

COMPLEXITY THEORY, ADAPTATION, AND ADMINISTRATIVE LAW

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ABSTRACT

Recently, commentators have applied insights from complexity theory to legal analysis generally and to administrative law in particular. This Article focuses on one of the central problems that complexity theory addresses, the importance and mechanisms of adaptation within complex systems. In Part I, the Article uses three features of complex adaptive systems—emergence from self-assembly, nonlinearity, and sensitivity to initial conditions—and explores the extent to which they may add value as a matter of positive analysis to the understanding of change within legal systems. In Part II, the Article focuses on three normative claims in public law scholarship that depend explicitly or implicitly on notions of adaptation: that states offer advantages over the federal government because experimentation can make them more adaptive, that federal agencies should themselves become more experimentalist using the tool of adaptive management, and that administrative agencies should adopt collaborative mechanisms in policymaking. Using two analytic tools found in the complexity literature, the genetic algorithm and evolutionary game theory, the Article tests the extent to which these three normative claims are borne out.

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INTRODUCTION

It is not surprising that administrative law scholars, like legal scholars generally, have recently discovered complexity theory.¹ Most theories of jurisprudence include a theory of change, and complexity theory has emerged over the past quarter century from attempts to shed light on patterns of change, many quite surprising, that occur across an exceptionally broad range of natural and artificial systems. Because competing explanations of American public institutions are

1. See, e.g., J.B. Ruhl, *Complexity Theory as a Paradigm for the Dynamical Law-and-Society System: A Wake-Up Call for Legal Reductionism and the Modern Administrative State*, 45 *DUKE L.J.* 849, 916–26 (1996) (using the metaphor of complex adaptive systems to model the administrative state and to call for fundamental doctrinal changes in the case law); J.B. Ruhl & James Salzman, *Mozart and the Red Queen: The Problem of Regulatory Accretion in the Administrative State*, 91 *GEO. L.J.* 757, 806–09 (2003) (using the analogy of complex adaptive systems to explain system effects in the regulatory landscape). Professors Ruhl and Salzman claim there is a “recent explosion in [legal] scholarship employing complex systems theory.” *Id.* at 802. On the use of complexity theory by legal scholars in areas other than “core” administrative law, see, for example, Mark J. Roe, *Chaos and Evolution in Law and Economics*, 109 *HARV. L. REV.* 641 (1996), which uses features of chaos theory to explain comparative corporate law, and Vincent Di Lorenzo, *Legislative Chaos: An Exploratory Study*, 12 *YALE L. & POL’Y REV.* 425 (1994), which proposes use of chaos theory to seek the development of a model of legislation richer than pluralism and public choice theory provide.

so diverse,² one can understand the allure complexity theory promises: that new insights really could be gained by seeing in the administrative state the overarching tendencies of a complex, adaptive system.

Nonetheless, for those not attuned to this emerging science, it must seem almost perverse to apply complexity theory to administrative law. After all, there already exist fairly dense bodies of work explaining administrative law alternatively in terms of interest-group pluralism,³ civic republicanism,⁴ public choice economics,⁵ substantive welfarism,⁶ and positive political theory.⁷ Now to seek explanatory power from an emerging discipline that focuses, among other things, on the study of chaos might appear merely to be asking for trouble.

This Article asks whether complexity theory is worth the trouble by focusing on one of the central problems that the theory addresses: the importance and mechanisms of adaptation within complex systems. Focusing on adaptation promises payoffs on two fronts. First, as a matter of positive analysis, it raises the possibility that complexity theory may be capable of illuminating features of the legal landscape—seen from the perspective of change over time—more completely than other explanatory tools. Second, as a normative matter, focusing on the mechanisms of adaptation may improve the evaluation of claims that regulatory policymaking should itself be more explicitly experimentalist and adaptive.⁸

2. See *infra* notes 3–7.

3. E.g., Richard B. Stewart, *The Reformation of American Administrative Law*, 88 HARV. L. REV. 1669 (1975).

4. E.g., Mark Seidenfeld, *A Civic Republican Justification for the Bureaucratic State*, 105 HARV. L. REV. 1511 (1992).

5. E.g., David B. Spence & Frank Cross, *A Public Choice Case for the Administrative State*, 89 GEO. L.J. 97 (2000).

6. E.g., CASS R. SUNSTEIN, ONE CASE AT A TIME: JUDICIAL MINIMALISM ON THE SUPREME COURT 31 (1999) (“Much of administrative law consists of an effort to ensure reasoning by regulatory agencies”); Cary Coglianese & Gary E. Marchant, *Shifting Sands: The Limits of Science in Setting Risk Standards*, 152 U. PA. L. REV. 1255, 1256 (2004) (“Administrative law aspires to bring reason to agency policymaking.”).

7. E.g., Matthew D. McCubbins et al., *Structure and Process, Politics and Policy: Administrative Arrangements and the Political Control of Agencies*, 75 VA. L. REV. 431 (1989); Eric A. Posner, *Controlling Agencies with Cost-Benefit Analysis: A Positive Political Theory Perspective*, 68 U. CHI. L. REV. 1137 (2001); Pablo T. Spiller, *A Positive Political Theory of Regulatory Instruments: Contracts, Administrative Law or Regulatory Specificity?*, 69 S. CAL. L. REV. 477 (1996).

8. Claims for regulatory experimentation and adaptation, roughly speaking, tend to

Part I of this Article considers whether theories of adaptation, especially those found in the complexity theory literature, might add value descriptively to legal doctrines, institutions, and analytic tools. In this part of the Article, I introduce complexity theory generally and focus on three aspects in which adaptation plays an important role: emergence from self-assembly, nonlinearity, and sensitivity to initial conditions.

Part II of the Article focuses on three normative claims that either explicitly or implicitly depend for their support on notions of adaptation. The three claims are, respectively, that states offer advantages in policy formation over the federal government because experimentation can make them more adaptive, that federal agencies should themselves become more experimentalist by using the tool of “adaptive management,”⁹ and that administrative agencies should adopt “collaborative” mechanisms capable of enlisting regulatory stakeholders in problem-solving partnerships with regulatory

reflect three different types of administrative law reform projects. The first reflects a devolutionary project based on the premise that more localized decisionmakers will experiment with policymaking because they must react to competing and competitive pressures among local jurisdictions. *See, e.g.*, Michael C. Dorf & Charles F. Sabel, *A Constitution of Democratic Experimentalism*, 98 COLUM. L. REV. 267, 284 (1998) (arguing for local policymaking as more responsive and innovative in light of greater experimentalism at the local decisionmaking level); Helen Hershkoff, *State Courts and the “Passive Virtues”: Rethinking the Judicial Function*, 114 HARV. L. REV. 1833, 1916 (2001) (“The leading scholarship on federalism describes the value of local participation in utilitarian and dignitary terms, associating political action at the local level with experimental and improved policymaking . . .”). The second reflects a substantive neoclassical interest in attaining efficient outcomes in policymaking by use of experimental approaches to explore uncertainty. *See, e.g.*, John H. Davidson & Thomas Earl Geu, *The Missouri River and Adaptive Management: Protecting Ecological Function and Legal Process*, 80 NEB. L. REV. 816, 834–60 (2001) (analyzing the treatment of adaptive management as a decisionmaking strategy in the “Master Manual” for the Missouri River adopted by the U.S. Army Corps of Engineers). The third reflects a proceduralist interest in improving stakeholder participation, in part by allowing for provisional approaches. *See, e.g.*, Jody Freeman, *Collaborative Governance in the Administrative State*, 45 UCLA L. REV. 1, 28–29 (1997) (observing that provisionalism requires deliberation so as to avoid surprise to stakeholders). The categorization of administrative law into neoclassical and proceduralist camps is taken from Matthew D. Adler, *Beyond Efficiency and Procedure: A Welfarist Theory of Regulation*, 28 FLA. ST. U. L. REV. 241, 243–88 (2000), which criticizes this categorization.

9. *See, e.g.*, Bradley C. Karkkainen, *Adaptive Ecosystem Management and Regulatory Penalty Defaults: Toward a Bounded Pragmatism*, 87 MINN. L. REV. 943, 943 (2003) (“Conservation ecologists and natural resource managers assert that integrated management of complex ecosystems requires an iterative and adaptive management approach.”); J.B. Ruhl, *Thinking of Environmental Law as a Complex Adaptive System: How to Clean Up the Environment by Making a Mess of Environmental Law*, 34 HOUS. L. REV. 933, 996 (1997) (noting that adaptive management establishes that a “failure to experiment . . . would be folly”).

agencies.¹⁰ To evaluate these claims from the perspective of complexity theory, I draw on insights from two mechanisms of adaptation found in the complexity literature, the genetic algorithm and evolutionary game theory.

I. COMPLEXITY THEORY AS A DESCRIPTIVE TOOL: APPLICATIONS IN ADMINISTRATIVE LAW

A theory of change is central to understanding the science of complexity. Although I elaborate further, for present purposes it is sufficient that complexity theory is understood to involve “the study of many actors and their interactions.”¹¹ Part of the theory’s allure is that it operates on a very high level of generality. Thus, the actors can be “atoms, fish, people, organizations, or nations.”¹² And their interactions can include “attraction, combat, mating, communication, trade, partnership, or rivalry.”¹³ Because the theory operates at such a general level, it has been used to describe such features of natural systems as evolutionary selection¹⁴ and climate change,¹⁵ as well as features of such artificial systems as the economy,¹⁶ government,¹⁷ and computer networks.¹⁸ For the same reason, there are elements of

10. See, e.g., Freeman, *supra* note 8, at 22 (“Collaborative governance seeks to respond to the litany of criticisms about the quality, implementability, and legitimacy of rule making by reorienting the regulatory enterprise around joint problem solving . . .”).

11. ROBERT AXELROD, *THE COMPLEXITY OF COOPERATION: AGENT-BASED MODELS OF COMPETITION AND COLLABORATION* 3 (1997).

12. *Id.*; see also Ruhl, *supra* note 1, at 875 (“Chaos, emergence, and catastrophe can be explained using the examples of snowflakes, snow, and avalanches.”).

13. AXELROD, *supra* note 11, at 3.

14. See ROBERT AXELROD & MICHAEL D. COHEN, *HARNESSING COMPLEXITY: ORGANIZATIONAL IMPLICATIONS OF A SCIENTIFIC FRONTIER* 117–18 (1999) (using natural selection as an example of a complex adaptive system, but also noting that natural selection has disadvantages when compared to other methods of adaptation).

15. See JOHN H. HOLLAND, *EMERGENCE: FROM CHAOS TO ORDER* 43–44 (1998) (noting that, even though “[c]haos theory is often cited as an explanation for the difficulty of predicting weather and other complex phenomena,” in the short term there can be useful, predictive models of weather prediction); Douglas A. Kysar, *Climate Change, Cultural Transformation, and Comprehensive Rationality*, 31 B.C. ENVTL. AFF. L. REV. 555, 568 (2004) (“[O]ur current understanding suggests that climate change may represent just such a chaotic system.”).

16. See AXELROD & COHEN, *supra* note 14, at 29 (noting that Adam Smith’s concept of the “hidden hand” in economics reflects what modern theorists would recognize as emergent properties of a complex system).

17. See *infra* notes 103–13 and accompanying text (discussing claims that complexity theory offers advantages over public choice analysis in explaining legislation and the legislative process).

18. See AXELROD & COHEN, *supra* note 14, at xiii (noting that computer scientists studying

overlap between complexity theory and explanatory tools developed in other disciplines such as evolutionary theory in biology and game theory in economics.¹⁹

Of particular interest to the science of complexity are the ways that interactions cause actors to adapt, and how even minor adaptations can echo recursively throughout a system, leading to outcomes that might not have been predicted, or predictable, by “linear” mathematical methodologies.²⁰ Indeed, because such outcomes sometimes lead to catastrophic, chaotic upheavals,²¹ complexity theory is often described as, or defined to include, “chaos” theory.²² Complexity theory studies complex adaptive systems²³ and asserts not only that they can reflect nonlinear properties²⁴ but that such properties can play an essential role in the sustainability and success of some of these systems.²⁵

There are three features of complexity theory that are worth drawing out to appreciate the strengths and weaknesses that

distributed and network-mediated computing are probing deeper questions of “what it takes to make systems of many agents work together and grow”).

19. *Id.* at xiii–xiv.

20. See, e.g., Daniel A. Farber, *Probabilities Behaving Badly: Complexity Theory and Environmental Uncertainty*, 37 U.C. DAVIS L. REV. 145, 152–54 (2003) (stating that nonlinearity is a distinctive feature of complex adaptive systems); Ruhl, *supra* note 1, at 878–79 (arguing that complexity theory “demolishes the centuries-old myth of predictability and time-symmetric determinism, and with it any idea of a clockwork universe” (quoting PETER COVENEY & ROGER HIGHFIELD, *THE ARROW OF TIME* 37 (1990))).

21. See Farber, *supra* note 20, at 153:

This attribute is known as “chaos” and involves extreme sensitivity to initial conditions, so that immeasurable variations in the current state of affairs can lead over time to arbitrarily large divergences in eventual outcomes. Such systems also produce a characteristic distribution of outcomes: “a high frequency of small fluctuations, punctuated by the occasional large shift in system conditions.”

(footnote omitted) (quoting Ruhl, *supra* note 9, at 952).

22. *Id.*; see also Roe, *supra* note 1, at 642 (stating that the science of chaos involves systems in which “small changes in the original position make for very large changes in outcome”).

23. See AXELROD & COHEN, *supra* note 14, at 7 (using the phrase “Complex Adaptive System” to refer to systems that “contain agents or populations that *seek* to adapt”).

24. See *id.* at 14 (“What makes prediction especially difficult in these settings is that the forces shaping the future do not add up in a simple, systemwide manner. Instead, their effects include nonlinear interactions.”). Not all nonlinear systems are complex systems; the standard exponential growth model, for example, is nonlinear but not “complex” as that term is typically used in the complexity literature. J. Barkley Rosser, Jr., *Introduction to COMPLEXITY IN ECONOMICS*, at x (J. Barkley Rosser, Jr. ed., 2004).

25. See Ruhl, *supra* note 1, at 857, 860, 866 (referring to a blend of features, including nonlinearity, that can lead to sustainability and adaptiveness in a system). *But see* AXELROD & COHEN, *supra* note 14, at 18–19 (noting that not all complex adaptive systems necessarily achieve improved performance).

complexity theory may bring to the study of change in legal systems generally and to administrative law reform in particular. These are: (1) emergence from self-assembly, (2) sensitivity to initial conditions, and (3) nonlinearity.

A. *Self-Assembly, Emergence, and Evolutionary Properties in Law*

Well before complexity theory arrived, theories of legal change reflected the impact of evolution as first articulated by Charles Darwin in 1859 in *The Origin of Species*.²⁶ As Professor Herbert Hovenkamp observes about Darwin's theory of evolution, "Only a few ideas in intellectual history have been so powerful and captivating that they have overflowed the brim of the discipline from which they came and spilled over into everything else."²⁷

But not every legal theory that references Darwin or that calls itself "evolutionary" really is based on a central mechanism that operates, as does natural selection in Darwin's theory, to explain *how* adaptation occurs. Thus, as Professor Donald Elliott explains,²⁸ influential nineteenth-century theories of legal evolution such as those articulated by Friedrich Karl von Savigny²⁹ and Sir Henry James Sumner Maine³⁰ generally were vague about the mechanisms that caused law to evolve³¹ and were at times "hopelessly metaphorical and unscientific."³² Even the so-called "Social Darwinists," led by political theorist Herbert Spencer in his widely influential book *Social Statics*,³³ may be said merely to have poached from Darwin a concept

26. CHARLES DARWIN, ON THE ORIGIN OF SPECIES BY MEANS OF NATURAL SELECTION: OR THE PRESERVATION OF FAVOURED RACES IN THE STRUGGLE FOR LIFE (Castle Books ed., 2004) (1859).

