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## **Contracts as Systems**

Spencer Williams

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## CONTRACTS AS SYSTEMS

SPENCER WILLIAMS\*

### ABSTRACT

*A contract is much more complex than its individual terms would suggest. Yet contract scholars have traditionally taken a reductionist approach to the study of contracts. According to "contractual reductionism," a contract can be understood through each of its constituent terms. Recent scholarship, however, has begun to challenge contractual reductionism's term-by-term view of contracts. Building on this work, this Article provides the first application of complex systems theory to contracts, arguing that a contract is a complex system that is greater than the sum of its terms. A complex system is composed of many components that interact in a nontrivial manner. Complex systems theory is an interdisciplinary field of study that has been used to analyze a broad range of complex systems including living organisms, cities, economies, technology systems, and ecosystems. One of the key findings of complex systems theory is that complex systems exhibit a surprising degree of similarity and common behavior across diverse contexts – a finding that holds when extended to contracts. To provide a framework for understanding and analyzing a contract as a complex system, the Article models a contract using concepts drawn from complex systems theory. The Article then uses this model to demonstrate that contract systems exhibit many key properties observed in other complex systems. The Article ends by discussing how a complex systems approach to contracts informs contract design, interpretation, and analysis. The Article makes three primary contributions. First, the Article extends the scholarship challenging contractual reductionism through the first application of complex systems theory to contracts. Second, the Article models a contract as a complex system and identifies key properties of contract systems. Third, the Article shows how complex systems theory can be used to improve the design, interpretation, and analysis of contracts. The Article's*

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*findings have significant implications for lawyers, judges, and legal technology companies.*

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## I. INTRODUCTION

A contract is much more complex than its individual terms would suggest.<sup>1</sup> Yet contract scholars have traditionally taken a term-by-term,

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<sup>1</sup>See *infra* Section III.C.1. (discussing the meaning of "complex" in the context of complex systems).

reductionist approach to the study of contracts.<sup>2</sup> According to "contractual reductionism," a contract can be understood through each of its constituent terms.<sup>3</sup> This reductionist view of contracts has influenced many of the key theoretical discussions in contract scholarship, including contract design, interpretation, and the role of the transactional lawyer.<sup>4</sup> Beyond contract theory, empirical studies of contracts have largely focused on individual terms and their effects rather than viewing these terms as parts of a greater contractual whole.<sup>5</sup> Furthermore, many legal technology companies developing contract analysis products, such as natural language processing and machine learning-assisted prediction, have built their products based on reductionist models of contracts.<sup>6</sup>

Contractual reductionism overlooks the complexity and significance of macro-level effects in contracts.<sup>7</sup> Recent scholarship, however, has begun to challenge contractual reductionism.<sup>8</sup> This line of scholarship started with a focus on the importance of modularity in contract design.<sup>9</sup> Scholars then evaluated interaction effects in the context of vague terms,<sup>10</sup> the use of multiple contracts to effectuate a single deal,<sup>11</sup> and the multidimensional nature of contracts designed to respond to a variety of transaction costs.<sup>12</sup> Most recently, Cathy Hwang and Matthew Jennejohn analyzed the role of contract structure in contract design and interpretation, proposing a theory of "contractual structuralism."<sup>13</sup> While

<sup>2</sup>See Cathy Hwang & Matthew Jennejohn, *Deal Structure*, 113 NW. U. L. REV. 279, 281-83, 293 (2018); see *infra* Section II.A. (discussing traditional contractual reductionism).

<sup>3</sup>See *infra* Section II.A.

<sup>4</sup>See *infra* Section II.A.

<sup>5</sup>See *infra* Section II.A.

<sup>6</sup>See *infra* Section IV.C.

<sup>7</sup>See Hwang & Jennejohn, *supra* note 2, at 282-84.

<sup>8</sup>See *infra* Section II.B.

<sup>9</sup>See Henry E. Smith, *Modularity in Contracts: Boilerplate and Information Flow*, 104 MICH. L. REV. 1175, 1179-80, 1187-99 (2006); see Margaret Jane Radin, *Boilerplate Today: The Rise of Modularity and the Waning of Consent*, 104 MICH. L. REV. 1223, 1223-26 (2006); see also George G. Triantis, *Improving Contract Quality: Modularity, Technology, and Innovation in Contract Design*, 18 STAN. J.L. BUS. & FIN. 177, 191-92 (2013).

