ROBUST YET FRAGILE

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NOTE TO WORKSHOP PARTICIPANTS: thank you for giving me the opportunity to present this work in progress. As you will see, it is has progressed no further than setting up the basic thesis and structure—much work remains to fill in examples from legal systems and to develop the final section on cost-benefit analysis and precautionary principles. Your comments, therefore, will be very helpful.

ABSTRACT

The American legal system has proven remarkably enduring over the course of centuries even in the face vast and often tumultuous political, social, economic, and technological change. Yet our system of law is not unlike other complex social, biological, and physical systems in exhibiting fragility in the midst of its robustness. This Article is the first effort in legal scholarship to apply a complex systems model for understanding why this "robust yet fragile" (RYF) dilemma persists in law and what to do about it.

Part I outlines five dimensions of robustness in complex social systems, each of which is shown to resonate in legal scholarship on the design and performance of policy institutions and instruments: (1) reliability; (2) efficiency; (3) scalability; (4) modularity, and (5) evolvability. Part II delves into design constraints that impede system legal robustness and outlines the work-around strategies for reducing their effects.

With those basic ingredients of the RYF model in place, Part III explores the role of complexity and organization as engines of legal system fragility. The drive to shore up robustness of law and legal institutions adds inexorably to system complexity, which in turn drives us to build highly-organized legal architecture to comprehend and operate the system. This state of organized complexity, while supporting robustness, also exposes the system to fragility. There is no way around this tradeoff, but the balance between the two is something we can hope to influence, particularly with the aim of avoiding large-scale disruption.

Part IV applies the RYF model to a concrete legal design context. I argue that cost-benefit analysis contributes to the legal system's organized complexity, and thus to its robustness, but also exposes the system to large-

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scale disruptions. Precautionary principles change the protocol for when system sensors go on alert and call for swifter proactive, preventative, and response measures even when cost-benefit analysis would not. Precautionary principles thus can help manage fragility in complex legal systems relying heavily on cost-benefit analysis.

OUTLINE

INTRODUCTION

How would you design a legal system to be *robust*? Perhaps a good starting point would be something like the American legal system, which has proven remarkably enduring over the course of centuries even in the face vast and often tumultuous political, social, economic, and technological change. Yet our history is riddled with crises exposing a pernicious fragility in law revealing itself at inopportune and unanticipated junctures. I need only mention the Great Recession and the Deepwater Horizon oil spill as recent examples.[1] Notwithstanding what is believed to be a strong and stable legal infrastructure for abating and responding to significant policy problems such as these, they just keep happening and law not only fails to come to the rescue, often it is deemed to be part of the problem and in need of reform.[2] Why is that? How can it be that our legal system is robust and fragile at the same time?

This question has received no formal theoretical treatment in legal scholarship. To be sure, many legal scholars have described our and other legal systems as robust,[3] or fragile,[4] but not both. Not surprisingly, as the

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[1] [BP report and CPR assessment; financial system reports]

[2] [Calls for reform in connection with BP and financial system]

[3] *See, e.g.*, Cai Congyan, *China-U.S. BIT Negotiations and the Future of Investment Treaty Regimes: A Grand Bilateral Bargain with Multilateral Implications*, 12 J. INT'L ECON. L. 457, ___ (2009) ("generally speaking, Chinese investment can be fairly treated and protected in the United States where the legal system is robust"); Carl N. Edwards, *In Search of Legal Scholarship: Strategies for the Integration of Science Into the Practice of Law*, 8 S. CAL. INTERDISC. L.J. 1, 33 (1998) (claiming that "the American legal system is astonishingly responsive yet robust," but not explaining the difference); James D. Fry, *International Human Rights Law in Investment Arbitration: Evidence of International Law's Unity*, 18 DUKE J. COMP. & INT'L L. 77, __ (2007) ("the international legal system seems to have been sufficiently robust and flexible to have weathered both hot and cold wars of the past few centuries"); John Fabian Witt, *Contingency, Immanence, and Inevitability in the Law of Accidents*, 1 J. TORT. L. 1, __ (2007) ("it is the common law system (in its American variation, at any rate) that has the most robust system of tort law").