27. Herbert Hovenkamp, *Evolutionary Models in Jurisprudence*, 64 TEX. L. REV. 645, 645 (1985).

28. See E. Donald Elliott, *The Evolutionary Tradition in Jurisprudence*, 85 COLUM. L. REV. 38 (1985).

29. FREDERICK VON SAVIGNY, OF THE VOCATION ON OUR AGE FOR LEGISLATION AND JURISPRUDENCE (Lawbook Exchange ed., 2002) (Abraham Hayward trans., 1831).

30. HENRY SUMNER MAINE, ANCIENT LAW: ITS CONNECTION WITH THE EARLY HISTORY OF SOCIETY AND ITS RELATION TO MODERN IDEAS (William S. Hein & Company ed., 1984) (1861).

31. See Elliott, *supra* note 28, at 46 ("[L]ike Savigny, Maine describes patterns of legal change without paying much attention to the processes that produce them. [He] asserts, for example, that there is a natural progression from heroic kingship to aristocracy, but does not tell us how or why.").

32. *Id.* at 43 (speaking of Savigny).

33. HERBERT SPENCER, SOCIAL STATICS (Robert Shackelford Publisher ed., 1995) (1892).

of fitness³⁴ without offering a scientifically defensible mechanism to explain how the fitness that they envisioned would necessarily come about.³⁵

The essential features of Darwinism are known to complexity theory as self-assembly and emergence. As Professor Elliott explains:

[T]he peculiar appeal of evolutionary models arises in part from their power to explain “the achievement of purposive or ends-guided processes through a mechanism involving blind, stupid, unforesightful elements.” One reason Darwin’s theory of the origin of the species was a watershed in intellectual history was its ability to explain complex structures in nature without invoking design choices by a Creator.³⁶

When mechanisms of self-assembly lead to properties of a system that are not shared by its constituent parts, these properties are called emergent.³⁷ Thus, “no single neuron has consciousness, but the human brain does . . . as an emergent property.”³⁸ The emergence of quite powerful properties can arise from the interaction of multiple actors, especially when there is a mechanism of selection designed to

34. It was Herbert Spencer, not Charles Darwin, who coined the phrase “survival of the fittest.” RICHARD HOFSTADTER, *SOCIAL DARWINISM IN AMERICAN THOUGHT* 39 (George Braziller, Inc. 1959) (1944).

35. See Hovenkamp, *supra* note 27, at 666 (“The evolutionary theory contained in the first edition of *Social Statics* was heavily Lamarckian, with God an active participant in the process.”); see also Owen D. Jones, *Evolutionary Analysis in Law: An Introduction and Application to Child Abuse*, 75 N.C. L. REV. 1117, 1135 n.47 (1997) (observing that it is reproduction, not individual survival as emphasized by Spencer, that is important to the mechanism of biological evolution). Based on this theoretically weak starting point, the Social Darwinists built sweeping claims that human progress depended on relentless competition among individuals that would weed out the weak and the sick, free from interference by the state. See Hovenkamp, *supra* note 27, at 667–70 (“Spencer viewed the state as an inefficient and potentially harmful instrument. It created an illusion of cooperation between individuals when in fact none existed . . . Society survived only when every person had maximum freedom with a minimum of restrictions.”) And it was, of course, to Spencer’s assertions that Justice Holmes directed his famous dissent in *Lochner v. New York*, 198 U.S. 48 (1905), when he stated that “the Fourteenth Amendment does not enact Mr. Herbert Spencer’s Social Statics,” *id.* at 75 (Holmes, J., dissenting).

36. Elliott, *supra* note 28, at 54–55 (quoting Donald T. Campbell, *Variation and Selective Retention in Socio-Cultural Evolution*, in *SOCIAL CHANGES IN DEVELOPING AREAS: A REINTERPRETATION OF EVOLUTIONARY THEORY* 19, 26–27 (Herbert Barringer et al. eds., 1965)).

37. See HOLLAND, *supra* note 15, at 121–22 (describing emergence as interactions resulting in a system characterized by behavior that “cannot be obtained by *summing* the behaviors of its constituent parts”).

38. AXELROD & COHEN, *supra* note 14, at 15.

separate successful individuals or strategies. This is so whether the mechanism is the natural selection process that Darwin described or a manmade selection mechanism that might be found in such an artificial system as an economy.³⁹ Professors Robert Axelrod and Michael Cohen make just this point: “Adam Smith’s 1776 description of a market introduced some of the key concepts of complex systems, including the notion of a hidden hand and market clearing, concepts that would now be called emergent properties of the system.”⁴⁰

True evolutionary theories of legal change reflect this emphasis on self-assembly, selection, and emergence—and indeed depend on these features for their intellectual strength. Perhaps the most widely noted examples of such theories were the “selective re-litigation” models of the common law, developed in the 1970s by Professors Paul Rubin⁴¹ and George Priest.⁴² These theories postulated that the common law was efficient *not* because judges consciously adopted efficient doctrines, but because *even when* doctrines were inefficient and judges made mistakes, people suffering under the inefficiency of such rules would have a greater incentive to litigate and relitigate them.⁴³ Because the system asymmetrically selects inefficient rules for litigation, the Rubin/Priest models claimed that inefficient rules were more likely eventually to be modified or abandoned, causing efficiency to emerge.⁴⁴ The Rubin/Priest models drew a fairly large critical literature challenging some of the models’ assumptions and specifications.⁴⁵ But for purposes of this Article, the significant point

39. See *id.* at 7 (describing how complex systems change strategies by means of selection).

40. *Id.* at 29. Evolutionary biologist Stephan Jay Gould makes a similar observation, albeit without consciously invoking complexity theory, when he observes, “I believe that the theory of natural selection should be viewed as an extended analogy—whether conscious or unconscious on Darwin’s part I do not know—to the *laissez faire* economics of Adam Smith.” STEPHAN JAY GOULD, *THE PANDA’S THUMB: MORE REFLECTIONS IN NATURAL HISTORY* 66 (1980).

41. Paul H. Rubin, *Why Is the Common Law Efficient?*, 6 J. LEGAL STUD. 51 (1977).

42. George L. Priest, *The Common Law Process and the Selection of Efficient Rules*, 6 J. LEGAL STUD. 65 (1977).

43. See, e.g., E. Donald Elliott, *Law and Biology: The New Synthesis?*, 41 ST. LOUIS U. L.J. 595, 601 (1997) (“So if judges err—including because the internal selection system of legal doctrines is ‘wrong’ . . . then people in the community . . . are going to keep coming back to the courts to test that rule, and that rule is more likely to be modified or abandoned eventually.”); see also Elliott, *supra* note 28, at 62–71 (discussing economic theories of legal evolution).

44. Elliott, *supra* note 43, at 600–01.

45. See, e.g., Robert Cooter, *Models of Morality in Law and Economics: Self-Control and Self-Improvement for the “Bad Man” of Holmes*, 78 B.U. L. REV. 903, 910 n.27 (1998) (discussing the Rubin/Priest models and the literature that challenges them); Robert D. Cooter, *Decentralized Law for a Complex Economy: The Structural Approach to Adjudicating the New*

of the models is that they reflect how properties from complexity theory involving selection, self-assembly, and emergence might be used to explain features of the legal system.

An even more recent application of these features was proposed by Professor Jason Johnston to evaluate the efficiency of regulatory cost-benefit analysis and statutory design.⁴⁶ Johnston's thesis is especially intriguing because it reaches a nonobvious result: that statutes requiring administrative agencies to employ cost-benefit analysis may actually lead to the emergence of inefficiency. Like the selective relitigation models, this outcome is driven by the unintended operation of asymmetrical selection pressures. Specifically, Johnston analyzes the effect on agency behavior of the choice by regulated firms to challenge agency action either through lobbying (marshalling political pressure on the agency to rescind a proposed rule)⁴⁷ or through litigation (seeking judicial reversal of an agency's final rule under the Administrative Procedure Act).⁴⁸ Johnston compares the effects of these challenges on agency decisions promulgated under "benefits" statutes (which direct an agency to maximize a benefit such as health or environmental purity without cost-benefit calculations) with agency decisions promulgated under "cost-benefit" statutes (which include a judicially enforceable requirement that the costs of agency action not exceed the benefits).⁴⁹ Johnston posits that firms choosing whether to lobby or to litigate will have either low

Law Merchant, 144 U. PA. L. REV. 1643, 1694 (1996) [hereinafter Cooter, *Decentralized Law*] ("[S]elective-litigation pressure and blind evolution fail to explain the level of efficiency observed in common law."); Robert Cooter & Lewis Kornhauser, *Can Litigation Improve the Law Without the Help of Judges?*, 9 J. LEGAL STUD. 139, 140 (1980) (finding that blind evolution only moderately influences legal improvements); Elliott, *supra* note 28, at 62–71 (surveying the critical literature on economic theories of legal evolution); Gillian K. Hadfield, *Bias in the Evolution of Legal Rules*, 80 GEO. L.J. 583, 594–96 (1992) (discussing "non-motivational" accounts of selective litigation pressures); Thomas S. Ulen, *The Prudence of Law and Economics: Why More Economics Is Better*, 26 CUMB. L. REV. 773, 804 n.75 (1996) (discussing the selective litigation process).

46. Jason Scott Johnston, *A Game-Theoretic Analysis of Alternative Institutions for Regulatory Cost-Benefit Analysis*, 150 U. PA. L. REV. 1343 (2002).

47. *Id.* at 1358.

48. *Id.* at 1359.

49. See Matthew D. Adler, *The Positive Political Theory of Cost-Benefit Analysis: A Comment on Johnston*, 150 U. PA. L. REV. 1429, 1430–32 (2002) (summarizing Johnston's distinction between "benefits" statutes and "cost-benefit" statutes).

compliance costs or high compliance costs,⁵⁰ and that generally the agency does not really know the true value of these costs.⁵¹

Professor Johnston's key insight is that, under benefits statutes, firms will signal their true compliance costs by the efforts they expend on lobbying or litigation, and that agencies, calculating whether it is worth agency resources to fight such efforts, will implicitly sort their rules by a shadow type of cost-benefit test and proceed only with those rules that promise regulatory benefits in excess of the agency's costs.⁵² As law professor Matthew Adler states in analyzing Johnston's model, "Why does the 'sorting' scenario occur? It occurs because of the effect that firm lobbying and litigation have on the agency's expected net benefit from enacting the directive, and because high-cost firms have a greater incentive to lobby and litigate than do low-cost firms."⁵³ In contrast, under cost-benefit statutes, agencies factor into their decisionmaking the chance that reviewing courts will err in processing cost-benefit arguments; under certain scenarios this leads agencies either to forego adopting regulations that are truly cost-benefit justified or, contrariwise, to promulgate regulations that in reality are not cost-benefit justified and find them upheld by mistake-prone courts.⁵⁴

Although the early returns on the validity of Professor Johnston's model are promising,⁵⁵ it is, of course, not yet known whether the model will withstand further empirical investigation and analytic scrutiny any better than did the Rubin/Priest models. But

50. Johnston, *supra* note 46, at 1353–55.

51. *See id.* at 1366–68 (discounting what firms merely "tell" agencies about compliance expenditures as "cheap" talk).

52. Adler, *supra* note 49, at 1432–33.

53. *Id.* at 1433.

54. *See id.* at 1436 ("Because of firm lobbying and litigation, a statute that not only instructs the agency to apply a cost-benefit test, but also makes [cost benefit analysis] judicially reviewable, *might nonetheless fail to induce the agency to sort between welfare-enhancing and welfare-reducing litigation.*"(emphasis added)).

55. *See id.* at 1429 (making numerous analytical suggestions but nonetheless calling Professor Johnston's model a "substantial contribution" to the positive political theory of regulation); *see also* Daniel A. Farber, *Building Bridges over Troubled Waters: Eco-pragmatism and the Environmental Prospect*, 87 MINN. L. REV. 851, 871 (2003) (referencing Professor Johnston's article as shifting the debate on cost-benefit analysis "more on its institutional implementation, a topic that lends itself to more reasoned and constructive debate than the earlier battles over the morality of the technique"); Emerson H. Tiller, *Resource-Based Strategies in Law and Positive Political Theory: Cost-Benefit Analysis and the Like*, 150 U. PA. L. REV. 1453, 1470–71 (2002) (suggesting that Professor Johnston's analysis may produce even stronger results in more "political" versions of positive political theory).

Johnston has revealed an aspect of the legal system in general and identified a hidden debate over cost-benefit analysis in particular that has heretofore escaped attention by utilizing insights on self-assembly, selection, and emergence.⁵⁶

B. Sensitivity to Initial Conditions: A Broader Reading of Arrow's Impossibility Theorem and Its Applicability to the "Adaptationist's Fallacy"

Professor Kenneth Arrow's "Impossibility Theorem"⁵⁷ is typically offered to show that legislators' preferences in a democracy cannot coherently be combined to produce a stable body of law that reflects the public's welfare.⁵⁸ Arrow posited a voting "system" comprised of representatives with rationally transitive preferences in which decisions are made purely by majority vote.⁵⁹ Professors Daniel Farber and Philip Frickey use the example of three legislators who must choose among three states in which to locate a federal facility: Legislator 1 prefers Texas over Illinois, and Illinois over Florida; Legislator 2 prefers Illinois over Florida, and Florida over Texas; and Legislator 3 prefers Florida over Texas, and Texas over Illinois.⁶⁰ In

56. It is worth noting, however, that in an article published several years before Professor Johnston's article, Professor Daniel Farber speculates on ways in which asymmetrical compliance costs could cause implementation of an agency rule to be felt first by firms with low compliance costs, and at least delayed for firms with high costs. See Daniel A. Farber, *Taking Slippage Seriously: Noncompliance and Creative Compliance in Environmental Law*, 23 HARV. ENVTL. L. REV. 297, 316 (1999) ("It is at least plausible that the most rapid compliance will involve sources with lower compliance costs or high environmental impacts, while the greatest delays will occur for sources with high costs or low impacts."). Although Professor Farber neither identifies nor specifies a mechanism by which this asymmetry might affect the ultimate distribution of costs and benefits, as does Professor Johnston, it is significant that Farber appreciated the same point made in the text above: that a legal doctrine (cost-benefit analysis) can be affected by mechanisms of adaptation. See *id.* at 317 ("[I]t is at least clear that an assessment of existing regulations cannot ignore the dynamics of the implementation process.").

57. See DANIEL A. FARBER & PHILIP P. FRICKEY, *LAW AND PUBLIC CHOICE: A CRITICAL INTRODUCTION* 38-39 (1991) (introducing Arrow's Theorem and noting that a summary of Arrow's work is found in DENNIS C. MUELLER, *PUBLIC CHOICE II*, at 384-99 (1989)).

58. See *id.* at 39 ("Arrow's Theorem presents a conceptual barrier to combining individual preferences into some overall measure of social welfare.").

59. Transitivity reflects the minimum rationality such that "[i]f society prefers outcome A to outcome B and outcome B to outcome C, then society prefers A over C." *Id.* at 38. For further discussion of transitivity in economic analysis, see Donald T. Hornstein, *Reclaiming Environmental Law: A Normative Critique of Comparative Risk Analysis*, 92 COLUM. L. REV. 562, 590-91, 598-603 (1992) (explaining, and critiquing, the use of transitivity in economic analysis involving incommensurable goods).