<sup>10</sup>See Albert Choi & George Triantis, *Strategic Vagueness in Contract Design: The Case of Corporate Acquisitions*, 119 YALE L.J. 848, 852-55, 859-60, 921-24 (2010) (arguing that vague terms combined with liquidated damages clauses and dispute resolution provisions can reduce moral hazard and adverse selection).

<sup>11</sup>See Cathy Hwang, *Unbundled Bargains: Multi-Agreement Dealmaking in Complex Mergers and Acquisitions*, 164 U. PA. L. REV. 1403, 1408-09 (2016) (discussing how complex deals, particularly M&A transactions, are effectuated using multiple interconnected contracts).

<sup>12</sup>See Matthew Jennejohn, *The Private Order of Innovation Networks*, 68 STAN. L. REV. 281, 313-28, 363-64 (2016) (proposing a framework of "multivalent contracting," in which a variety of contract terms are used in an integrated fashion to respond to a variety of transaction costs).

<sup>13</sup>See Hwang & Jennejohn, *supra* note 2, at 281, 284-85.

these works have implicated the systemic nature of contracts, none have fully addressed contracts as systems.

Building on this scholarship, this Article provides the first application of complex systems theory to contracts, arguing that a contract is a complex system that is greater than the sum of its terms.<sup>14</sup> A complex system is composed of many components that interact in a nontrivial manner.<sup>15</sup> In the case of a contract, the contract is the system and the terms are the components.<sup>16</sup> Complex systems theory is an interdisciplinary field of study that has been used to analyze a broad range of complex systems, including living organisms, cities, economies, technology systems, and ecosystems.<sup>17</sup> In the context of complex systems theory, "complex" refers to the degree of interaction between the components of a system.<sup>18</sup> The primary goal of complex systems theory is to understand the behavior of complex systems for analytical and predictive purposes.<sup>19</sup> One of the key findings of complex systems theory has been that complex systems exhibit a surprising degree of similarity and common behavior across diverse contexts—a finding that remains consistent when extended to contracts.<sup>20</sup> While complex systems theory has existed for decades, it has experienced a recent resurgence due to advances in computing and data collection.<sup>21</sup> Despite being applied to a variety of fields such as physics, biology, economics, and computer science, complex systems theory remains relatively underexplored in legal scholarship, particularly in contract and business law.<sup>22</sup>

To provide a framework for understanding and analyzing a contract as a complex system, this Article models a contract using concepts drawn from complex systems theory.<sup>23</sup> In this model, a contract system is represented as a coevolving multilayer network.<sup>24</sup> The system exists within an environment that contains external conditions such as contract law and norms.<sup>25</sup> The terms of the contract and the interactions between the terms evolve over time in tandem.<sup>26</sup> The Article then uses this model to

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<sup>14</sup>See *infra* Section III.A. (providing an overview of complex systems theory).

<sup>15</sup>See *infra* Section III.A.

<sup>16</sup>See *infra* Section III.B.

<sup>17</sup>See *infra* Section III.A.

<sup>18</sup>See *infra* Section III.A.

<sup>19</sup>See *infra* Section III.A.

<sup>20</sup>See *infra* Section III.A.

<sup>21</sup>See *infra* Section III.A.

<sup>22</sup>See *infra* Section III.A.

<sup>23</sup>See *infra* Section III.B.

<sup>24</sup>See *infra* Section III.B.

<sup>25</sup>See *infra* Section III.B.

<sup>26</sup>See *infra* Section III.B.

demonstrate that contract systems exhibit many key properties observed in other complex systems, including organized complexity, hierarchy, emergence, adaptation, sensitivity to initial conditions, nonlinearity, and punctuated equilibria.<sup>27</sup> The Article ends by discussing how a complex systems approach to contracts informs contract design, interpretation, and analysis.<sup>28</sup>

This Article makes three primary contributions. First, the Article extends the scholarship challenging contractual reductionism through the first application of complex systems theory to contracts.<sup>29</sup> Second, the Article models a contract as a complex system and identifies key properties of contract systems.<sup>30</sup> Third, the Article shows how complex systems theory can be used to improve the design, interpretation, and analysis of contracts.<sup>31</sup> The Article's findings have significant implications for lawyers, judges, and legal technology companies.