[4] See, e.g., Michael J. Bazyler, *Nuremberg in America: Litigating the Holocost in United States Courts*, 34 U. RICH. L. REV. 1, __ (2000) (referring to "the new and fragile legal systems of the post-Communist nations of Eastern Europe"); Henry J. Bourguignon, *The Federal Key to the Judiciary Act of 1789*, 46 S.C. L. REV. 647, 700 (1995) ("An effective Supreme Court, however, was needed to hold a fragile Union's legal system together…."); Sherri Burr, *The U.S. Supreme Court and the Alvarez-Machin Cases: Recasting International Law*, 13 U.S. MEX. L.J. 105, __ (2005) (referring to "the fragile international legal system that formulates customary law"); Tom Parker, *Prosecuting Saddam: The Coalition Provisional Authority and the Evolution of the Iraqi Special Tribunal*, 38 CORNELL INT'L L.J. 899, ___ (2005) (describing "Iraq's still-fragile legal system") William P. Quigley, *Thirteen Ways of Looking at Katrina: Human and Civil Rights Left Behind Again*, 81 TUL. L. REV. 955, ___ (2007) ("the New Orleans criminal legal system, which was fragile before, essentially collapsed after Katrina").

terms imply, the clear preference is for the robust.[5] Seldom, however, is any content provided to elaborate what it means for a legal system to be robust or fragile, much less how a legal system can be both robust *and* fragile. It helps little to interchange robust with synonyms such as "strong," or "healthy," or "stout" and to define "fragile" as the opposite. What do those terms mean when applied to legal systems, and how does a legal system attain their status? More to the point, is there a way to manage the balance between robustness and fragility?

This Article takes the position that law is not unlike other complex social, biological, and physical systems in exhibiting fragility in the midst of its robustness. Indeed, responding to a widely recognized need to better understand and manage complex social systems, the social sciences have begun to incorporate the emerging theories of system complexity and networks, law being no exception.[6] Central to complexity and network theories is the problem of fragility that results from the tradeoffs inherent in design decisions aimed at enhancing system robustness.[7] In their recent technical article on complex network-centric systems such as the Internet, systems engineers David Alderson and John C. Doyle develop a sophisticated model for probing this "robust yet fragile" (RYF) tradeoff, showing that it is an inherent quality of any complex, highly-networked system and explaining how it poses difficult institutional and instrument design issues.[8] The question is what to do about it.

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[5] *See, e.g.*, Elisabeth Rindskopf Parker, *National Security Advice for a New Administration: Initial Thoughts*, 3 J. NAT'L SECURITY L. & POL'Y 227, ___ (2009) ("a central plank [for national security policy] must be a robust international legal system"); Benjamin J. Richardson, *Is East Asia Industrializing Too Quickly? Environmental Regulation in its Special Economic Zones*, 22 UCLA PAC. BASIN. L.J. 150, ___ (2004) ("Singapore was virtually alone in emerging relatively unscathed from the East Asian financial turmoil because it had a reliable, robust legal system"); Zhao Xiuwen & Lisa A. Kloppenberg, *Reforming Chinese Arbitration Law and Practices in the Global Economy*, 31 DAYTON L. REV. 421, 422 (2006) (pointing to "development of a more robust legal system" as a positive trend in Chinese legal and economic conditions); Yesha Yadev, *The Specter of Sisyphs: Re-Making International Financial Regulation after the Global Financial Crisis*, 24 EMORY INT'L L. REV. 83, __ (2010) ("a sharper focus on the creation of a robust regulatory architecture at the international level may better support the work of regulators").

[6] For an overview of complex systems and network theories and how the social sciences, including law, have integrated them, see J.B. Ruhl, *Law's Complexity—A Primer*, 24 GA. ST. L. REV. 885 (2008). Further details on complexity in the legal system are provided *infra* Part III.

[7] *See* JOHN H. MILLER & SCOTT E. PAGE, COMPLEX ADAPTIVE SYSTEMS: AN INTRODUCTION TO COMPUTATIONAL MODELS OF SOCIAL LIFE 9-10, 27-31, 139-40 (2007).

[8] *See* David L. Alderson & John C. Doyle, *Contrasting Views of Complexity and Their Implications For Network-Centric Infrastructures*, 40 IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS 839 (2010).