60. FARBER & FRICKEY, *supra* note 57, at 39.

the parlance of complexity theory, as these actors interact through a series of votes, adaptation occurs, producing nonobvious results. Thus, if the three actors first choose between Texas and Illinois, with the winning location paired against Florida:

Legislators 1 and 3 prefer Texas, so it wins the first round, [in round two] legislators 2 and 3 combine to pick Florida over Texas . . . [but if there's a round three, legislators 1 and 2 combine to pick Illinois over Florida, which leads to a round four where legislators 1 and 3 recombine to pick Texas over Illinois] so we're right back where we started . . . trapped in a revolving door with no exit.⁶¹

Although the literature on complex adaptive systems does not typically cite the Impossibility Theorem, the economic and social theory literature sometimes classifies it as part of a family of observations known as “chaos theorems.”⁶²

Scholars have invoked the Impossibility Theorem to make many points. It has been used to caution against democratic voting systems because legislative “cycling,” the back-where-we-started feature highlighted by Professors Farber and Frickey, means that any particular legislative choice may not actually reflect the stable preferences of a majority.⁶³ For the same reason, it has been used in administrative law scholarship to justify Congress's delegation of rulemaking powers to agencies as a welfare-enhancing way to avoid legislative cycling.⁶⁴

61. *Id.*

62. See P. ORDESHOOK, *GAME THEORY AND POLITICAL THEORY: AN INTRODUCTION* 71–82 (1986) (positing that Arrow's Theorem is important “because it compels us to acknowledge that [social preference] paradoxes can prevail with any preference aggregation mechanism”), cited in FARBER & FRICKEY, *supra* note 57, at 40 n.2; Jim Chen, *The Mystery and the Mastery of the Judicial Power*, 59 MO. L. REV. 281, 299 (1994) (referring to “chaos theorem” as a corollary to Arrow's Impossibility Theorem); David Luban, *Social Choice Theory as Jurisprudence*, 69 S. CAL. L. REV. 521, 542 (1996) (discussing Professors Richard McKelvey and Norman Schofield's use of “closely related [chaos] theorems whose importance may eclipse that of Arrow's Theorem itself”).

63. See WILLIAM H. RIKER, *LIBERALISM AGAINST POPULISM: A CONFRONTATION BETWEEN THE THEORY OF DEMOCRACY AND THE THEORY OF SOCIAL CHOICE* 167 (1982) (highlighting the ineradicability of strategic voting in all voting systems). See also FARBER & FRICKEY, *supra* note 57, at 40.

64. See William T. Mayton, *The Possibilities of Collective Choice: Arrow's Theorem, Article I, and the Delegation of Legislative Power to Administrative Agencies*, 1986 DUKE L.J. 948, 952 (“[R]elaxing Arrow's nondictatorship condition is of some appeal Such a dictatorship is today established, in the person of bureaucrats, by open-ended delegations of legislative power to agencies.”); Jeffrey Rosen, *Overcoming Posner*, 105 YALE L.J. 581, 595 (1995) (book review) (“Some scholars have invoked the Arrow Impossibility Theorem to

But the Impossibility Theorem also illustrates a feature of complexity theory that might have even broader application in legal analysis: that outcomes in some systems are extremely sensitive to initial conditions, a phenomenon related to path dependence.⁶⁵ Taking Professor Farber and Frickey's example of the three legislators, if the location of the federal facility was chosen solely after the first vote, rather than via an endless series of votes, then the final choice would be Texas. And, although this choice could be criticized normatively as merely an artifact of the new voting procedure, the choice can also be used descriptively for the more general insight that outcomes can be extremely sensitive to initial conditions, with large differences in outcomes attributable to very small changes in the original position.⁶⁶ This feature of Arrow's Theorem is often observed among complex adaptive systems, with perhaps the most commonly known example (the "butterfly effect") involving weather patterns so complex that "a butterfly flapping its wings today on one side of the globe could induce a torrential downpour next week on the other side of the globe."⁶⁷

The sensitivity of complex systems to initial starting points has important implications for legal theory, especially in its ability to highlight the "adaptationist fallacy"⁶⁸—the Panglossian idea that everything that exists must be fit (in the evolutionary sense) simply to have survived the competitive pressures of adaptation. Thus, biology is often (mis)understood to mean, as Herbert Spencer incorrectly explained it, that evolutionary pressures result in survival only of

support broad congressional delegation of lawmaking power to administrative agencies, relying on technocrat expertise to replace the irrationality of democratic decisionmaking.").

65. See Roe, *supra* note 1, at 641–43 (noting overlap between path dependence and sensitivity to initial conditions).

66. See JAMES GLEICK, CHAOS: MAKING A NEW SCIENCE 8 (1987) ("Tiny differences in input could quickly become overwhelming differences in output—a phenomenon given the name 'sensitive dependence on initial conditions.'"); Roe, *supra* note 1, at 642 ("Some phenomena are extremely sensitive to initial conditions: small changes in the original position make for very large changes in outcome.").

67. Roe, *supra* note 1, at 642 (citing GLEICK, *supra* note 66, at 8). But see HOLLAND, *supra* note 15, at 43–44 (noting that, as for day-to-day changes in the weather, butterfly effects can be negligible in relation to huge movements of air masses, making relatively accurate predictions possible in the short term, when "chaos theory has little relevance").

68. The term is used in Elliott, *supra* note 43, at 598–99. See also Stephen J. Gould & Richard C. Lewontin, *The Spandrels of San Marcos and the Panglossian Paradigm: A Critique of the Adaptationist Programme*, 205 PROC. ROYAL SOC'Y LONDON BIOLOGICAL SCI. 581, 581–98 (1979) (critiquing the adaptationist programme of understanding evolution).

“the” fittest.⁶⁹ Properly understood, of course, in biology it is not unusual for there to be numerous solutions to evolutionary pressures.⁷⁰ In law and economics, Professor Mark Roe criticizes a “paradigm of Darwinian survival of the fittest,”⁷¹ that holds “[w]hat survives is presumptively efficient: if it were inefficient, the practice, the law, or the custom would be challenged by its more efficient competitors [and] . . . the more efficient practice or law [would] prosper, while its less efficient competitors wither and die.”⁷² In an influential article, Professor Roe uses the property of path dependence stemming from sensitivity to initial conditions to suggest that today’s legal forms might reflect, instead of efficiency, a culture’s unique political and cultural institutions, chaotic chance events, or the fact that sunk costs make inefficient forms regrettable but not worth changing.⁷³ After offering case studies of comparative corporate and bankruptcy law, Professor Roe notes that descriptive analysis incorporating path-dependence can offer advantages over traditional law and economics models in terms of better explaining “why we have the institutions we have,”⁷⁴ for better evaluating the continuation of an institution or legal rule that arose “to resolve a problem that is irrelevant today,”⁷⁵ and for highlighting generally that not all current arrangements are necessarily optimal.⁷⁶

69. See *supra* notes 33–35 and accompanying text (contrasting Spencer and Darwin).

70. Elliott, *supra* note 43, at 598–99 (noting that, unlike Herbert Spencer’s bastardized notion of survival of “the” fittest, in biology “it is very rare that there is only one unique solution that will survive. . . . Most of the time . . . [t]here is a very broad range of characteristics that can survive and exist within the population”).

71. Roe, *supra* note 1, at 642.

72. *Id.* at 641.

73. *Id.* at 646–53. Professor Roe’s article has engendered a spirited debate over path dependence and adaptationism in corporate law. See, e.g., Lucien Arye Bebchuk & Mark J. Roe, *A Theory of Path Dependence in Corporate Ownership and Governance*, 52 STAN. L. REV. 127 (1999) (discussing the role of path dependence in corporate ownership structures); John C. Coffee, Jr., *The Future as History: The Prospects for Global Convergence in Corporate Governance and Its Implications*, 93 NW. U. L. REV. 64 (1999) (critiquing the traditional “Berle and Mean” paradigm and noting that “Professor Roe’s work has been the dominant influence in this field”); Craig LaChance, Note, *Nature v. Nurture: Evolution, Path Dependence and Corporate Governance*, 18 ARIZ. J. INT’L & COMP. L 279, 287–88 (2001) (noting that Professor Roe’s piece challenged the conventional “Berle and Mean” paradigm that “corporate structure in other countries would inevitably evolve into something similar to the U.S. system”).

74. Roe, *supra* note 1, at 658.

75. *Id.*

76. *Id.*

Other legal scholars are also beginning to use the insights of sensitivity to initial conditions and path dependence to analyze particular areas of statutory and administrative law such as securities law,⁷⁷ environmental regulation,⁷⁸ and banking law.⁷⁹ And these insights have been used more broadly to describe features of the administrative state such as the overaccumulation of rules⁸⁰ and “lock-in” effects.⁸¹ To be sure, these efforts are relatively new, and it is too early to confirm the strength of their contribution to descriptive analysis. But there are at least indications that complexity theory in this regard promises improvements, if not a more robust model, than traditional law and economics models stressing the adaptive power of competition alone.

C. *Nonlinearity: Adding Context to the Logic of Collective Action*

Most theories of jurisprudence contain a theory of change.⁸² And one of the strongest features of some economic models of law is that they attempt to stipulate plausible mechanisms to explain the shape of existing law as well as the direction of legal change.⁸³ In his 1965

77. See, e.g., Stephen M. Bainbridge, *Insider Trading Regulation: The Path Dependent Choice Between Property Rights and Securities Fraud*, 52 SMU L. REV. 1589, 1589–91 (1999) (concluding that, given the costs, insider trading regulation should be permitted to continue down its path-dependent course with only some modifications).

78. See, e.g., Gail Charnley & E. Donald Elliott, *Risk Versus Precaution: Environmental Law and Public Health Protection*, 32 ENVTL. L. REP. (ENVTL. L. INST.) 10,363, 10,365 (2002) (“Environmental health regulation is path-dependent: actions taken now affect the nature of actions taken later.”); Eric W. Orts, *Reflexive Environmental Law*, 89 NW. U. L. REV. 1227, 1334 n.458 (1995) (“One wonders in light of the history of securities regulation how much the heavily substantive approach of contemporary environmental law owes to path dependence concerning the choices of original legal strategies rather than to deliberative choice.”).

79. See, e.g., Eric J. Gouvin, *Banking in North America: The Triumph of Public Choice over Public Policy*, 32 CORNELL INT’L L.J. 1, 16 (1998) (“The conflict between [the Federal Reserve and the Comptroller of the Currency] appears to be the path dependent result of historical policy decisions affecting branching in the United States.”).

80. See Ruhl & Salzman, *supra* note 1, at 818 (“Over time, the accretion of rules will present more regulatory decision nodes, which will add to the path dependence of present regulatory positions, and will therefore limit the options for new rules.”).

81. See Clayton P. Gillette, *Lock-in Effects in Law and Norms*, 78 B.U. L. REV. 813, 817 (1998) (“Although much of the literature has concerned technological development—ranging from typewriter keyboards to computer operating systems to light bulbs—lock-in may apply with equal force to . . . law itself. Regulatory regimes—legal or extralegal—provide obvious analogies to technological standards.” (footnotes omitted)).

82. See Hovenkamp, *supra* note 27, at 646 (“Today every theory of jurisprudence worth contemplating incorporates a theory of change.”).

83. See, e.g., Francesco Parisi & Jonathan Klick, *Functional Law and Economics: The Search for Value-Neutral Principles of Lawmaking*, 79 CHI.-KENT L. REV. 431, 450 (2004)

book *The Logic of Collective Action*,⁸⁴ Professor Mancur Olson articulated an economic theory of interest groups that has been widely influential in public law.⁸⁵ The key insight is well-known: smaller groups will have an easier time organizing and exerting influence on public decisionmakers than will larger groups, such as the public at large, because legislation that benefits everyone encourages members of the public to free ride on what they perceive to be the efforts of the much larger group of beneficiaries.⁸⁶ Given this logic, the prospect of public interest decisionmaking recedes as politics becomes dominated by better-organized special interest groups.⁸⁷ This insight has been quite influential in administrative law, leading some commentators to claim that, to avoid agency capture by special interests, “[C]ongress turned to increasingly specific statutory provisions in environmental legislation and to the use of agency-forcing devices such as statutory deadlines and statutorily defined ‘default’ rules that took effect in the absence of agency action.”⁸⁸

As a theory of change, Professor Olson’s logic undoubtedly gained much of its power because it supplied a mechanism rather than a mere metaphor. The mechanism—the relative organizational superiority of special interest groups—rested on plausible

(arguing that “[t]hrough its ex ante perspective, the functional school focuses on mechanism design issues to explain the origins of law”); Fred S. McChesney, *Positive Economics and All That—A Review of The Economic Structure of Corporate Law by Frank H. Easterbrook & Daniel R. Fischel*, 61 GEO. WASH. L. REV. 272, 295 (1992) (“Landes and Posner’s economic theory of tort law recognizes the need for a ‘causal mechanism’ to explain why judicial and legislative lawmakers do what they do.”). *But see* Wil Waluchow, *In Pursuit of Pragmatic Legal Theory: The Practice of Principle by Jules Coleman*, 15 CAN. J.L. & JURISPRUDENCE 125, 138 (2002) (book review) (“Coleman’s principal objection to viewing economic theories as causal-functional explanations is that they post no plausible causal mechanism to explain why the rules and practices of tort law are structured to achieve economic goals.”).

84. MANCUR OLSON, *THE LOGIC OF COLLECTIVE ACTION: PUBLIC GOODS AND THE THEORY OF GROUPS* (1965).

85. *See* Dan M. Kahan, *The Logic of Reciprocity: Trust, Collective Action, and Law*, 102 MICH. L. REV. 71, 71 (2003) (“The *Logic of Collective Action* has for decades supplied the logic of public-policy analysis. . . . [and] dominate[d] public-policy analysis and public policy itself across a host of regulatory domains” (footnotes omitted)).

86. *See* FARBER & FRICKEY, *supra* note 57, at 23 (discussing the free-rider problem and its organizational difficulties for large groups) (citing OLSON, *supra* note 84, at 132–34).

87. *See id.* (“Thus, if Olson is correct, politics should be dominated by ‘rent-seeking’ special interest groups.”).

88. Donald T. Hornstein, *Lessons from Federal Pesticide Regulation on the Paradigms and Politics of Environmental Law Reform*, 10 YALE J. ON REG. 369, 409–10 (1993) (footnotes omitted).

assumptions and had at least some empirical support.⁸⁹ In that sense, it offered the allure of a principled means of making more accurate predictions of legal change than had an earlier literature on “interest-group pluralism” that offered only the indeterminate metaphor of finding in legislation an “equilibrium” among competing forces.⁹⁰ Yet, despite its intellectual appeal, *The Logic of Collective Action* has faced mounting challenges from those scholars who would replace some of Olson’s core assumptions.⁹¹ Some of these critics understand individuals not solely as the rational, self-interested, calculating beings postulated by Professor Olson but as “emotional/moral reciprocators” capable of altruism.⁹² Others point to empirical evidence that both legislators and voters are motivated by ideology more than by calculations of material self-interest.⁹³

This is what one might call the conventional administrative law debate. And the conventional debate helps to frame a feature of complexity theory that may prove useful in legal analysis. Complexity theory is strongly antireductionist.⁹⁴ It claims that the behavior of complex adaptive systems cannot be explained in a mechanical,

89. See FARBER & FRICKEY, *supra* note 57, at 24 (“[A]s the political science literature indicates, special interest groups do appear to play a major role in the legislative process.”).

90. See, e.g., JAMES M. BUCHANAN & GORDON TULLOCK, *THE CALCULUS OF CONSENT: LOGICAL FOUNDATIONS OF CONSTITUTIONAL DEMOCRACY* 288 (1962) (“Many modern students of pressure-group phenomena seem to rely on [there being an] ‘equilibrium.’”); EARL LATHAM, *THE GROUP BASIS OF POLITICS: A STUDY IN BASING-POINT LEGISLATION* 36 (1952) (“What may be called public policy is the equilibrium reached in this struggle at any given moment, and it represents a balance which the contending factions of groups constantly strive to weight in their favor.”).

91. See FARBER & FRICKEY, *supra* note 57, at 27–33 (noting the different types of challenges that have been brought); see also *infra* notes 92–93 and accompanying text.

92. See ALEXANDER J. FIELD, *ALTRUISTICALLY INCLINED?: THE BEHAVIORAL SCIENCES, EVOLUTIONARY THEORY, AND THE ORIGINS OF RECIPROCITY* 21–25 (2004) (arguing that humans show altruism by failing to harm other humans whom they do not know); Kahan, *supra* note 85, at 71–74 (“Olson’s *Logic [of Collective Action]* is false. In collective-action settings, individuals adopt not a materially calculating posture but rather a richer, more emotionally nuanced *reciprocal* one.”).

93. See, e.g., Reza Dibadj, *Saving Antitrust*, 75 U. COLO. L. REV. 745, 797 (2004) (“[D]espite empirical studies showing ideology to be a better predictor of legislative votes than economics, public choice ignores the ideology of politicians and bureaucrats.” (footnote omitted)); Edward L. Rubin, *Public Choice, Phenomenology, and the Meaning of the Modern State: Keep the Bathwater, but Throw Out That Baby*, 87 CORNELL L. REV. 309, 335 (2002) (“Participants in social movements are even more obviously motivated by ideology, particularly in those movements that are unconnected with their personal well-being.”).

