch.[60] However, within the judicial branch, a social institution where scholars have consistently found differential levels of social esteem—even across actors with equivalent levels of formal authority,[61] the great weight of the available evidence implies that "peer effects" matter.

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60. This clear statement is an effort to avoid the type of overreaching that is at the core of the dispute between popular science author Malcom Gladwell and networks scientist Duncan Watts. *See* Clive Thompson, *Is the Tipping Point Toast?*, Jan. 28, 2008, http://www.fastcompany.com/magazine/122/is-the-tipping-point-toast.html (quoting Professor Watts "If society is ready to embrace a trend, almost anyone can start one—and if it isn't, then almost no one can. . . . To succeed with a new product, it's less a matter of finding the perfect hipster to infect and more a matter of gauging the public's mood."). Returning to the claims asserted herein and in an effort to avoid any Gladwellian overreaching, it is important to clearly assert that issue or idea salience together with social structure and exogenous forces ultimately dictate whether a cascade will or will not follow.

61. *See, e.g.,* David Klein & Darby Morrisroe, *The Prestige and Influence of Individual Judges on the U.S. Courts of Appeals*, 28 J. Legal Stud. 371 (1999); William M. Landes, Lawrence Lessig & Michael E. Solimine, *Judicial Influence: A Citation Analysis of Federal Courts of Appeals Judges*, 27 J. Legal Stud. 271 (1998).

The complete adjudication of either the presence or corresponding magnitude of such "peer effects" is an empirical question beyond the scope of this article. However, we hope future research designed to answer these questions will be aided by the effort contained herein. Specifically, working from the assumption that different forms of social architecture consequence aggregate decision outputs in differential manners, the article provides a sweep across the possibility frontier. By considering the various states that the social world could assume and the micro level process that could plausibly produce them, we hope to motivate development of a positive theory of judicial social structure—theory that could be well seated under the larger umbrella of positive political theory.