This Article employs the RYF tradeoff model to help answer that question for law.[9] Part I outlines the five dimensions of robustness in complex networked systems, each of which is shown to resonate in legal scholarship on the design and performance of policy institutions and instruments: (1) reliability; (2) efficiency; (3) scalability; (4) modularity, and (5) evolvability. Part II then delves into design constraints that impede system robustness and outlines work-around strategies for reducing their effects. Constraints exist at component, system, and protocol levels of a system, and those three forces combine to produce emergent system-wide constraints as well. Regulating these effects is difficult. The predominant work-around strategies rely primarily on using ultraquality system components, redundancy in system operations, and sensors to detect undesirable system behavior with feedback mechanisms to alert system operation actuators to anticipated consequences.

Part III uses the RYF tradeoff model developed in Parts I and II to show how the drive to shore up robustness of law and legal institutions through work-around strategies adds inexorably to system complexity by proliferating system structure and rules.[10] This resulting state of increasingly organized complexity, while supporting robustness, also exposes the system to fragility. The spiral toward increasing organization is relentless, and while the resulting highly articulated system infrastructure is, indeed, robust for many proposes, its feedback prone, specialized, interdependent architecture leaves the system open to disruption by perturbations that can in some cases render the system massively ineffective. Hence the RYF tradeoff. And there is no way around it—we will always be managing complex social systems like law for robustness and against fragility. Yet the balance between the two is something we can hope to influence, particularly with the aim of avoiding large-scale disruptions.

With the RYF model and its implications for legal systems in mind, Part IV gets back to the original question—how would we design a robust legal system? I suggest that, like the complex systems and network researchers of today, we should focus on how to calibrate the balance between robustness and fragility as one of the overarching themes. As an example of where that would lead, the discussion places the goal of reducing large-scale disruption in the context of the ongoing debate in environmental law between adherents of cost-benefit analysis and those who advocate use of

[9] Although a number of legal scholars have begun to incorporate complex systems and network theories into legal theory, *see* Ruhl, *supra* note 6, at 909-10, the RYF tradeoff problem has not received the level of attention or formal theoretical development as this Article offers.

[10] *See* Alderson & Doyle, *supra* note 8, at __.

precautionary principles in its stead.[11] I argue that as a protocol for decision making cost-benefit analysis contributes to the legal system's organized complexity, and thus to its robustness, but also exposes the system to large-scale disruptions. As a form of sensor, precautionary principles change the protocol for when system sensors go on alert and call for swifter proactive, preventative, and response measures even when cost-benefit analysis would not. Precautionary principles thus can help manage fragility in complex legal systems using cost-benefit analysis as a core decision-making instrument. Hence, rather than being in fundamental opposition, cost-benefit analysis and precautionary principles can work together to calibrate the legal system's RYF tradeoff.

The ideal of a robust legal system is ubiquitous in legal scholarship, but little attention has been given to a global theory of robustness for law. Most failures in law are treated as the result of defects or glitches in the system that can be "fixed" through surgical legal reform. Perhaps some such failures can be patched up, but not so, I contend, for the system as a whole. Rather, our work to build robustness into the legal system is itself what exposes the system to fragility events. There will always be glitches; the point is to avoid those with catastrophic consequences. Legal reform, therefore, must also take place at the system level to attend to the inherent background presence of fragility and to manage it as best as we can to reduce and prepare for the big failures. Using the RYF tradeoff model, this Article is a step toward better understanding of how the tradeoff works in the legal system and how to design the legal architecture necessary to manage it.

I. ROBUSTNESS IN LAW

Despite numerous references in legal scholarship to "robust" legal systems, the term is never defined and, more to the point, seldom is any attention given to what makes a legal system robust. In the technical language of complexity science, a system or property of a system is robust if it is invariant with respect to a set of perturbations.[12] Using this framework, a legal system could be described as robust if it remains relatively intact endogenously notwithstanding disruptions from exogenous forces and endogenous failures. This is the meaning I will use herein,

[11] For background on this debate, see DOUGLAS A. KYSAR, REGULATING FROM NOWHERE: ENVIRONMENTAL LAW AND THE SEARCH FOR OBJECTIVITY (2010); Frank Ackerman & Lisa Heinzerling, *Pricing the Priceless: Cost-Benefit Analysis of Environmental Protection*, 150 U. PA. L. REV. 1553 (2002). Further details on cost-benefit analysis and precautionary principles are provided *infra* Part IV.