94. Certainly one of the most forceful advocates of this view, as applied to administrative law in particular, is law professor J.B. Ruhl, who has found in complexity theory a “[w]ake-up [c]all for [l]egal [r]eductionism.” See Ruhl, *supra* note 1, at 849.

“linear” way—such as might be promised by the application of a reductionist insight such as Olson’s or even by the promise of interest-group pluralism to find a recurring “equilibrium” in legislation.⁹⁵ Instead, complex adaptive systems reflect the more unpredictable properties of nonlinearity.⁹⁶ Perhaps the most common use of this observation in the legal literature is reflected in citations by environmental law scholars to evidence that ecosystems are no longer modeled simply as reflecting the “balance” of nature or as reflecting the predictable, evolutionary succession of “stages” of ecological development.⁹⁷ Instead, “ecology is following physics as it owes much to chaos theory. Non-equilibrium ecology rejects the vision of a balance of nature. Change and instability are the new constants.”⁹⁸

Professor Daniel Farber notes that complex adaptive systems, even those with *basic* interactions that are well understood in precise equations, demonstrate *overall* behavior characterized by mathematical “power laws” that do not follow “familiar bell-curve” statistical distributions.⁹⁹ Instead, complex adaptive systems are often characterized by extreme events that might otherwise seem random or catastrophic.¹⁰⁰ Moreover, nonlinearity reflects what are known to complexity scholars as “strange attractors,” which can amplify even

95. See FARBER & FRICKEY, *supra* note 57, at 17 (finding that in the 1950s “a pluralistic interpretation of politics had emerged, in which legislative outcomes were said simply to mirror the equilibrium of competing group pressures”).

96. See AXELROD & COHEN, *supra* note 14, at 14 (noting that “[w]hat makes prediction especially difficult in these settings is that the forces shaping the future do not add up in a simple, systemwide manner” but instead “include nonlinear interactions”).

97. See, e.g., Gerald Andrews Emison, *The Potential for Unconventional Progress: Complex Adaptive Systems and Environmental Quality Policy*, 7 DUKE ENVTL. L. & POL’Y F. 167, 173 (1996) (“Any policy built on a view of the environment as not changing is likely to fall short of its stated objectives . . .”); Alyson C. Flournoy, *Preserving Dynamic Systems: Wetlands, Ecology and Law*, 7 DUKE ENVTL. L. & POL’Y F. 105, 131 (1996) (noting that the term can be misapplied, but stating that one of the central lessons of the “new” ecology is greater appreciation of the role that “disturbance regimes play in sustaining ecological processes”); Jonathan Baert Wiener, *Beyond the Balance of Nature*, 7 DUKE ENVTL. L. & POL’Y F. 1, 11–12 (1996) (finding that “balance” in nature is a meaningless concept).

98. Fred Bosselman & A. Dan Tarlock, *The Influence of Ecological Science on American Law: An Introduction*, 69 CHI.-KENT L. REV. 847, 869–70 (1994), *quoted in* Farber, *supra* note 20, at 152.

99. Farber, *supra* note 20, at 152–53.

100. See *id.* at 153 (“This unusual statistical distribution is the most significant feature of complexity.”). See Ruhl, *supra* note 1, at 878 (“That is *catastrophe*: a sudden qualitative change in a dynamical system brought about by a continuous change in a system variable.”).

the smallest perturbation of a system's interactions into just such extreme events.¹⁰¹

One of the difficult features of complexity theory, especially in a field like law, is that its emphasis on nonlinearity means that it does not lend itself well to the development of predictive, falsifiable models.¹⁰² That does not, however, strip it of value: it may yet be capable of capturing elements of legal systems that otherwise elude reductionist, linear models.

An example of nonlinearity in public law comes from the literature on "republican moments," which are defined as extraordinary periods when broad segments of the electorate suddenly become intensely interested in a political issue, causing legislators to enact statutes that are far more in line with public values than special interest models would predict.¹⁰³ That is, in the parlance of complexity theory, even if the logic of collective action is accepted as generally true in terms of the day-to-day operation of politics, it does not capture the behavior of the political system as a whole after factoring in the element of nonlinear extreme events. Indeed, Professor James Pope, claims that "[t]he most important transformations in our political order . . . were brought on by republican moments."¹⁰⁴ Nonlinearity, in other words, is a feature of the political system that may allow it to transcend the effects of such routine interactions as special interest lobbying.

101. *See id.* at 864:

While the system is on a particular orbit around a strange attractor, moreover, it is highly sensitive to small perturbations so that if "nudged" ever so slightly off the orbit path just a little bit, the system responds over time with an arbitrarily large trajectory shift. Strange attractors systems thus "amplify tiny differences hidden far along the decimal tail, well below any error threshold you may care to set.

(quoting JACK COHEN & IAN STEWART, *THE COLLAPSE OF CHAOS* 191 (1994)).

102. *See, e.g., id.* at 928 ("I confess—as any adherent of dynamical systems theory must—that I cannot predict the outcome of [proposed] reforms with precision . . .").

103. *See* Daniel A. Farber, *Politics and Procedure in Environmental Law*, 8 J.L. ECON. & ORG. 59, 66 (1992) ("[P]olitics alternates between normal periods, in which public attention is weak, and extraordinary periods, in which the issue has high salience for the public. . . . Those periods are likely to be attended by new legislative initiatives responding to this public demand."); Hornstein, *supra* note 88, at 418 ("[E]nvironmental statutes are enacted not during the 'normal' political periods that are typically responsive to conventional interest group pressures, but rather during 'extraordinary moments' when broad segments of the population become intensely interested in environmental issues . . .").

104. James Gray Pope, *Republican Moments: The Role of Direct Popular Power in the American Constitutional Order*, 139 U. PA. L. REV. 287, 291–93 (1990).

In an article with the especially intriguing title *Is Democracy Like Sex?*,¹⁰⁵ law professor Glenn Reynolds puts the point explicitly in terms of complexity theory when he argues that, even if electoral choices in a democracy are unstable, their very randomness and unpredictability can have the effect of increasing the political *system's* resistance to such social parasitism as special interest influence. He compares this result to the explanation by evolutionary biologists of sexual reproduction as a means of creating a genetic "moving target" that thwarts biological parasites in a more effective way than would the more genetically predictable mechanism of asexual reproduction.¹⁰⁶ The adaptiveness in both kinds of systems, which results from aperiodic events that mix things up, leads Professor Reynolds to conclude that "discoveries resulting from the application of complexity theory to the question of evolutionary fitness among biological systems have important implications for . . . the fitness of the body politic."¹⁰⁷

A somewhat less flamboyant, but equally interesting, illustration of nonlinearity in legislative activity is offered by law professor Vincent Di Lorenzo.¹⁰⁸ Using well-known case studies of federal legislation,¹⁰⁹ he finds that the operation of a number of factors—including the role of policy entrepreneurs, publicity, ideology, electoral advantage, legislative procedures, and chance—better explains statutory outcomes than do reductionist, special interest models.¹¹⁰ Di Lorenzo is careful to note that "[t]here is no attempt in this Article to substitute a constant, multiple-factor linear approach for the one-factor approach which prevailed in the past."¹¹¹ Rather, with explicit reference to complexity theory, Di Lorenzo argues instead that there are inescapable and important elements of chance that, "in combination with other forces, lead to unexpected periods of

105. Glenn Harlan Reynolds, *Is Democracy Like Sex?*, 48 VAND. L. REV. 1635 (1995).

106. See *id.* at 1637–38 ("[T]he conclusions reached by evolutionary biologists regarding the advantages of sexual reproduction are likely to be applicable to complex dynamic systems that are not biological, including political systems.").

107. *Id.* at 1637.

108. Di Lorenzo, *supra* note 1.

109. Professor Di Lorenzo uses studies of congressional trade legislation during the period 1953–1963 conducted by Professors Raymond Bauer, Ithiel de Sola Pool, and Lewis Dexter, *id.* at 436–38; Professor Martha Derthick's study of the Social Security Act, *id.* at 438–40; and a study of legislation affecting disabled persons by Professors Stephan Percy and Richard Scotch, *id.* at 440–43.

110. *Id.* at 433–35.

111. *Id.* at 434–35.

turbulence.”¹¹² The role of a strange attractor in the legal system, and the powerful effect of small perturbations in complex adaptive systems, is perhaps captured no better than in a newspaper story quoted by Di Lorenzo: “For years, a bill requiring advertisers to attach safety warnings to liquor commercials has collected more dust than votes. Then Nancy Moore Thurmond, the 22-year old daughter of the Republican Senator from South Carolina, was . . . killed by a drunken driver . . . Her death gave the legislation a new life.”¹¹³

II. COMPLEXITY THEORY AND NORMATIVE CLAIMS TO INCREASE EXPERIMENTATION AND ADAPTABILITY IN ADMINISTRATIVE GOVERNANCE

Having introduced some of the key features of complexity theory and having attempted to show their possible contributions to legal analysis, I wish now explicitly to add an important note of caution. To be sure, as Robert Shaw so eloquently observed, “You don’t see something until you have the right metaphor to let you perceive it.”¹¹⁴ But it is precisely because there has sometimes been such infatuation with complexity theory in the legal literature¹¹⁵ that one should remember that metaphors generally, and complexity theory in particular, can have important limitations.

112. *Id.* at 435.

113. *Id.* at 443–44 (quoting Clifford Kraus, *Liquor—Warning Bill Reflects Personal Impact on Public Policy*, N.Y. TIMES, May 16, 1993, at A20).

114. GLEICK, *supra* note 66, at 262.

115. See, e.g., Thomas Earl Geu, *Chaos, Complexity, and Coevolution: The Web of Law, Management Theory, and Law Related Services at the Millennium* (pt 1), 65 TENN. L. REV. 925, 926 (1998) (suggesting the overarching use of complexity theory to analyze features across economic and legal systems); 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, 1481–84 (1996) (calling for devolution of power to the states to reflect a “long jump” to a new fitness landscape); Ruhl, *supra* note 1, at 923 (calling for ending deference to administrative agency decisions to take advantage of the more dynamical qualities of the judicial experience); Ruhl, *supra* note 9, at 980 (claiming that environmental law must be “revolutionized” with complex adaptive systems as its model); J.B. Ruhl & Harold J. Ruhl, Jr., *The Arrow of the Law in Modern Administrative States: Using Complexity Theory to Reveal the Diminishing Returns and Increasing Risks the Burgeoning of Law Poses to Society*, 30 U.C. DAVIS L. REV. 405, 467 (1997) (issuing a broad call to “break the cycle” of complex legal structures); Ruhl & Salzman, *supra* note 1, at 806–09 (using an analogy of complex adaptive systems to explain the accretion of rules across the regulatory landscape); James Salzman et al., *Regulatory Traffic Jams*, 2 WYO. L. REV. 253, 270–74 (2002) (identifying positive and negative feedback loops as features of complex adaptive systems in law generally).

Claims based on complexity theory, because of the nonlinear attributes on which they gain their strength, are often impossible to falsify¹¹⁶ and thus may be dangerous to invoke for normative purposes. Thus, to say that chance sometimes, even often, plays a role in the legislative process¹¹⁷ does not necessarily mean that special interest distortions are not worth correcting.¹¹⁸ Similarly, to say that feedback loops are important in understanding complex adaptive systems does not mean that simply designing any kind of artificial process that generates feedback for use in human institutions will necessarily generate good information for policymakers—after all, if there are even small flaws in the design, sensitivity to initial conditions will operate to magnify the resultant errors. In this Part of the Article, I address the contributions that complexity theory might make in evaluating the numerous claims in the legal literature that public policy formation in general and regulatory design in particular should be more expressly experimental and adaptive.

It is almost impossible to condense the claims made over the past ten years that urge greater use of experimentalism in public policy formation. At the level of structural federalism, law professors Michael Dorf and Charles Sabel make perhaps the most sweeping normative proposal: a shift from centralized regulation to a plethora of local governance units that would engage in “deliberative polyarchy” and experimentally address a broad range of social problems.¹¹⁹ Numerous commentators, including Professors Farber and Freeman in this Symposium, allude to the possibilities for effective “modular” regulatory arrangements that promise to be more adaptive in addressing regional environmental problems.¹²⁰ The

116. See Roe, *supra* note 1, at 667 (noting, even after making the case that path dependence may explain comparative features of corporate governance structures, that, “[r]ight now, none of the three paradigms—chaos, evolution to the local hilltop, or path dependence—is developed enough to enable us to make explanatory predictions”).

117. See Di Lorenzo, *supra* note 1, at 434–35 (“A recurring conclusion flowing from chaos theory is that change—from legislative inertia to action—is unpredictable. The very existence of some of the factors inducing change—e.g. chance and publicity—cannot be predicted even in the short-term.”).

118. See *infra* notes 186–93 and accompanying text (expressing concern that special interest distortions could affect an experimentalist program of adaptive management).

119. See Dorf & Sabel, *supra* note 8, at 287–88 (arguing that the United States should create “linked systems” of local and interlocal governments to share information about local solutions to common problems).

120. Daniel A. Farber & Jody Freeman, *Modular Environmental Regulation*, 54 DUKE L.J. 795 (2005); see also Karkkainen, *supra* note 9, at 951–52 (discussing broader conceptions of

growing legal literature on “adaptive management” addresses the possibility that administrative agencies can base management decisions on programs of structured experimentation and learning.¹²¹

A. *The Genetic Algorithm and the Allure of Adaptation*

The broad literature on experimentalism includes frequent analogies drawn to complexity theory and to the role of adaptation in complex adaptive systems.¹²² To illustrate both the promise and the peril of these analogies, I turn to the genetic algorithm. Within the past twenty-five years, researchers in the field of artificial intelligence have taken some of the mechanisms of adaptation found in biological evolution and transposed them into the simulated environment of computer programming.¹²³ One of the most notable of these techniques, the genetic algorithm, was developed in 1975 by Professor John Holland.¹²⁴ In many ways, a genetic algorithm is almost a

adaptive management that include “evolving institutional configurations”).

121. See, e.g., Holly Doremus, *Adaptive Management, the Endangered Species Act, and the Institutional Challenges of “New Age” Environmental Protection*, 41 WASHBURN L.J. 50, 52 (2001) (“Perhaps the best concise definition of adaptive management is simply ‘learning by doing.’”); Emison, *supra* note 97, at 190 (“We need to promote experimentation . . .”); Karkkainen, *supra* note 9, at 948–49 (describing adaptive management as a form of scientific hypothesis-testing by which agencies could “identify areas of uncertainty, develop testable hypotheses, and use the implementation phase of the proposed action to verify and to field-test these hypotheses”); Bradley C. Karkkainen, *Toward A Smarter NEPA: Monitoring and Managing Government’s Environmental Performance*, 102 COLUM. L. REV. 903, 938–40 (2002) (proposing that agencies “devise and implement a monitoring program . . . [and] be required to disclose postdecision monitoring data to the public, and, under [some] circumstances . . . to adjust mitigation measures, modify their plans, or revise their environmental analysis in light of revealed conditions”); John M. Volkman, *How Do You Learn from a River? Managing Uncertainty in Species Conservation Policy*, 74 WASH. L. REV. 719, 739 (1999) (“Adaptive management does not call just for experimentation, but for experimentation that generates a measurable response.”).

122. See, e.g., Emison, *supra* note 97, at 180–87 (linking key features of adaptive management systems to such features of complex adaptive systems as nonlinearity, emergence, and attractors); Bradley C. Karkkainen, *Collaborative Ecosystem Governance: Scale, Complexity, and Dynamism*, 21 VA. ENVTL. L.J. 189, 196 (2002) (referring to “important and non-trivial insight from complexity theory, applicable across complex non-linear dynamic systems in general”); Ruhl, *supra* note 9, at 943–54, 996 (discussing the environment in terms of a complex adaptive system and then arguing for adaptive management as an appropriate policy device to be used by environmental managers).