The remainder of this Article proceeds as follows. Section II discusses the traditional reductionist approach to contracts and the recent scholarship challenging contractual reductionism.<sup>32</sup> Section III provides a brief overview of complex systems theory, uses complex systems theory to model a contract as a complex system, and identifies key properties of contract systems.<sup>33</sup> Section IV discusses the implications of a complex systems approach to contracts for contract design, interpretation, and analysis.<sup>34</sup> The Article concludes with a discussion of opportunities for further research.<sup>35</sup>

## II. CONTRACTUAL REDUCTIONISM

This section examines contractual reductionism and the recent scholarship challenging this longstanding approach to the study of contracts. Section II.A discusses the traditional reductionist approach to contracts.<sup>36</sup> Section II.B highlights the recent work moving away from contractual reductionism.<sup>37</sup>

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<sup>27</sup>See *infra* Section III.C.

<sup>28</sup>See *infra* Section IV.

<sup>29</sup>See *infra* Section II.

<sup>30</sup>See *infra* Section III.

<sup>31</sup>See *Infra* Section IV.

<sup>32</sup>See *infra* Section II.

<sup>33</sup>See *infra* Section III.

<sup>34</sup>See *infra* Section IV.

<sup>35</sup>See *infra* Conclusion.

<sup>36</sup>See *infra* Section II.A.

<sup>37</sup>See *infra* Section II.B.

### A. *The Traditional Reductionist Approach to Contracts*

Contract scholars have traditionally taken a term-by-term, reductionist approach to the study of contracts.<sup>38</sup> Reductionism has its roots in the natural sciences, particularly physics,<sup>39</sup> and has since become commonplace in the social sciences as well.<sup>40</sup> The core idea of reductionism is that one can understand the whole by understanding the parts.<sup>41</sup> Similarly, according to "contractual reductionism," one can understand a contract by understanding each of its constituent terms.<sup>42</sup> Contractual reductionism largely stems from the law and economics "efficient contracting" view of contracts that originated from the Coase Theorem.<sup>43</sup> According to efficient contracting, a contract is a collection of terms that the parties have efficiently selected from the universe of possible terms to maximize the joint value generated by the contract.<sup>44</sup> If circumstances change such that the collection of terms in the contract is no longer optimal, the parties merely add, delete, or modify the individual terms to move the contract back to optimality.<sup>45</sup> This approach is inherently reductionist as it places the focus of analysis on the terms of the contract rather than the contract as a whole.

Contractual reductionism has influenced many of the key theoretical discussions in contracts scholarship, including contract design, interpretation, and the role of the transactional lawyer.<sup>46</sup> With respect to

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<sup>38</sup>See Hwang & Jennejohn, *supra* note 2, at 281-83, 293.

<sup>39</sup>See NEIL JOHNSON, *SIMPLY COMPLEXITY: A CLEAR GUIDE TO COMPLEXITY THEORY* 17 (2007); see generally JOHN H. MILLER & SCOTT E. PAGE, *COMPLEX ADAPTIVE SYSTEMS* 10 (2007).

<sup>40</sup>See MILLER & PAGE, *supra* note 39, at 27.

<sup>41</sup>MILLER & PAGE, *supra* note 39 ("[B]y reducing complicated systems to their constituent parts, and fully understanding each part, we will then be able to understand the world.").

<sup>42</sup>Steven Shavell, *On the Writing and the Interpretation of Contracts*, 22 J.L. ECON. & ORG. 1, 3 (2006).

<sup>43</sup>See Smith, *supra* note 9, at 1187 (discussing how Coase divided "property into its smallest constituent parts" and then drawing the comparison to dividing contracts into their constituent terms); see R.H. Coase, *The Problem of Social Cost*, 3 J.L. & ECON. 1, 15-16 (1960).

<sup>44</sup>See Alan Schwartz & Robert E. Scott, *Contract Theory and the Limits of Contract Law*, 113 YALE L.J. 541, 544, 552 (2003); see Robert E. Scott & George G. Triantis, *Incomplete Contracts and the Theory of Contract Design*, 56 CASE W. RES. L. REV. 187, 188 (2005).