[12] Anderson & Doyle, *supra* note 8, at 840.

recognizing that it carries no particular normative dimensions—what most Americans might consider a contemptible legal system could nonetheless be a robust one. The point is that it is reasonable to assume that most Americans want our legal system to be normatively satisfactory *and* robust, as it wouldn't be much of a legal system if it were normatively desirable yet subject to collapse at any moment. To be sure, it may be the case that the measures necessary to make and maintain robustness in a legal system have consequences some of which may be normatively unsatisfactory. It may also be the case that our normative desires for the legal system limit our capacity to make it robust. But these concerns are putting the cart before the horse for my purposes at this stage. In this part of the Article, my aim is to explore what robustness of law means independent of normative goals for the legal system.

In their deep examination of robustness in complex systems, Anderson and Doyle explain that several features of a system contribute to robustness:

> *Reliability* involves robustness to component failures. *Efficiency* is robustness to resource scarcity. *Scalability* is robustness to changes to the size and complexity of the system as a whole. *Modularity* is robustness to structured component rearrangements. *Evolvability* is robustness of lineages to changes on long time scales.[13]

While legal scholars do not use this precise terminology and typology, each of these concepts finds a rich tradition of analysis and debate in legal scholarship. Legal scholars, it should be no surprise, are quite focused on the robustness of law in all its dimensions.

A. Reliability

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B. Efficiency

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C. Scalability

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[13] *Id.* (emphases in original).

D. Modularity

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E. Evolvability

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II. DESIGN CONSTRAINTS AND WORKAROUND STRATEGIES

Envision a team of legal experts designing a legal system from the ground up with the aim of maximizing system robustness around the five attributes of the model outlined in Part I. It doesn't take much thought to anticipate that they would soon run into design tradeoffs if they work to maximize all dimensions of system robustness at once. A system that is highly efficient in using scarce resources, for example, might as a consequence be less reliable because of lack of redundancy in important system functions.[14] As a legal system example, consider what might happen to the system reliability the Constitution has provided as a source of structural stability were we to focus singly on increasing its evolvability by lowering Article V barriers to amendments. Without suggesting what the tradeoffs would be, it seems obvious there would be some.[15] Understanding these constraints and their tradeoffs will lie at the heart of the design challenge for robustness of law.[16] Of course, a truly great legal mind might devise strategies for working around this kind of conflict, but inevitably more constraints will arise as work continues on the system design. Designing a robust legal system thus is largely an exercise in identifying constraints on functionality and behavior that arise independent of the system design process and then building workaround strategies into the system architecture.[17]

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[14] *See* Anderson & Doyle, *supra* note 8, at 840 (using the example of efficiency and reliability as possible system tradeoffs). Tradeoffs such as this are known more generally in complex systems science as conflicting constraints. *See* Ruhl, *supra* note 6, at 902.

[15] [Discuss state constitutions as different model (from ND)]

[16] References to "design" in complex systems models "in no way implies a designer but merely a process, such as Darwinian evolution." Anderson & Doyle, *supra* note 8, at 840. Of course, humans are the conscious designers of social systems.

[17] *See* Anderson & Doyle, *supra* note 8, at 840 (stressing that these constraints arise "largely independent of the process by which this organization arises, whether by design or evolution")

A. Constraints on Legal Robustness

Alderson and Doyle identify four kinds of constraints on system robustness: (1) component-level; (2) system-level; (3) protocols, and (4) emergent constraints. As with their dimensions of robustness, their constraints typology also maps remarkably well onto the legal system and legal scholars' concerns about the inherent limits of its performance.

1. Component-Level Constraints

The first and most obvious constraint on robustness is that "the components that comprise any system are typically constrained in terms of what they can do, even separately."[18]

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2. System-Level Constraints

Just as there are constraints inherent in each component in a system, "there are complex constraints on the system as a whole that are not consequences of those on the components."[19] These include functional requirements defining what the system needs to accomplish and environmental and operating requirements defining the conditions under which the system is working to achieve its functions.[20]

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3. Protocols

Protocols are "rules for the configuration and/or interaction of system components" and as such may, but will not necessarily, impose additional constraints on the overall system.[21] Some rules will limit the number of possible system solutions, but others may facilitate ways the system searches for robust solutions.