123. See, e.g., Kenneth De Jong et al., *A History of Evolutionary Computation*, in HANDBOOK OF EVOLUTIONARY COMPUTATION § A2.3.1, § A2.3.3 (Thomas Bäck et al. eds., 1997) (recounting the history of evolutionary computing, including the development of the genetic algorithm).

124. See JOHN H. HOLLAND, ADAPTATION IN NATURAL AND ARTIFICIAL SYSTEMS 32–36 (1975) (explaining the basic concepts underlying genetic algorithms).

paradigm for harnessing the power of adaptation to solve difficult problems.

A computer program using a genetic algorithm unleashes a variety of problem-solving “strategies,” each one captured in a relatively simple string of computer code, onto a “problem space” designed to represent a problem that needs solving.¹²⁵ None of these strategies has “cognition”; instead, each simply attacks the problem space following the only approach it has—the one coded into its program in much the same way that a biological gene is associated with a single trait.¹²⁶ Just as a matter of blind luck, some strategies will be more successful at solving the problem than others, based on some external measure of success (“fitness”). After an interval of time, the most successful strategies are directed to recombine (“mate”) with each other.¹²⁷ Thus, the most successful strategy may be mated with the next most successful, the third most successful strategy with the fourth, and so on.¹²⁸ Mating between a pair of programs produces an offspring, a new strategy, made up partly of computer code from “Parent 1” and partly of computer code from “Parent 2.”¹²⁹ These second-generation programs are then allowed to operate within the problem space until the action is again stopped, fitness is determined, and only the most successful second-generation programs are allowed to recombine their strategies into a third generation of offspring.¹³⁰ And so on. Being *in silico*, rather than in real life, each iteration-episode often only takes an instant.¹³¹ The process is repeated—in a simple case, three hundred to four hundred iterations may be

125. The text captures an oversimplified explanation of a genetic algorithm, leaving out features that are quite important in other contexts, such as the introduction of random mutations, the crossover point used in recombinations, and the number of agents. Excellent explanations of genetic algorithms are found in John H. Holland, *Genetic Algorithms*, SCI. AM., July 1992, at 66, 66–72, and John H. Holland, *Adaptive Algorithms for Discovering and Using General Patterns in Growing Knowledge Bases*, 4 INT’L J. POL’Y ANALYSIS & INFO. SYSTEMS 245, 245–68 (1980).

126. See EMANUEL FALKENAUER, GENETIC ALGORITHMS AND GROUPING PROBLEMS 25–34 (1998) (discussing the design and encoding of genetic algorithms in terms of such biological features as genes, genotypes, and phenotypes).

127. AXELROD, *supra* note 11, at 17.

128. *Id.*

129. *Id.*

130. *Id.*

131. See *infra* note 140 (referencing a real-time applet that demonstrates the algorithm’s speed).

completed in less than one minute¹³²—until there is little room for marginal improvement between iterations, at which point a strategy has evolved that represents an approximate solution to the problem.¹³³

In the parlance of complexity theory, a genetic algorithm shares some of the features of a complex adaptive system. It is composed of “agents” (the individual strategies) that “interact” with the environment (the “problem space”) and that “adapt” based on those interactions (through the selection mechanism that sorts strategies by fitness and then combines strategies to produce offspring).¹³⁴ There is an element of “self-assembly” that follows some relatively simple and predetermined selection rules. And from repeated trial-and-error iterations and selection, an approximate solution “emerges.” It reflects a paradigmatic example of structured problem solving over time.

The power of this problem-solving mechanism can be impressive. An especially striking example of this power involves an “intractable” computational problem known as “the traveling salesman problem” (TSP), which occurs in numerous real-world settings, including the coordination of airline schedules and the routing of telephone calls.¹³⁵ But the goal in the basic TSP is to find the shortest “tour” that allows a salesman to visit each of N cities, finishing the tour in the same city from which the salesman began.¹³⁶ As a matter of straight calculation,¹³⁷ testing every possibility for a thirty-city tour would require 2.65×10^{32} additions.¹³⁸ This is such a huge number that, even

132. The reader can see how a genetic algorithm works in real time with an easy-to-use demonstration applet found at <http://math.hws.edu/xJava/GA/>.

133. See Thomas Earl Geu, *The Tao of Jurisprudence: Chaos, Brain Science, Synchronicity, and the Law*, 61 TENN. L. REV. 933, 953–54 (1994) (describing genetic algorithms to include the process whereby, “[i]f an existing network does not satisfactorily solve the novel problem, the computer will recombine strong if-then statements into new networks of connections and test these new networks as a solution to the problem”).

134. See FALKENAUER, *supra* note 126, at 29–30 (describing genetic algorithms as a method by which an initial population of solutions first is applied to the search space, then subjected to a fitness evaluation for each individual in the population, with the more fit individuals then selected to form a parental set that are recombined to produce offspring).

135. *Id.*

136. See *id.* at 438 (describing the format and goal of the TSP).

137. The total number of possible routes in an n -city tour is $n!$ (n factorial). See ADIT Software, *Travelling Salesman*, at http://www.adit.co.uk/html/travelling_salesman.html (last visited Jan. 27, 2005) (on file with the *Duke Law Journal*) (“With five cities the number of possible alternative routes is 5! (five factorial) which is $1 * 2 * 3 * 4 * 5 = 120 \dots$ ”).

138. See *id.* (finding that the number of possible routes in a thirty-city tour is 30! (thirty factorial), which is 2.65×10^{32}); Michael LaLena, *Travelling Salesman Problems Using Genetic*

with a computer capable of performing one billion calculations per second, it would take over 8,000,000,000,000,000 *years* for the computer to finish the job.¹³⁹ The same computer, programmed with a genetic algorithm, could employ the power of iterated trial-and-error feedback loops and evolve a solution within about three *seconds*.¹⁴⁰

Although the genetic algorithm is almost a paradigm for the power of problem solving through trial-and-error experimentation, it has one subtle but important drawback. At least in the simple form explained above, it tends to evolve a single solution.¹⁴¹ The problem is that this single solution, although successful in many ways, may not be the best solution—it is simply a solution that has been selected from the strategies at hand. Economists often refer to this as a “local maximum.”¹⁴² The standard example of such a local maximum is that of mountain climbers trying to climb a peak in the fog by following the rule “always keep going up.”¹⁴³ If they make it and their goal was to climb only the one peak, then their solution was the best one possible—a “global maximum.” If, however, their goal was to traverse a range of mountains, and there are several higher ones nearby, then their rule will strand them only on that one peak (the “local

Algorithms, at <http://www.lalena.com/ai/tsp/> (last visited Jan. 27, 2005) (on file with the *Duke Law Journal*) (calculating the number of possible combinations in a thirty-city tour as 2.65×10^{32}).

139. LaLena, *supra* note 138; see also Eric Kades, *The Laws of Complexity and the Complexity of Laws: The Implications of Computational Complexity Theory for the Law*, 49 RUTGERS L. REV. 403, 436 (1997) (noting that the power of exponentiation can cause the total number of possible calculations in a four-by-four puzzle to “equal[] the number of microseconds . . . since the Big Bang”).

140. The reader can see a demonstration in real time (the three-second part) of a genetic algorithm applied to a TSP at <http://www.ads.tuwien.ac.at/~guenther/tspga/TSPGA.html>. Of course, because the genetic algorithm finds only an approximate solution, albeit a highly accurate approximation, its power can be overstated by comparing it only to the complete computational solution that would be found after an exhaustive search of all thirty-factorial tours. A full appreciation of the genetic algorithm’s powers would have to include a comparison with other approximation algorithms that have been applied to the TSP. See THOMAS CORMEN ET AL., INTRODUCTION TO ALGORITHMS 1022–33 (2d ed. 2001) (“[I]t is unlikely that we can find a polynomial-time algorithm for solving this [Traveling Salesman] problem exactly. We therefore look instead for good approximation algorithms.”). I am indebted to my colleague Andrew Chin for this insight.

141. See *id.* at 1032 (explaining that this problem can affect the ability of a genetic algorithm to guarantee close approximate solutions in the most general case of TSP); see also FALKENAUER, *supra* note 126, at 41 (noting that, in the absence of a “mutation operator,” a genetic algorithm can converge toward a local maximum).

142. See, e.g., Cooter, *Decentralized Law*, *supra* note 45, at 1687–88 (contrasting “local maxim[a]” and “global maxim[a]”).

143. *Id.*

maximum”) and obscure the broader set of strategies (the “global maximum”) that would allow them to complete the traverse into higher terrain.¹⁴⁴

One of the ways to prevent a system from getting stuck at a local maximum is to introduce greater variance among the strategies in play.¹⁴⁵ For this reason, genetic algorithms often deliberately introduce mutations into the mix of evolving solutions—to prevent the otherwise inexorable selection process from overlooking possibilities.¹⁴⁶ But the linkage between variance and adaptation is hardly limited to genetic algorithms:¹⁴⁷ such linkage can occur in social and political systems too.¹⁴⁸ As Professors Robert Axelrod and Michael Cohen observe, “the surprising dynamics that occur in complex systems are often consequences of such variety, as when a long-reigning political coalition collapses with the arrival of what seemed to be a minor new participant.”¹⁴⁹

B. *Lessons from the Genetic Algorithm for Designing Experimental Governance*

1. *The Argument for Devolution.* Consider first the burgeoning academic literature on increasing experimentalism through

144. *Id.*; see also Roe, *supra* note 1, at 643 (“To achieve the next, much higher summit in the chain of hills . . . we would have to go down this hill, and then up the next one. But natural selection, by selecting only upward-bound characteristics, stymies us from going down the hill. We are stuck in a local equilibrium . . .”).

145. See FALKENAUER, *supra* note 126, at 41 (noting that, to avoid undue convergence on a local maximum, “it is the mutation operator which is in charge of reintroducing those missing alleles back into the genetic pool”).

146. *Id.*; see also LaLena, *supra* note 138 (“Mutation is when the [genetic algorithm] randomly changes one of the solutions. Sometimes a mutation can lead to a better solution that a crossover would not have found.”).

147. The exploration/exploitation dilemma is not unique to genetic algorithms but also affects “greedy” algorithms generally. See CORMEN ET AL., *supra* note 140, at 370 (discussing the effect on “greedy” algorithms, which make the choice that appears optimal at every opportunity). I am again indebted to my colleague Andrew Chin for this observation.

148. Legal analysis too has been informed by the use of, and difficulties presented by, local and global maxima. In addition to Cooter, *Decentralized Law*, *supra* note 45, other legal scholarship also refers to the concepts of local maxima and global maxima on occasion. See, e.g. Adrian Vermeule, *Judicial Review and Institutional Choice*, 43 WM. & MARY L. REV. 1557, 1563 (2002) (arguing that a regime of judicial review could “constitute a local-maximum trap, akin to the problem facing subsistence farmers who are unable to switch to more productive technologies because they will starve to death in the meantime”).

149. AXELROD & COHEN, *supra* note 14, at 32.

devolution from federal to state and local governments.¹⁵⁰ To a large extent, proponents anchor their claims to the promise that devolution will increase variance, leading to better solutions. Thus, for example, Professors Dorf and Sabel argue that “pursuit of many alternatives is the best way to understand the advantages and disadvantages of each, and so contributes to selection of the best current possibilities.”¹⁵¹ Professor Gary Bryner, addressing devolution of environmental regulation, argues that state and local governance would increase “innovation, experimentation . . . and the opening up of politics to [new] groups.”¹⁵² Professor Jonathan Adler claims that, “[g]iven the stagnation of environmental reform efforts at the federal level and the tremendous burst of environmental innovation in many states, encouraging environmental devolution is anything but anti-environmental.”¹⁵³

The appeal to greater variance, however, is not without its costs. Indeed, it poses a familiar problem to students of complex adaptive

150. See, e.g., Michael C. Dorf, *The Limits of Socratic Deliberation*, 112 HARV. L. REV. 4, 60 (1998) (referring to Justice Brandeis’ oft-repeated characterization of the states as experimental “laboratories” (quoting *New State Ice Co. v. Liebmann*, 285 U.S. 262, 310–11 (1932) (Brandeis, J. dissenting))); Brandon L. Garrett & James S. Liebman, *Experimentalist Equal Protection*, 22 YALE L. & POL’Y REV. 261, 276–77 (2004) (describing as “‘experimentalist innovations’ . . . a variety of administrative arrangements characterized by continuous, interactive cycles of local innovation and central monitoring”); Sarah C. Rispin, Comment, *Cooperative Federalism and Constructive Waiver of State Sovereign Immunity*, 70 U. CHI. L. REV. 1639, 1662 (2003) (finding that cooperative federalism is often touted as a means to allow “for more innovation and experimentation in government” (quoting *Gregory v. Ashcroft*, 501 U.S. 452, 458 (1991))). But see Fernando R. LaGuarda, Note, *Federalism Myth: States as Laboratories of Health Care Reform*, 82 GEO. L.J. 159, 160 (1993) (identifying, and then challenging, the notion that states offer loci of robust policy experimentation).

151. Dorf & Sabel, *supra* note 8, at 303; see also S. Candice Hoke, *Preemption Pathologies and Civic Republican Values*, 71 B.U. L. REV. 685, 712 (1991) (arguing that devolution would “permit[] subnational governments to engage in regulatory experimentation” to reflect a broad diversity of community cultures).

152. Gary C. Bryner, *Policy Devolution and Environmental Law: Exploring the Transition to Sustainable Development*, 26 ENVIRONS ENVTL. L. & POL’Y J. 1, 8 (2002).

153. Jonathan H. Adler, *Free & Green: A New Approach to Environmental Protection*, 24 HARV. J.L. & PUB. POL’Y 653, 694 (2001). There is, of course, a vibrant literature contesting the argument that states have been the source of “tremendous” innovation. See, e.g., Rena I. Steinzor, *Devolution and the Public Health*, 24 HARV. ENVTL. L. REV. 351, 382–400 (2000) (noting that the failures of state environmental regulation have been well-documented); Kirsten H. Engel, *State Environmental Standard-Setting: Is There a “Race” and Is It “To the Bottom”?*, 48 HASTINGS L. J. 271, 294–295 (1997) (stating that one concern of federal environmental legislation is laxity of state standards resulting from interstate competition); Andrew Hecht, Note, *Obstacles to the Devolution of Environmental Protection: States’ Self-Imposed Limitations on Rulemaking*, 15 DUKE ENV. L. & POL’Y F. 105, 198 (2004) (arguing that state environmental agencies are hampered by legal limitations in adopting protective rules).

systems: the dilemma between exploration and exploitation.¹⁵⁴ This dilemma reflects the tension between copying (and enjoying the benefits) of tested strategies that have proven somewhat effective—exploitation—and the search for untested types that might be better—exploration.¹⁵⁵ As Professors Axelrod and Cohen observe, “This trade-off . . . has turned out to be illuminating across a wide range of settings from simple genetics to organizational resource allocation, wherever the testing of new types comes at some expense to realizing benefits of those already available.”¹⁵⁶ Not all exploration is successful. And especially when irreversible outcomes are possible, policy experimentation can result in irreplaceable losses.¹⁵⁷

There is never an easy answer to the exploration-exploitation dilemma. But the dilemma itself may help explain why so much of the current legal literature on adaptive federalism tends to focus on institutional redesigns for cooperative federalism and federal-state coordination under the supervision of federal *administrative agencies*, rather than the more extreme alternative of complete defederalization.¹⁵⁸ To be sure, some scholars favor just this kind of defederalization, premised on the notion that competition among states for citizens and firms will mediate the benefits and costs of state

154. See, e.g., James G. March, *Exploration and Exploitation in Organizational Learning*, 2 *ORG. SCI.* 71, 71 (1991) (“A central concern of studies of adaptive processes is the relation between the exploration of new possibilities and the exploitation of old certainties.”).

155. AXELROD & COHEN, *supra* note 14, at 43.

156. *Id.*; see also March, *supra* note 154, at 71 (“Both exploration and exploitation are essential for organizations, but they compete for scarce resources.”).