<sup>45</sup>See generally FRANK H. EASTERBROOK & DANIEL R. FISCHEL, *THE ECONOMIC STRUCTURE OF CORPORATE LAW* 1-39 (HARVARD UNIV. PRESS 1991); see Marcel Kahan & Michael Klausner, *Path Dependence in Corporate Contracting: Increasing Returns, Herd Behavior and Cognitive Biases*, 74 WASH. U. L.Q. 347, 347, 366 (1996); see also Spencer Williams, *Predictive Contracting*, 2019 COLUM. BUS. L. REV. 621, 626 n.18 (2019) (discussing theoretical and empirical critiques of efficient contracting).

<sup>46</sup>See Albert Choi & George Triantis, *The Effect of Bargaining Power on Contract Design*, 98 VA. L. REV. 1665, 1667 (2012); see also Ronald J. Gilson, *Value Creation by Business Lawyers: Legal Skills and Asset Pricing*, 94 YALE L.J. 239, 255 (1984).



contract design, scholars have typically viewed the "design" of the contract simply as the collection of terms that make up the contract.<sup>47</sup> Theories of how lawyers should design contracts are often based on economic models that assume contracts are decomposable into their constituent terms.<sup>48</sup> Contractual incompleteness, a well-discussed topic in contract design, is subject to contractual reductionism as well.<sup>49</sup> Scholars have argued that parties make term-by-term decisions regarding the level of specificity for a term in order to balance the front-end cost of writing a more specific term with the back-end cost of increased litigation resulting from a less specific term.<sup>50</sup> Furthermore, the scholarly discussion on standardization has long taken the view that contractual "boilerplate" is merely a collection of homogenized, easily reusable terms whose primary function is to reduce transaction costs.<sup>51</sup> A similar view has been advanced with respect to default terms supplied by contract law.<sup>52</sup> The timing of term selection has also been framed in a reductionist manner, with key terms being negotiated upfront through term sheets and memorandums of understanding and less important terms being left for later.<sup>53</sup> A core assumption running through much of the contract design scholarship is that terms should be viewed simply as distinct provisions rather than interconnected parts of a broader contractual whole.

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<sup>47</sup>See, e.g., Choi & Triantis, *supra* note 46, at 1667 (describing contract design as the nonprice terms in the contract).

<sup>48</sup>See, e.g., Shavell, *supra* note 42, at 2-9.

<sup>49</sup>See *id.* at 2.

<sup>50</sup>See Scott & Triantis, *supra* note 44, at 190-91, 196-97 (distinguishing between front-end costs and back-end costs and discussing how parties balance these costs when designing a contract); see Robert E. Scott & George G. Triantis, *Anticipating Litigation in Contract Design*, 115 YALE L.J. 814, 814, 817, 836-38 (2006) (arguing that more specific terms increase front-end costs but decrease back-end costs whereas less specific terms do the opposite).

<sup>51</sup>See Claire A. Hill, *Why Contracts Are Written in "Legalese"*, 77 CHI.-KENT L. REV. 59, 59-63 (2001) (describing the use of "forms" in transactional law); see Michelle E. Boardman, *Contra Proferentem: The Allure of Ambiguous Boilerplate*, 104 MICH. L. REV. 1105, 1107 (2006) (arguing that boilerplate terms carry less litigation uncertainty and therefore reduce transaction costs); see also MITU GULATI & ROBERT SCOTT, *THE 3 1/2 MINUTE TRANSACTION* 2-3 (2012) (discussing the widespread use of a boilerplate "pari passu" term in sovereign bond contracts).

<sup>52</sup>See Charles J. Goetz & Robert E. Scott, *The Limits of Expanded Choice: An Analysis of the Interactions Between Express and Implied Contract Terms*, 73 CALIF. L. REV. 261, 262 (1985) (noting that default contract terms reduce transaction costs by providing parties with standardized and generally applicable "preformulations"). *But see* Ian Ayres & Robert Gertner, *Filling Gaps in Incomplete Contracts: An Economic Theory of Default Rules*, 99 YALE L.J. 87, 90-91 (1989) (arguing that default rules should be unfavorable to incentivize the parties to design their own transaction-specific terms).

<sup>53</sup>See Albert H. Choi & George Triantis, *Designing and Enforcing Preliminary Agreements*, 98 Tex. L. Rev. 440, 440-44 (2020).