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[18] Anderson & Doyle, *supra* note 8, at 840.

[19] Anderson & Doyle, *supra* note 8, at 841.

[20] *See* Anderson & Doyle, *supra* note 8, at 841.

[21] Anderson & Doyle, *supra* note 8, at 841.

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4. Emergent Constraints

Component-level, system-level, and protocol-based constraints can interact to produce emergent constraints that would not exist or be identified absent those interactions.[22] Indeed, "emergent fragilities, whether unintended or the result of hard tradeoffs, are dominant problems in complex systems."[23]

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B. Strategies for Enhancing Legal Robustness

The set of constraints described in the previous section do not aggregate to produce some sort of composite meta-constraint with uniform effect throughout the system. Rather, their effects are such that "a system can have a property that is robust to one set of perturbations and yet fragile for a different property and/or perturbation," and hence "understanding RYF tradeoffs lies at the heart of the design challenges for network-centric infrastructure."[24] …

1. Ultraquality Components

One obvious strategy for managing component-level constraints on system robustness is to improve the quality of the system components so they rarely fail. Design for such ultraquality components would strive to improve repeat performance over time with acceptable costs of component production and operation.[25]

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[22] *See* Anderson & Doyle, *supra* note 8, at 841.

[23] Anderson & Doyle, *supra* note 8, at 841.

[24] Anderson & Doyle, *supra* note 8, at 840.

[25] *See* Anderson & Doyle, *supra* note 8, at 841.

2. Redundancy

Achieving ultraquality widely throughout the components of a system has its own set of constraints, such as cost, and may simply not be possible to achieve at levels that significantly enhance system robustness if other forms of system constraints are substantial in effect. Provision for backups and other forms of redundancy in components and system subparts thus is a well-studied and common strategy in systems application.[26]

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3. Sensors

Ultraquality and redundancy techniques "can be effective at providing robustness in the face of component uncertainty, but they do not help to achieve robustness to the external environment, and the latter drives most of system complexity."[27] Another broad strategy for managing constraints, therefore, is to design protocols that direct system components and subsystems how to respond to changes in endogenous and exogenous conditions. The first type of protocol necessary for implementing such a strategy consists of rules for sensing changed conditions of potential concern. These "system sensors can monitor system performance; detect individual component wear, damage, or failure; and/or identify external threats and perturbations to the system."[28] Indeed, if not all components can achieve ultraquality reliability, priority might be given to achieving ultraquality of sensor components given their role in monitoring threats to the system.

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4. Feedback to Actuators

The point of building sensor protocols into a system is to provide relevant information about system failure potentials to system actuators—the components and subsystems that would use information to initiate system responses. As Alderson and Doyle summarize the function of these feedback protocols:

[26] See Anderson & Doyle, *supra* note 8, at 841.

[27] Anderson & Doyle, *supra* note 8, at 841.

[28] Anderson & Doyle, *supra* note 8, at 841.

> While the ability to maintain an appropriate level of situational awareness of both components and environment is critical for complex systems of all types, such visibility is of limited value if the system cannot act upon that information, and taking appropriate action typically drives complexity far more than does sensing. Using feedback interconnection of sensors and actuators, it is possible to combine components with very different properties to create systems with robustness that far exceeds that of the components separately….Feedback control can blend powerful but sloppy actuators with ultraquality sensors to create systems that approach the power of the actuators and the ultraquality of the sensors.[29]

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III. COMPLEX LEGAL ORGANIZATION AS THE ENGINE OF FRAGILITY

Though they seldom use the synthesis outlined above or all its terminology, I have shown that legal scholars have anticipated all of the elements of system robustness, constraints, and workaround strategies that Alderson and Dyole include in their comprehensive RYF model. It is reasonable to assume, therefore, that our gathering of great legal minds would quickly assemble all of these concepts into a similar model for the legal system and set out to implement it. Indeed, great minds have done so in many fields, producing technological systems such as the Internet. And biological systems, with no conscious designer but with tremendous inherent drive toward robustness, also have had to deal with these essential design challenges. What kinds of systems have come out of these other robustness design efforts? Alderson and Doyle summarize the prototype:

> 1) they are highly modular (versus integrated); 2) they use diverse components that are imperfect (versus perfect); 3) they have late (versus early) binding of functionality. This allows for 4) a diversity of evolvable (versus frozen) capabilities and behavior; and 5) these systems have fast (versus slow) pace of change, and adaptive (versus preplanned) behavior via distributed (versus centralized) control, with extensive use of feedback.