157. See AXELROD & COHEN, *supra* note 14, at 51 (developing conditions under which exploration may be justified, citing problems that have a “low risk of catastrophe from exploration”); see also Doremus, *supra* note 121, at 67 (noting that robust agency experimentation on the Columbia River was dampened by concern over effects on already endangered salmon runs); *infra* notes 186–93 and accompanying text.

158. The literature on this feature of cooperative federalism, although not explicitly recognizing either complexity theory or the exploration/exploitation dilemma, is large. See, e.g., Dorf & Sabel, *supra* note 8, at 434–35 (suggesting that Congress has used cooperative federalism in the Federal Clean Air Act and in “other areas as well”); Michael S. Greve, *Against Cooperative Federalism*, 70 *MISS. L.J.* 557, 561–62 (2000) (comparing and critiquing cooperative federalism in Germany and the United States); Philip J. Weiser, *Cooperative Federalism and Its Challenges*, 2003 *MICH. ST. L. REV.* 727, 728–29 (noting aspects of cooperative federalism of the 1996 Telecommunications Act but recognizing that, “[a]lthough relatively new to the telecommunications industry, cooperative federalism is a familiar feature in other regulatory regimes”); Michael L. Gallo, Note, *AT&T Corp. v. Iowa Utilities Board*, 15 *BERKELEY TECH. L.J.* 417, 431 (2000) (“In spite of the Supreme Court’s comment [in *AT&T v. Iowa Utilities Board*] that ‘a federal program administered by 50 independent state agencies is surpassing strange,’ this sort of ‘cooperative federalism’ characterizes many laws . . .” (footnote omitted)).

experimentation.”¹⁵⁹ But such arguments have met objections questioning whether there really is enough of a competitive “market” for states to create beneficial variance if left to their own devices.¹⁶⁰ Assuming that the results of this theoretical debate have not yet settled, it is empirically plain that most federal programs have shied away from radical defederalization and, instead, have located reforms within the more familiar boundaries of cooperative federalism.¹⁶¹

The exploration-exploitation dilemma described by complexity theory may help explain why this is, and should be, the case. Policy experiments within existing statutory and administrative structures carry with them the advantage of maintaining as a fallback mechanism the (exploitation) benefits of minimum federal standards, while allowing under varying levels of supervision a search for different ways of doing things (exploration).¹⁶² This explains, for example, not only the basic structure of cooperative federalism (as opposed to rank defederalization), but also the location of regulatory reforms within the cooperative federalism framework. For example, the devolution literature itself often emphasizes the Federal Environmental Protection Agency’s “Project XL” experiment, which allows for regulatory flexibility only for firms promising “superior environmental performance” over the Agency’s baseline of preexisting rules.¹⁶³ It also explains the innumerable “variance” and

159. See, e.g., Richard L. Revesz, *Rehabilitating Interstate Competition: Rethinking the “Race-to-the-Bottom” Rationale for Federal Environmental Regulation*, 67 N.Y.U. L. REV. 1210, 1236–44 (1992) (arguing that, as a result of competition, states will maximize social welfare to attract citizens and businesses and thus will refrain from adopting suboptimally lax regulations—contrary to the traditional race-to-the-bottom dynamic).

160. See, e.g., Kirsten H. Engel, *supra* note 153, at 278 (questioning the assumption of perfect competition among states); Kirsten Engel, *Reconsidering the National Market in Solid Waste: Trade-Offs in Equity, Efficiency, Environmental Protection, and State Autonomy*, 73 N.C. L. REV. 1481, 1505–06 (1995) (arguing that immobility and lack of information undermine the existence of a market in citizens sufficient to insulate states from an inefficient race to the bottom). *But see* Richard L. Revesz, *The Race to the Bottom and Federal Environmental Regulation: A Response to Critics*, 82 MINN. L. REV. 535, 549–51 (1997) (claiming that an interstate market for citizens and firms does function competitively).

161. See *supra* note 158 and accompanying text (noting the widespread use of cooperative-federalism designs in federal statutes across a wide programmatic spectrum).

162. See *supra* note 158 (describing how frequently federal statutes enlist states in regulatory endeavors characterized by cooperative-federalism).

163. See, e.g., Farber, *supra* note 56, at 309–10 (“[T]he idea is to excuse some supposedly less significant regulatory violations in exchange for agreements to transcend the standards in more important respects”); Freeman, *supra* note 8, at 55–66 (describing the implementation of two XL agreements); Beth S. Ginsberg & Cynthia Cummins, *EPA’s Project XL: A Paradigm for Promising Regulatory Reform*, 26 *Envtl. L. Rep. (Envtl. L. Inst.)* 10,059, 10,060–61 (1996)

“adjustment” mechanisms in federal environmental and public health statutes that allow agencies to retain the exploitation benefits of federal rules while simultaneously allowing some members of the regulated community an opportunity to demonstrate innovative ways to meet regulatory objectives (exploration).¹⁶⁴ Indeed, in an especially thoughtful piece, law professor Bradley Karkkainen captures perfectly the dynamic behind the exploration-exploitation dilemma by arguing for the use of “regulatory penalty default[s]” by which administrative agencies would impose on parties a known baseline of prescriptive regulation (exploitation) against which the parties would have an incentive to bargain around in developing a less expensive, more innovative means of reaching the agency’s goals (exploration).¹⁶⁵ In this case, viewing governance as a complex adaptive system offers insights on when regulatory reform efforts are most apt to provide policymaking improvement.

2. *The Argument for Adaptive Management.* More often than not, proponents of adaptive regulation have in mind something other than increasing variance through devolution. Instead, they propose a reform project for administrative agencies grounded partly in the

(comparing Project XL to other legislative reform initiatives). In highlighting the Agency’s “Project XL” experiment, I do not seek to endorse its effectiveness. Indeed, there are reasons to think that, in practice, it may be highly ineffective. See, e.g., Rena I. Steinzor, *Regulatory Reinvention and Project XL: Does the Emperor Have Any Clothes?*, 26 *Envtl. L. Rep.* (Envtl. L. Inst.) 10527, 10529–30 (1996) (describing Project XL as a “free-for-all” of unrelated exemptions and firm “wish lists” that do not, in fact, receive effective agency review). My point is that, with the exploitation/exploration insight from complexity theory, it is at least understandable why regulatory experimentation took this form, and should have taken this form, over a more radical devolutionary approach.

164. See Robert L. Glicksman & Sidney A. Shapiro, *Improving Regulation Through Incremental Adjustment*, 52 *KAN. L. REV.* 1179, 1187 (2004) (providing examples of five statutes that allow federal agencies flexibility to adjust the application of the statutes at the “back end”). Undoubtedly the most discussed of such mechanisms, at least in the adaptation-through-experimentation literature, are the provisions for Habitat Conservation Plans (HCPs) under the Federal Endangered Species Act. See, e.g., David A. Dana, *The New “Contractarian” Paradigm in Environmental Regulation*, 2000 *U. ILL. L. REV.* 35, 38–39 (discussing the origin and purpose of HCPs); Doremus, *supra* note 121, at 68–74 (discussing the history and application of HCPs); Donald C. Baur & Karen L. Donovan, *The No Surprises Policy: Contracts 101 Meets the Endangered Species Act*, 27 *ENVTL. L.* 767, 767–89 (discussing the qualities of HCPs).

165. Karkkainen, *supra* note 9, at 967. To illustrate such default rules, Professor Karkkainen points to the Federal Endangered Species Act’s “incidental take” permits, by which land developers who implement federally approved HCPs can avoid the Act’s strict regulatory default provision prohibiting private landowners from “taking” the habitat of listed species.” *Id.* at 970–75.

aspirations of scientific pragmatism:¹⁶⁶ that agencies themselves can reap the benefits of structured learning over time through a systematic program of active experimentation.¹⁶⁷ The emphasis on experimentation is especially noticeable in claims that environmental agencies should follow the principles of “adaptive management.”¹⁶⁸ In an insightful article, Professor Holly Doremus notes the nuances of adaptive management but nonetheless offers a useful simplification: adaptive management is “learning by doing.”¹⁶⁹ In a recent report of the National Research Council,¹⁷⁰ adaptive management was defined to include several key features: regularly revisited management objectives,¹⁷¹ a range of management choices,¹⁷² mechanisms for incorporating learning into future decisions,¹⁷³ the use of models that can accommodate uncertainty,¹⁷⁴ and the monitoring and evaluation

166. See, e.g., Joel A. Mintz, *Some Thoughts on the Merits of Pragmatism as a Guide to Environmental Protection*, 31 B.C. ENVTL. AFF. L. REV. 1, 1–13 (2004) (noting the resurgence of pragmatism in legal thought and also noting difference among different schools of pragmatic philosophy).

167. See, e.g., Jamie A. Grodsky, *The Paradox of (Eco)pragmatism*, 87 MINN. L. REV. 1037, 1046 (2003) (“[T]he political process itself may exhibit many attributes of pragmatism—in particular, a reliance on experimentation and feedback as an approach to problem solving”); Mintz, *supra* note 166, at 5 (finding that pragmatism emphasizes experimentation among other values); Volkman, *supra* note 121, at 739–55 (“Adaptive management does not call just for experimentation, but for experimentation that generates a measurable response.”).

168. See, e.g., Doremus, *supra* note 121, at 52 (“The essence of adaptive management . . . is simply ‘learning by doing.’”); Farber, *supra* note 55, at 882 (asserting that institutions for eco-pragmatism will require careful design to allow for “flexible, experimental management”); Ana M. Parma et al., *What Can Adaptive Management Do for Our Fish, Forests, Food, and Biodiversity?*, 1 INTEGRATIVE BIOLOGY 16, 19 (1998) (“[A]daptive management consists of managing according to a plan by which decisions are made and modified as a function of what is known and learned about the system, including information about the effect of previous management actions.”).

169. Doremus, *supra* note 121, at 52.

170. NAT’L RESEARCH COUNCIL, *ADAPTIVE MANAGEMENT FOR WATER RESOURCES PROJECT PLANNING* (2004).

171. The Panel was clear in establishing that adaptive management does not postpone action until “enough” is known, *id.* at 19, and that there must be some level of agreement among management objectives if the undertaking should even begin, *id.* at 24.

172. When possible, adaptive management envisions the simultaneous implementation of “two or more carefully monitored actions [that] can allow for rapid discrimination among competing models.” *Id.* at 26.

173. The Panel was clear that adaptive management will not achieve improved policymaking unless there is a “mechanism to integrate knowledge gained in monitoring into management actions” and “the political will to act upon knowledge gained from monitoring.” *Id.* at 27.

174. The Panel stressed that, precisely because adaptive management was intended to operate in areas of high uncertainty, “complete or perfect . . . models . . . [would] not need to be crafted in order to support decisions.” *Id.* at 25.

of outcomes.¹⁷⁵ At bottom, adaptive management involves “feedback,”¹⁷⁶ is “iterative,”¹⁷⁷ and is “structured”¹⁷⁸ to take advantage of a “mix of progress and setbacks.”¹⁷⁹

Adaptive management, thus, shares essential features with genetic algorithms, which are also structured to provide iterative feedback that is used to take advantage of successes and failures.¹⁸⁰ Of course, this is not to say that the proponents of adaptive management base their arguments expressly on analogies to the problem-solving attributes of genetic algorithms.¹⁸¹ But the genetic algorithm is useful because it highlights in a visible, simple way one of the key features of successful, adaptive problem solving: meaningful feedback. In a genetic algorithm, feedback is produced every time that the various strategies are measured for success, and then the feedback is used to create the next generation of strategies, which, in turn, generate more meaningful feedback when they are measured for success as the process repeats itself.¹⁸² Of special relevance for purposes of this Article is that, in a genetic algorithm, the metric of success (the fitness function) is clear-cut and uncontested, fitness itself is measurable and measured accurately, the results of each iteration are used meaningfully to structure the next iteration, there are multiple iterations generating feedback, and feedback is fast.¹⁸³

To assume that any of these features would have their analogue in a real-life regulatory setting is beyond heroic. That is not to say

175. The Panel emphasized that “[m]onitoring systems should be an integral part of program design at the outset and not simply added *post hoc* after implementation.” *Id.* at 26.

176. *Id.* at 22.

177. *Id.* at 24.

178. *Id.* at 22.

179. *Id.* at 24.

180. See *supra* notes 125–33 and accompanying text.

181. Proponents of adaptive regulation do, however, allude regularly to complexity theory for general support. See, e.g., Lee P. Breckinridge, *Nonprofit Environmental Organizations and the Restructuring of Institutions for Ecosystem Management*, 25 *ECOL. L.Q.* 692, 703 n.32 (1999) (citing to the literature on complexity theory as relevant to institutions for collaborative governance); Jon Cannon, *Choices and Institutions in Watershed Management*, 25 *WM. & MARY ENVTL. L. & POL’Y REV.* 379, 382 & n.16 (2000) (noting the importance of underlying adaptability in complex adaptive systems to institutions for collaborative governance); Emison, *supra* note 97, at 167 (identifying the need to model environmental management institutions themselves as complex adaptive systems); Farber, *supra* note 55, at 880 (making the case for pragmatism in part because of the nature of “complex dynamic systems”).

182. See FALKENAUER, *supra* note 126, at 45–53 (describing strategies for the selection of fitness).

183. *Id.* at 29–30.

that designing adaptive administrative processes is impossible, only that the newfound enthusiasm for this project seems curious. After all, federal administrative agencies have shown relatively little interest in systematic program evaluation as a general matter,¹⁸⁴ and “[t]rue random experimental designs are rare, if not entirely nonexistent, in environmental policy.”¹⁸⁵ The data generated in any real-world experiments, moreover, would undoubtedly be contested and subject to political pressure,¹⁸⁶ and agencies facing hard look judicial review have been “chary of revisiting old rules, even in the name of flexibility.”¹⁸⁷

These problems are not necessarily insurmountable. But, in addition to the types of difficulties just enumerated, there is a more systematic design problem that has so far eluded discussion in the adaptive management literature. The problem stems from the exploration-exploitation dilemma and might be especially relevant for regulatory programs in which experimentation is substituted, at least in part, for action.¹⁸⁸ After all, no one is suggesting that agencies relax all of their rules and substitute rank trial-and-error simply for its own sake. Instead, experimentation will be of most value when there is a level of uncertainty that might be reduced by a systematic program of scientific inquiry.¹⁸⁹ Yet, in determining the value of experimentation (exploration), values will be discounted by the foregone benefits of applying the agency’s existing regulations (exploitation). Especially

184. See Cary Coglianese & Lori Snyder Benneer, *Evaluating Environmental Policies*, 47 ENVIRONMENT (forthcoming 2005) (manuscript at 2, on file with the *Duke Law Journal*) (noting that “program evaluation research has been remarkably scarce”).

185. *Id.* (manuscript at 15).

186. See Doremus, *supra* note 121, at 82 (claiming that “[m]onitoring data are likely to be ambiguous, difficult to interpret, and at the frontiers of scientific knowledge . . . [and] disagreement among the experts within the agency[] is likely to exacerbate the tendency to interpret data according to political, rather than scientific, signals”). See generally Donald T. Hornstein, *Accounting for Science: The Independence of Public Research in the New, Subterranean Administrative Law*, 66 LAW & CONTEMP. PROBS. 227, 228 (Fall 2003) (discussing new features in administrative law, the Shelby Amendment and Data Quality Act, as “a new subterranean, battleground . . . in which the scent of future regulation is caught by stakeholders who then battle to shape the scientific facts on which future regulation may be based”).

187. Thomas O. McGarity, *Some Thoughts on “Deossifying” the Rulemaking Process*, 41 DUKE L.J. 1385, 1420 (1992).

188. See, e.g., NAT’L RESEARCH COUNCIL, *supra* note 170, at 26–27 (describing the role of experimentation in adaptive management).