[29] Anderson & Doyle, *supra* note 8, at 842.

These seem like the kind of properties most lawyers would seek to achieve for a legal system, as well. At least we find few calls for a legal system that is frozen, slow, preplanned, centralized, and lacking feedback. But systems that are evolvable, fast, adaptive, distributed, and use feedback come with a cost in the form of complexity and what follows from it.

Law is complicated—in the United States one must study law three years just to have the privilege of taking the bar exam—but is it complex? Complicatedness and complexity are not the same. The "very basic question we must consider is how complex, versus complicated, are social worlds."[30] The distinction goes to the essence of complexity science:

> In a complicated world, the various elements that make up the system maintain a degree of independence from one another. Thus, removing one such element (which reduces the level of complication) does not fundamentally alter the system's behavior apart from that which directly resulted from the piece that was removed. Complexity arises when the dependencies among the elements become important. In such a system, removing one such element destroys system behavior to an extent that goes well beyond what is embodied by the particular element that is removed.[31]

No experienced lawyer could fail to appreciate the difference between complicated and complex, as so defined, in law. Law is hard to learn; there are a lot of procedural and substantive rules to follow; many agencies and courts are involved; and wading through statutes, rules, and cases to find answers is, well, complicated. But there is more to it than just a bunch of independent actors, institutions, and rules that happen to be working on the same page. There are interactions and dependencies between the parts that tie them together. That's why we call it the legal *system*.[32] If we were to pluck out, say, the United States Supreme Court, it seems unlikely that we would describe the effect as there being just one less court to deal with.

Complexity science studies these inter-agent dependencies and the system-wide effects they produce. While there is no universally agreed

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[30] MILLER & PAGE, *supra* note 7, at 27.

[31] *Id*. at 9. Thus "work is needed on distinguishing the complex … from the just complicated in the presence of many possible explanatory models and imperfect data." Nicholas W. Watkins and Marvyn P. Freeman, *Natural Complexity*, 320 SCIENCE 323, 333 (2008).

[32] *See* J.B. Ruhl & James Salzman, *Mozart and the Red Queen: The Problem of Regulatory Accretion in the Administrative State*, 91 GEO. L.J. 757, 796-806 (2003) (exploring the difference between complicated and complex sets of legal rules).

upon metric for measuring complexity in such a system,[33] the theoretical model has come to rest on a collection of agent and system properties that are at the core of complexity. These include multiple equilibria, dynamics, adaptation, and decentralized interactions.[34] Anderson and Doyle contend that the key complexity properties for purposes of the RYF tradeoff are "large and/or diverse number of components, the complexity of their interconnections and interactions, and the complexity of the behaviors that result."[35]

But how do systems, particularly social worlds like law, become complex, and why would they also become fragile? Anderson and Doyle argue broadly that "complexity in highly organized systems arises primarily from design strategies intended to create robustness."[36] As more and more of these design strategies are incorporated into the system architecture, they contend, the system "components are arranged in a very specialized structure that enables their functionality and/or robustness features."[37] The organization of the system "is essentially the specialized structure that allows a system to satisfy the aforementioned constraints."[38] The problem for such a highly organized system, however, "is that even minimal random rearrangement of that structure tends to destroy its most salient features."[39] In other words, it is the complex structural organization necessary for robustness that also breeds fragility. Alderson and Doyle devote their work to supporting these related claims in their general model; in this section I do so in the focused context of the legal system.

A. How Complexity Breeds Organization

One way of thinking of the legal system is as an enormous collection of robustness constraint workaround strategies. Law's relations with other social systems, and law's internal set of rules, are designed to deliver higher quality components, redundancy, sensors, and feedback. As a system among the multitude of social systems, law's aim is to regulate constraints and failures the other social systems face: people killing people (criminal law);

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[33] *See* MILLER & PAGE, *supra* note 7, at 233-36; Anderson & Doyle, *supra* note 8, at 840.

[34] *See* MILLER & PAGE, *supra* note 7, at 19-20. For a review of these and other complex systems properties in the context of legal systems, *see* Ruhl, *supra* note 6, at 892-901.

[35] Anderson & Doyle, *supra* note 8, at 840.

[36] *Id.*

[37] *Id.*

[38] *Id.* at 841.

[39] *Id.* at 840.

people dumping waste in rivers (environmental law); people not living up to agreements (contract law); people arguing over what constitutes income (tax law); and so on. And the legal system has layers of workaround strategies for its own internal constraints: appellate judges review lower court decisions; rules of civil procedure direct lawyers how to act; agencies must deliver performance reviews to legislatures; and so on. Every feature in our modern legal system, at bottom, is part of a workaround strategy for managing constraints on the robustness of other social systems and of the legal system itself.

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B. How Organization Breeds Fragility

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VI. LEGAL ARCHITECTURE FOR MANAGING THE ROBUST YET FRAGILE DILEMMA

Given that the legal system organization necessary for robustness is also what gives rise to the system's fragility, the two properties put law in an inherent dilemma: any effort to reduce fragility by reducing organization would also reduce robustness, but increasing organization to increase robustness also increases fragility. The drive for robustness thus fuels an ever more intense RYF effect. As Alderson and Doyle explain:

> The emergence of complexity can often be seen as a spiral of new challenges and opportunities that organisms and/or technologies exploit, but which also lead to new fragilities, often from novel perturbations. When successful, fragilities are met with increasing complexity and robustness, which, in turn, creates not only new opportunities but also new fragilities, and so on. Managing or, ideally, preventing this "RYF complexity spiral" remains a central challenge in engineering, medicine, and human society.[40]

Law is not immune to the RYF spiral, and hence, as with other important social systems, "we need to better manage the tradeoff between functional robustness and emergent fragility."[41] While no management strategy will overcome the intrinsic RYF tradeoffs, Anderson and Doyle

[40] Anderson & Doyle, *supra* note 8, at 842.

[41] Anderson & Doyle, *supra* note 8, at 851.

believe "we should be able to minimize the potential risk of catastrophic failure."[42] They recognize, however, that "there is little consensus on even the most basic strategies to avoid this in real-world networks,"[43] and I offer law as a prime example, with legal scholarship mired in many debates over what to do to best improve performance. In what follows I argue that at least one legal system strategy as it has been deployed—cost-benefit analysis—is not working effectively toward implementing this balance and that we should incorporate the strategy of precautionary principles as a check on its fragility effects.

A. The Fragility of Cost-Benefit Analysis

Cost-benefit analysis clearly is a means of balancing constraints within the legal system to enhance robustness. Done properly, it allows decision makers to consider multiple scales within the system to evaluate how the proposed action will affect each scale. For example, beyond simply asking what the costs of constructing an offshore oil well are and comparing that to the revenue stream of the product, cost-benefit analysis can probe effects on the environment, commercial fishing, employment, tourism, and so on. It seems obvious from a complex systems modeling perspective that we would want to ask such questions, as doing so contributes to the "flexibility in exploiting tradeoffs at component levels to provide effective tradeoffs at the system level."[44]

But many system failures "are due to fragilities that were direct side effects of mechanisms that promised to provide great benefits, including robustness."[45] Alderson and Doyle explain how highly formalized control mechanisms like cost-benefit analysis can present such side effects:

> Most of the complexity in highly engineered or evolved systems is in control processes that regulate the internal state and respond to external changes…These automated control systems are the primary source of RYF in complex systems, since the same systems that provide robustness under normal operating conditions can yield extreme fragilities if they fail or are hijacked.[46]

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[42] *Id.*
[43] *Id.*
[44] Anderson & Doyle, *supra* note 8, at 842.
[45] Anderson & Doyle, *supra* note 8, at 839.
[46] Anderson & Doyle, *supra* note 8, at 842.

B. Managing for Fragility through Precautionary Principles

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CONCLUSION

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