189. See *id.* at 25–27 (noting that adaptive management is intended to operate in areas of high uncertainty in which there is a mechanism for integrating knowledge gained from monitoring into management actions).

when such values are high, for example when a species might become extinct or public health could worsen because of these foregone benefits, this discount rate will be high and the agency will perennially reach a rational cost-benefit calculation that it is not worth experimenting.¹⁹⁰ Moreover, to the extent that the results of experimentation will not be available for a length of time (which is likely to be the case in most of the ecological settings in which adaptive management has been championed), agencies will rationally discount even further the benefit of experimentation.¹⁹¹ Indeed, these dynamics may help explain the results of the nation's longest-running experience with adaptive management, involving salmon recovery efforts within the Columbia River Basin.¹⁹² Professor Doremus recounts that impediments to experimentation by the Northwest Power Planning Council include the "risk of harm to species teetering on the edge of extinction [which] arouses opposition to experiments . . . [and the fact that] the political system operates on a much shorter time scale than that needed to generate firm data."¹⁹³

At this point, I hasten to add that I am not necessarily hostile to reform projects championing adaptive management.¹⁹⁴ At least as framed by their original developers, these projects genuinely seek to improve the quality of regulatory decisionmaking. But my reading of this rich, emerging literature is that it often ends in contested

190. This insight was applied to courts in Hadfield, *supra* note 45, at 593–94, which concluded that the greater a court's confidence that its prior rule had value in preventing harm, the more heavily it will discount relaxing that rule to gather information that might be helpful in designing a better one.

191. *See id.* (concluding that courts would similarly discount the value of experimentation in the development of common-law doctrine).

192. *See generally* Volkman, *supra* note 121 (discussing the case history of adaptive management on the Columbia River).

193. Doremus, *supra* note 121, at 67.

194. *See, e.g.*, Fred Bosselman, *A Role for State Planning: Intergenerational Equity and Adaptive Management*, 12 J.L. & PUB. POL'Y 311, 320 (2001) ("The growing support for adaptive management as a planning system is a reaction to our increasing recognition that we are living in an unstable environment."); Davidson & Geu, *supra* note 8, at 818 n.7 (citing literature on adaptive management); Farber, *supra* note 20, at 148 ("Adaptive management can prevent the worst consequences of a power law from being realized."); Karkkainen, *supra* note 9, at 943 ("Conservation ecologists and natural resource managers assert that integrated management of complex ecosystems requires an iterative and adaptive management approach."); Wiener, *supra* note 97, at 21–22 (discussing interest in adaptive management); *see also* Freeman, *supra* note 8, at 22 (noting that collaborative governance is supported in part because of its advantages under conditions of uncertainty involving continuous monitoring and evaluation); Karkkainen, *supra* note 122, at 193 (supporting collaborative governance in part to respond to underlying dynamism and uncertainty in ecosystems).

empirical claims and might be improved (while the empirical debate settles) by attention to the theoretical design features with which any program of experimentation must grapple.¹⁹⁵ This, in turn, may help policymakers identify the necessary, real-world conditions under which adaptive governance by administrative agencies might indeed lead to genuine social improvement. Contrariwise, greater attention to these necessary conditions will help reveal those policymakers who would merely appropriate the metaphor of adaptation and dismantle existing governance structures under false pretenses¹⁹⁶ without providing the mechanisms that would make experimentation work.¹⁹⁷

C. *Lessons from Evolutionary Game Theory for Collaborative Administrative Regimes*

Some of the literature arguing for more adaptive agencies posits a process of stakeholder involvement and collaboration rather than solely a process of scientific experimentalism.¹⁹⁸ Simply from the perspective of improved knowledge this is understandable: as the National Research Council itself found, “unbounded conflict can tear apart the social fabric, thwarting learning.”¹⁹⁹ But those commentators

195. See, e.g., STEFAN H. THOMKE, EXPERIMENTATION MATTERS 4, 10–14 (2003) (noting that “experimentation is not an isolated phenomenon but part of a larger organizational effort toward innovation” and suggesting six design principles to guide successful experimentation programs).

196. See Doremus, *supra* note 121, at 88 (“Adaptive management can be used as a smokescreen to conceal political accommodations that sacrifice the protection of species or natural systems.”).

197. Of course, attention to real-world conditions will require more than attention to decisional strategies designed to provide good information and opportunities to learn. Administrative law involves more than simply reaching substantive results. It also reflects critical political values—accountability, transparency, and fairness. Therefore, even coherently designed adaptive regulatory structures will challenge administrative law. For example, as a matter of basic political legitimacy, to what extent may an agency with the statutory obligation to take action choose instead a program self-consciously designed to be experimental? Are agency policy choices “final” for purposes of judicial review when regulators may see such choices merely as adjusting a variable in an overarching program of experimental probing? If judicial review is available, what should be its scope? How is the public to gather information and participate in an agency’s program of policy experimentation and adaptation, especially those members of the public who may see in the agency’s experimental approach a transformation of their own status from regulatory beneficiary to guinea pig? Questions such as these are beyond the focus on this Article but are plainly noteworthy.

198. See, e.g., Freeman, *supra* note 8, at 6 (arguing that parties need to share responsibility for policymaking); Karkkainen, *supra* note 122, at 238 (noting that participation is a deeper process than the term “stakeholder” involvement suggests, and arguing for such deep participatory involvement).

199. NAT’L RESEARCH COUNCIL, *supra* note 170, at 24 (quoting Kai. N. Lee, *Appraising*

arguing for collaboration claim that it promises additional benefits for regulatory endeavors in increased creativity,²⁰⁰ improved implementation,²⁰¹ and heightened democratic participation.²⁰² These claims underlie regulatory initiatives designed to induce regulatory compliance by firms²⁰³ as well as broader efforts to create stakeholder involvement in the design of regulatory programs themselves.²⁰⁴

The collaborationists' project has spawned a counterliterature arguing that stakeholder-driven processes lack legitimacy in part because the participants' self-interest may work to undercut just such "voluntary" or "collaborative" endeavors.²⁰⁵ The counterliterature

Adaptive Management, 3 CONSERVATION ECOLOGY Art. 3, Dec. 1999, at <http://www.ecologyandsociety.org/vol3/iss2/art3>).

200. Freeman, *supra* note 8, at 23.

201. *Id.* at 23–24.

202. *Id.* at 27–29.

203. The Federal Occupational Health and Safety Administration (OSHA), for example, implemented in the early 1990s a Voluntary Protection Program whereby firms with strong safety records were exempted from regular agency inspection and given primary responsibility for monitoring compliance with OSHA regulations. Clifford Rechtschaffen, *Deterrence vs. Cooperation and the Evolving Theory of Environmental Enforcement*, 71 S. CAL. L. REV. 1181, 1209–10 (1998). In 1995, the Federal Environmental Protection Agency (EPA) adopted incentives for self-policing designed to reduce penalties for firms that discover, report, and correct regulatory violations. Incentives for Self Policing; Discovery, Disclosure, Correction and Prevention of Violations, 60 Fed. Reg. 66,706, 66,711–66 (Dec. 22, 1995). EPA also began a voluntary program, known as the "33/50 program," to induce firms to reduce the emissions of toxic chemicals by 33 percent in a first phase and by 50 percent in a second phase. Arora Seema & Timothy N. Carson, *An Experiment in Voluntary Environmental Regulation: Participation in EPA's 33/50 Program*, 28 J. ENVTL. ECON. & MGMT. 271, 271 (1995). More generally, the Federal Sentencing Guidelines reward corporations for postoffense cooperation. William S. Laufer, *Corporate Prosecution, Cooperation, and the Trading of Favors*, 87 IOWA L. REV. 643, 644–45 (2002).

204. In addition to the habitat-conservation-plan program under the Endangered Species Act, *see supra* note 164, such efforts would include the encouragement of regulatory negotiation (so-called "reg-neg") by which stakeholders play a significant role in the development of agency regulations, Freeman, *supra* note 8, at 36–55, as well as such "place-based" efforts as the multistate Chesapeake Bay Program to address nonpoint pollution, Daniel A. Farber, *Triangulating the Future of Reinvention: Three Emerging Models of Environmental Protection*, 2000 U. ILL. L. REV. 61, 72–73, and the multistakeholder CALFED process for managing water and ecological resources in the Bay-Delta system near San Francisco, Farber & Freeman, *supra* note 120, at 838.

205. *See, e.g.*, Rechtschaffen, *supra* note 203, at 1211 ("In the end, in the absence of more supporting evidence, those advocating a wholesale departure from a deterrence-based approach bear some burden of persuasion . . ."); Mark Seidenfeld, *Empowering Stakeholders: Limits on Collaboration as the Basis for Flexible Regulation*, 41 WM. & MARY L. REV. 411, 500 (2000) (noting potential problems with empowering stakeholders as a means of creating collaborative government); Sidney A. Shapiro, *Outsourcing Government Regulation*, 53 DUKE L.J. 389,

repeatedly emphasizes economic theory to suggest the frailty of the collaborationists' theoretical foundation.²⁰⁶ The collaborationists, in turn, point to growing experience with just such flexible programs and suggest that it may be theory, rather than reality, that is "under informed."²⁰⁷

It is out of this exchange over the theoretical foundations of cooperation that law professor Bradley Karkkainen, a proponent of collaborative regulation, makes a noted (albeit tongue-in-cheek) plea for critics simply to stop using the prisoner's dilemma as an analytical objection to adaptive collaboration: "I want to propose (only half-facetiously) a moratorium on indulgence in the use of such shopworn tools as the Tragedy of the Commons and the Prisoner's Dilemma to analyze the deep structure of these [collaborative] arrangements and thereby to prove their impossibility"²⁰⁸ In fact, as Professor Karkkainen himself explores in his subsequent work,²⁰⁹ it is precisely *within* the game-theoretic tradition of the prisoner's dilemma that a theoretical foundation *for* the collaborationists' project might be found.

The reason that the prisoner's dilemma can be a bane, or boon, for collaborationists lies in the difference between the static, "one-shot" form of the game and the iterated, "repeated-play" form, especially when this more dynamic form allows for the possibility of adaptive behavior.²¹⁰ Game theory, of which the prisoner's dilemma is a part, shares with complexity theory such features as actors, interactions, and emergence (equilibriums).²¹¹ Most students of the law are familiar with the static 2×2 "one-shot" form of the prisoner's

426–29 (2003) (noting how firms' opportunistic behavior can increase agency transaction costs in monitoring firm self-regulation); Rena I. Steinzor, *Reinventing Environmental Regulation: The Dangerous Journey from Command to Self-Control*, 22 HARV. ENVTL. L. REV. 103, 201 (1998) (noting that genuine efforts to "reinvent" environmental regulation has not been shown to be supported by firms' self interest); Stephen M. Nickelsburg, Note, *Mere Volunteers? The Promise and Limits of Community-Based Environmental Protection*, 84 VA. L. REV. 1371, 1382–89 (1998) (using bargaining theory to identify potential obstacles to agreement).

206. *E.g.*, Shapiro, *supra* note 205, at 426–429; Nickelsburg, *supra* note 205, at 1382–89.

207. Karkkainen, *supra* note 122, at 226.

208. *Id.*

209. *See* Karkkainen, *supra* note 9, at 966 n.75 (citing works that discuss the possibilities for collaboration under evolutionary game theory).

210. *See* ROBERT AXELROD, *THE EVOLUTION OF COOPERATION* 19–20 (1984) (introducing the idea that cooperation can emerge in an iterated Prisoner's Dilemma).

211. *See generally* DOUGLAS G. BAIRD ET AL., *GAME THEORY AND THE LAW* 6–11 (1994); SHAUN P. HARGREAVES HEAP & YANIS VAROUFAKIS, *GAME THEORY* 41–79 (1995).

dilemma.²¹² Because the outcome of the prisoner's dilemma is that rational actors, in a particular setting, will not cooperate even when it is to their mutual advantage,²¹³ it is a theoretical thorn in the side for those commentators who argue for increased use of cooperation through collaborative institutions (as Professor Karkkainen recognizes).²¹⁴

To appreciate how adaptation can change this outcome, consider first the basic lesson of the static, "one-shot" form of the prisoner's dilemma. The basic lesson was popularized by biologist Garrett Hardin as the tale of two livestock herders in the "tragedy of the commons"²¹⁵ and was recently transposed especially well into game theory's 2×2 static form by political scientist Elinor Ostrom.²¹⁶ The story involves two mountain goat herders sharing an unregulated, open-access common area onto which their goats can graze. If they turn out too many goats onto the commons, exceeding the area's sustainable carrying capacity, the commons will collapse, the goats will starve, and both herders will end up with a "payoff" of 0. If, however, the two herders cooperate, determine the overall carrying capacity, and abide by an agreement to limit their goats

212. For an excellent history of the development of the Prisoner's Dilemma, see WILLIAM POUNDSTONE, *PRISONER'S DILEMMA* (1992). The legal literature on the Prisoner's Dilemma is large and varied. See, e.g., Thomas W. Merrill, *Pluralism, The Prisoner's Dilemma, and the Behavior of the Independent Judiciary*, 88 NW. U. L. REV. 396 (1998); John W. Lam, Note, *The Prisoner's Dilemma: Reassessment of Borrero v. Aljets and the Indefinite Detention of Inadmissible Aliens*, 37 LOY. L.A. L. REV. 1297 (2004); Daniel P. Petrov, Note, *Prisoners No More: State Investment Relocation Incentives and the Prisoners' Dilemma*, 33 CASE W. RES. J. INT'L L. 71 (2001); Neil S. Siegel, Comment, *State Sovereign Immunity and Stare Decisis: Solving the Prisoners' Dilemma Within the Court*, 89 CAL. L. REV. 1165 (2001).

213. POUNDSTONE, *supra* note 212, at 118–20. In the original form from which the prisoner's dilemma gets its name,

Two suspects are taken into custody and separated. The district attorney is certain that they are guilty of a specific crime, but he does not have adequate evidence to convict them at trial. He points out to each prisoner that each has two alternatives: to confess to the crime the police are sure they have done, or not to confess. If they both do not confess, then . . . they will both receive minor punishment [based on evidence that the police do have of more minor offenses]; if they both confess [to the major offense] they will be prosecuted, but he will recommend less than the most severe sentence; but if one confesses and the other does not, then the confessor will receive lenient treatment for turning state's evidence whereas the latter will get 'the book' slapped at him.

R. DUNCAN LUCE & HOWARD RAIFFA, *GAMES AND DECISIONS: INTRODUCTION AND CRITICAL SURVEY* 95 (1957).

214. See *supra* note 208 and accompanying text.

215. Garrett Hardin, *The Tragedy of the Commons*, 62 SCIENCE 1243, 1244 (1968).

216. ELINOR OSTROM, *GOVERNING THE COMMONS: THE EVOLUTION OF INSTITUTIONS FOR COLLECTIVE ACTION* 2–5 (1990).

appropriately, then each will profit and receive a payoff of 10. But if one of the herders secretly “defects” from the agreement and exceeds his sustainable allotment, he receives a “cheater’s bonus” of 11 (as he will make up in extra goats the incremental weight loss suffered by each goat due to overgrazing), whereas the other herder, who naively restricts his goats to the agreed-upon allotment, will get the “sucker’s payoff” of -1 (because he will not make up the weight loss of individual goats with any “extra” animals and will end up losing money). The payoff structure, thus, looks like this (Herder *A* payoff, Herder *B* payoff):

Herder A	Herder B	
	Cooperate	Defect
Cooperate	10, 10	-1, 11
Defect	11, -1	0, 0

The result of a one-shot “play,” in which the herders know the payoff structure but are unsure what the other will do, is tragic: even though both herders realize that they would be better off cooperating (10, 10) than mutually defecting (0, 0), each herder’s self-interest in maximizing gains causes him rationally to defect.²¹⁷ This scenario, in which the players are left to resolve their problems in an unregulated market, as Professor Karkainen appreciates, does not bode well for collaborationists.

The “standard” solution, which Professor Ostrom calls “Leviathan,”²¹⁸ is to posit an infallible administrative agency that will always detect and punish defectors with a penalty of, say, -2 .²¹⁹ This changes the payoff structure to incentivize the preferred outcome of mutual cooperation. Thus, with Leviathan (-2), the new structure becomes:

217. A player is tempted to defect either to seize the cheater’s payoff (if the other cooperates) or to avoid the sucker’s payoff (if the other defects). The resulting mutual defection leaves both worse off and suggests that government regulation is justified to rescue the unregulated marketplace from these poor outcomes.

218. See OSTROM, *supra* note 216, at 8–10.

219. See *id.* at 9–10 (representing Leviathan by assuming “that the central authority decides to impose a penalty of 2 profit units on anyone who is considered by that authority to be using a defect strategy”).

Herder A	Herder B	
	Cooperate	Defect
Cooperate	10, 10	-1, 9
Defect	9, -1	-2, -2

In the presence of Leviathan, one is always better off cooperating, leading society to enjoy the mutual gains shared by a population of cooperators.²²⁰ Thus, this outcome presents the standard case for regulation. Unfortunately, this solution also does not bode well for collaborationists, who generally argue against the need for inflexible Leviathans.

But Leviathan is not the only way to overcome prisoner's dilemma situations, especially when one relaxes the one-shot-play constraint and considers the real-world situation in which players in commons-type situations react with each other repeatedly over time; *evolutionary* game theory, which studies repeat games, can account for just this type of adaptation.²²¹ Political scientist Robert Axelrod published a provocative contribution in the mid-1980s, *The Evolution of Cooperation*,²²² that has been widely noted in the legal literature,²²³ and indeed become one of the most-cited works in the social sciences over the past twenty years.²²⁴ His basic insight stems from a

220. *Id.* at 10. A would-be cooperator who would otherwise fear the sucker's payoff will not defect defensively because Leviathan's sanction for defectors (-2) is worse than the sucker's payoff itself (-1); conversely, a would-be defector seeking the cheater's payoff also will not defect because Leviathan's punishment for defection reduces the cheater's payoff from 11 to 9 and because the reward for cooperation (10) is greater than the newly adjusted cheater's payoff (9). *Id.*

221. See AXELROD, *supra* note 11, at 4 ("The main alternative to the assumption of rational choice is some form of adaptive behavior.").

222. AXELROD, *supra* note 210.

223. See, e.g., Russell B. Korobkin & Thomas S. Ulen, *Law and Behavioral Science: Removing the Rationality Assumption from Law & Economics*, 88 CAL. L. REV. 1051, 1138 n.355 (2000); Eric A. Posner, *The Regulation of Groups: The Influence of Legal and Nonlegal Sanctions on Collective Action*, 63 U. CHI. L. REV. 133, 139 n.12 (1996); Kenneth A. Dursht, Note, *From Containment to Cooperation: Collective Action and the Wassenaar Arrangement*, 19 CARDOZO L. REV. 1079, 1093 n.96 (1997); see also William H. Rodgers, Jr., *Where Environmental Law and Biology Meet: Of Pandas' Thumbs, Statutory Sleepers, and Effective Law*, 65 U. COLO. L. REV. 25, 41-42 (1993) (noting that Professor Axelrod's *Evolution of Cooperation* has been cited in more than one hundred law review articles).

224. See Robert Hoffman, *Twenty Years On: The Evolution of Cooperation Revisited*, 3(2) J.

“tournament” of some two hundred moves, with payoffs similar to those used above in the two-herder commons game.²²⁵ Thus, if two players meet and cooperate, they each receive 10 points; if one cheats the other, the cheater gets 11 and the sucker gets -1; if both cheat, they each receive 0. The two players collect their points and then move on to the next play, and so on. The significant new feature of the iterated prisoner’s dilemma is that each player knows what the other did on previous moves. Whoever has the highest cumulative point score at the end of all the plays wins the tournament.²²⁶

The consequences of iteration can be startling. Professor Axelrod invited people to submit computer programs embodying different strategies to the tournament.²²⁷ So, for example, one strategy might be to “always defect” (with the hope of accumulating some cheater’s bonuses), whereas another might be to “always cooperate” (with the hope of meeting some like-minded cooperators and accumulating the high-point outcomes of mutual cooperation). But neither of these strategies won the tournament. Whenever a program met a “pure defector,” there was no benefit in cooperating with such a player (and thereby getting the sucker’s payoff), and so the all-too-frequent result was mutual defection, with each player acquiring no points. The “always-cooperate” strategy did not win the tournament either. Whenever a program met such a “pure cooperator,” it could always do better by defecting (thereby getting the cheater’s payoff of 11) rather than cooperating (with a mutual-cooperation payoff of only 10); thus, sadly, pure cooperators were taken advantage of rather than rewarded with mutual cooperation. The winner of the tournament was a strategy known as Tit-for-Tat, which always reciprocated in kind. Thus, when Tit-For-Tat met a cooperator, it would reciprocate with cooperation and acquire the high points from mutual cooperation (10), but when the program met a defector, it also would reciprocate, thereby avoiding the sucker’s payoff (-1).²²⁸

ARTIFICIAL SOCIETIES & SOC. SIMULATION para. 1.2 (2000), at <http://www.soc.surrey.ac.uk/JASS/3/2/forum/1.html> (“According to the *Social Science Citation Index*, [Axelrod’s] work had been quoted more than one thousand times by 1992 and [has been cited] more than 2500 times to date.” (citations omitted)).

225. See AXELROD, *supra* note 210, at 30–31 (noting that the tournament paired strategies against each other for two hundred moves and that the payoffs were “the familiar” ones taken from the Prisoner’s Dilemma).

226. *Id.* at 30.

227. *Id.* at 31; AXELROD, *supra* note 11, at 16.

228. See AXELROD, *supra* note 11, at 16 (describing the experimental design of his original

The significance of Professor Axelrod's theoretical work for regulatory policy is that, in the real world, perfect Leviathans do not exist.²²⁹ Administrative agencies cannot reliably monitor the universe of potential violations and/or respond infallibly to punish defectors. In fact, they cannot come even close to doing so. It has been reported that over 40 percent of all state clean-water inspections are labeled "reconnaissance, flyovers, or drive-bys in which inspectors never even enter the facility."²³⁰ A recent study of seventeen states finds that eleven reported inadequate funding for enforcing the Clean Water Act,²³¹ whereas another study of thirteen states found "inconsistent" enforcement of hazardous waste laws.²³² Environmental enforcement agencies were reporting that they had only 60 percent and, in some cases as little as 20 percent, of the budgetary and manpower capability they felt were necessary to do their jobs.²³³ In the study on Clean Water Act enforcement,²³⁴ state regulators reported that they did not even have complete data on 96 percent of storm water dischargers and that approximately 25 percent of major facilities were known to be in significant noncompliance with the Act.²³⁵

One can envision a predictable organizational response to data such as these. Regulators, fearing widespread evasion of legal rules, hunker down into "deterrence mode," determined to make an example of any violators they do detect.²³⁶ Inspectors become

experiment).

229. See, e.g., Clifford Rechtschaffen, *Enforcing the Clean Water Act in the Twenty-First Century: Harnessing the Power of the Public Spotlight 1* (Center for Progressive Reg., White Paper No. 404, 2004), available at http://www.progressiveregulation.org/articles/Enforcement_WP_Oct_2004.pdf (reporting survey results showing that state enforcement of the Clean Water Act is "woefully inadequate").

230. *States Slack Off on Environmental Enforcement*, OMB WATCH, Feb. 20, 2002, at <http://www.ombwatch.org/article/articleprint/413/-1/235/> (on file with the *Duke Law Journal*) (internal quotations omitted).

231. Rechtschaffen, *supra* note 229, at 1.

232. See Clifford Rechtschaffen, *Competing Visions: EPA and the States Battle for the Future of Environmental Enforcement*, 30 *Env'tl. L. Rep. (Env'tl. L. Inst.)* 10,803, 10,809 n.60 (2000) (reporting on an EPA study of state enforcement under the Federal Resource Conservation and Recovery Act).

233. See Rechtschaffen, *supra* note 229, at 1, 17 (discussing state capabilities for Clean Water Act enforcement).

234. *Id.* at 1.

235. *Id.* at 1, 3.

236. See IAN AYRES & JOHN BRAITHWAITE, *RESPONSIVE REGULATION: TRANSCENDING THE DEREGULATION DEBATE* 61 (1992) (modeling conditions under which agencies respond to evasion by firms with a "rule-oriented" deterrence posture).

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inflexible and rule bound; prosecutors will push for maximum penalties even in cases that might otherwise warrant leniency.²³⁷ In 1992, using the example of a hypothetical environmental agency seeking to reduce pollution from a firm's factories, Professors Ian Ayres and John Braithwaite reported on the work of Professor John Scholz, who had employed the 2×2 prisoner's dilemma format to model the behavioral and organizational implications:²³⁸

Agency's Enforcement Options		
Firm's Options	Cooperative (goal-oriented)	Deterrence (rule-oriented)
Comply	Voluntary Compliance Compliance cost: \$2 million, 100 tons of pollution removed	Harassment Compliance cost: \$4 million, 125 tons of pollution removed
Evade	Opportunism Compliance cost: \$1 million, 50 tons of pollution removed	Legalistic Battles Compliance cost: \$3 million, 75 tons of pollution removed

An agency that positions itself in rule-bound "deterrence mode" is unlikely to elicit cooperative behavior from firms because firms feel that the agency will take advantage of such behavior by forcing firms to go by the book and pay \$4 million in compliance costs.²³⁹ Faced with an agency in such an enforcement posture, it is cheaper for a firm to skirt the law (evade) and spend only \$3 million after engaging in legal battles.²⁴⁰ The result of these battles is that the agency will "win" some measure of compliance, but only to the extent of 75 tons of pollution removed. In contrast, if the agency could only recognize which firms truly were willing cooperators (even despite the occasional mistake), it could reciprocate (Tit-For-Tat) by itself showing flexibility and cooperative behavior. The result, which

237. *Id.* at 60–61 (describing agency behavior as involving "legalistic battles").

238. *See id.* (reproducing the Scholz enforcement dilemma).

239. *Id.* at 61 (describing a situation in which "the firm may cooperate by developing and implementing innovative pollution-saving production techniques only to have the agency insist later that the legally required scrubber be installed as well" (quoting John T. Scholz, *Deterrence, Cooperation, and the Ecology of Regulatory Enforcement*, 18 LAW & SOC'Y REV. 179, 187 (1984))).

240. *Id.* at 62.

Professor Scholz calls “voluntary” compliance,²⁴¹ is actually better described, in Professor Axelrod’s terms, as “reciprocal” compliance. In this win-win scenario, the agency is rewarded with improved regulatory compliance (100 tons of pollution is removed), and the firm is rewarded with the flexibility to achieve this result at a cost of only \$2 million.²⁴²

There is, however, a rub. Professors Ayres and Braithwaite conclude that the very discretion that enables administrative agencies to consider reciprocal action simultaneously opens up opportunities for agencies to be “captured” by evasion-minded firms.²⁴³ Should that happen, then the two players of Scholz’s enforcement game would end up in the bottom-left quadrant, in which the firm successfully evades what would have been its legal obligations (and thus receives the cheater’s bonus of paying only \$1 million in compliance costs) and the agency nonetheless cooperates by foregoing enforcement, leaving the public with the sucker’s payoff of a suboptimally low level of environmental quality (only 50 tons of pollution removed).²⁴⁴

What is needed, therefore, is a mechanism to keep the regulators honest. Professors Ayres and Braithwaite suggest empowering another actor, citizen groups, in a system of “tripartism” in which such groups could punish regulators who deviated unjustifiably from a deterrence posture in the face of an evading firm.²⁴⁵ Law professor Cliff Rechtschaffen, who is skeptical of the collaborationists’ project, suggests both citizen suits and a “strict enforcement” regime in which agencies would be required to exact meaningful penalties from firms that failed to meet their promises.²⁴⁶ Professor Karkkainen proposes the use of regulatory penalty defaults that would take effect should parties not successfully bargain their way to a truly collaborative outcome.²⁴⁷

241. *See id.* at 60–61 (labeling the cooperate-cooperate outcome as “voluntary compliance”).

242. *Id.*

243. *See id.* at 56 (“This then is the policy nut we seek to crack. How do we secure the advantages of the evolution of cooperation while averting the evolution of capture and corruption?”).

244. *Id.* at 63–64.

245. *Id.* at 71–98.

246. *See* Rechtschaffen, *supra* note 203, at 1267 (“In return for this freedom [to participate in a program such as EPA’s “Project XL”], regulated entities should be held closely accountable for their promises.”).

247. Karkkainen, *supra* note 9, at 965–69.

It is beyond the scope of this Article to evaluate the relative merits of these, or other, mechanisms that would be necessary for cooperation to emerge from collaborative regimes. Nonetheless, it bears emphasizing that, in a two-tiered regulatory system—whereby agencies systematically recognized and rewarded cooperative firms and punished defectors—one would expect firms and agencies to learn, over time, that flexibility and cooperation are always better than deterrence and defection. In his more recent works,²⁴⁸ Professor Axelrod uses a genetic algorithm to show how, under the right conditions, a “metanorm” of cooperation can spread among rational actors²⁴⁹ when they are embedded in a truly reciprocal environment in which punishment, as well as rewards, are predictable.²⁵⁰ That said, the fact that cooperation can emerge under these conditions hardly means that a unilateral shift by regulatory agencies toward “cooperative-only” postures should be expected to bring about improved regulatory compliance by firms. It is, after all, a *reciprocal* environment, and not simply a lenient environment, from which cooperation emerges in complex adaptive systems. Thus, it should come as little surprise that the empirical evidence on regulatory experiments that emphasize only leniency is mixed at best.²⁵¹

In the end, it is fair to conclude that insights from evolutionary game theory suggest, but do not establish, that regulatory strategies

248. See AXELROD & COHEN, *supra* note 14; AXELROD, *supra* note 11.

249. AXELROD & COHEN, *supra* note 14, at 10–11; AXELROD, *supra* note 11, at 55.

250. AXELROD, *supra* note 11, at 23 (finding, by using a genetic algorithm’s ability to select successful behaviors over time, that “[a]s the reciprocators do well, they spread in the population, resulting in more and more cooperation and greater and greater effectiveness”); see also Randal C. Picker, *Simple Games in a Complex World: A Generative Approach to the Adoption of Norms*, 64 U. CHI. L. REV. 1225, 1226 (1997) (noting possible circumstances under which one norm will drive out a second).

251. Compare Raymond J. Burby, *Coercive Versus Cooperative Pollution Control: Comparative Study of State Programs to Reduce Erosion and Sedimentation Pollution in Urban Areas*, 19 ENVTL. MGMT. 359, 368 (1995) (finding that cooperative-only strategies by regulatory agencies were less effective than traditional deterrence strategies), and Cherly E. Wasserman, *Federal Enforcement: Theory and Practice*, in INNOVATION IN ENVIRONMENTAL POLICY 21, 30 (T.H. Pietsenberg ed., 1992) (finding that the EPA and the states were unsuccessful in bringing municipalities into compliance with the Clean Water Act using solely a compliance promotion approach), with Douglas C. Michael, *Cooperative Implementation of Federal Regulations*, 13 YALE J. ON REG. 535, 559–60 (1996) (finding benefits from the Voluntary Protection Program of the Federal Occupational Health and Safety Administration) and John T. Scholz, *Cooperative Regulatory Enforcement and the Politics of Administrative Effectiveness*, 85 AM. POL. SCI. REV. 115, 120, 128 (1991) (finding that increased cooperation by regulatory agencies can be measured by lower injury rates among workers). See generally Rechtschaffen, *supra* note 229, at 15–20 nn.96–150 (collecting empirical studies and anecdotal evidence).

can be developed to reap the benefits of cooperation between agencies and regulated firms. At this point, the emphasis should be not on the possibility that cooperation might emerge, but on the real-world conditions that are necessary for the emergence of sustained cooperation.

CONCLUSION

Professor John Holland, one of the leading contemporary contributors to complexity theory, observes that “[w]e are everywhere confronted with emergence in complex adaptive systems—ant colonies, networks of neurons, the immune system, the Internet, and the global economy, to name a few, and that [t]here . . . are deep questions about the human condition that depend on understanding the emergent properties of such systems.”²⁵² Given the breadth of applications to which complexity theory has been applied, it is not difficult to conclude that law generally, and regulatory environments in particular, might share the tendencies of complex adaptive systems. The purpose of this Article is to argue not that complexity theory best explains the law, but rather that existing law and the claims made by legal reformers, can be evaluated more fully by attention to both the metaphors and mechanisms that complexity theory offers.

252. HOLLAND, *supra* note 15, at 2.