As with contract design, scholarship on contract interpretation has typically come from a reductionist standpoint. Economic models of contract interpretation tend to be term-focused.<sup>54</sup> The long-standing debate between textualist interpretation and contextualist interpretation has generally assumed a term-by-term approach to interpretation.<sup>55</sup> Calls to embrace both textualism and contextualism have even been based in reductionism.<sup>56</sup> Discussions of the parol evidence rule, a core interpretive principle in contract law governing whether outside terms may be added to a written contract, are similarly reductionist.<sup>57</sup> Proposals for alternative theories of interpretation, such as interpreting contracts in a manner akin to statutory analysis<sup>58</sup> or through surveys<sup>59</sup> have also viewed contracts as collections of terms.

In addition to contract design and interpretation, research into the role of the transactional lawyer has been based on contractual reductionism.<sup>60</sup> In his pivotal article in 1984, Ronald Gilson characterized transactional lawyers as "transaction cost engineers."<sup>61</sup> According to Gilson, transactional lawyers add value to a transaction by reducing transaction costs through specific terms such as representations, warranties, and indemnification provisions.<sup>62</sup> Gilson's view of a contract is a combination of terms that can each be tweaked to reduce transaction

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<sup>54</sup>See, e.g., Richard A. Posner, *The Law and Economics of Contract Interpretation*, 83 TEX. L. REV. 1581, 1582 (2005) ("Contract interpretation is the undertaking by a judge or jury . . . to figure out what the terms of a contract are, or should be understood to be."); see also Shavell, *supra* note 42, at 12-18.

<sup>55</sup>See Eric A. Posner, *The Parol Evidence Rule, the Plain Meaning Rule, and the Principles of Contract Interpretation*, 146 U. PA. L. REV. 533, 533 (1998) [hereinafter Posner, *Parol Evidence*]; see Eric A. Posner, *A Theory of Contract Law Under Conditions of Radical Judicial Error*, 94 NW. U. L. REV. 749, 751 (2000) [hereinafter Posner, *Judicial Error*]; Schwartz & Scott, *supra* note 44, at 544, 598; see also Alan Schwartz & Robert E. Scott, *Contract Interpretation Redux*, 119 YALE L.J. 926, 931-32 (2010). Reductionism is present even in the interpretation of goods contracts under the Uniform Commercial Code (U.C.C.), which explicitly adopts a contextualist approach to interpretation. See Hwang & Jennejohn, *supra* note 2, at 313-14. Although the U.C.C. requires judges to consider contextual evidence such as usage of trade when interpreting a goods contract, the contract itself is still primarily seen as a collection of individual terms.

<sup>56</sup>See Ronald J. Gilson, Charles F. Sabel & Robert E. Scott, *Text and Context: Contract Interpretation as Contract Design*, 100 CORNELL L. REV. 23, 23-29 (2014).

<sup>57</sup>See Posner, *Parol Evidence*, *supra* note 55, at 533-40.

<sup>58</sup>See Stephen J. Choi & G. Mitu Gulati, *Contract as Statute*, 104 MICH. L. REV. 1129, 1131-32, 1160-61 (2006) (proposing an approach to interpreting boilerplate terms akin to legislative history where courts look to the intent of the original drafters of a term).

<sup>59</sup>See Omri Ben-Shahar & Lior Jacob Strahilevitz, *Interpreting Contracts via Surveys and Experiments*, 92 N.Y.U. L. REV. 1753, 1761-66, 1776-78 (2017) (proposing that courts could use surveys to determine the meaning of contract terms).

<sup>60</sup>See Gilson, *supra* note 46, at 255.

<sup>61</sup>See Gilson, *supra* note 46, at 255.

<sup>62</sup>See generally Gilson, *supra* note 46, at 256-93.

costs.<sup>63</sup> Subsequent scholarship has echoed Gilson's reductionist view.<sup>64</sup> This is especially true of recent research on the value of large law firms, which finds that large firms add greater value relative to small firms by compiling data on specific key terms to improve their client's negotiating leverage.<sup>65</sup>

Beyond contract theory, empirical studies of contracts have largely focused on individual terms and their effects rather than viewing these terms as integrated parts of a greater contractual whole. Contractual reductionism has influenced a wide range of empirical contracts scholarship, including studies on: clauses for liquidated damages in rental agreements,<sup>66</sup> transfer provisions in mortgages,<sup>67</sup> material adverse change clauses in M&A deals,<sup>68</sup> and a variety of terms in venture capital financings.<sup>69</sup> Empirical studies such as these have tended to view contracts as collections of terms that include the term(s) of empirical interest.<sup>70</sup> Recent empirical scholarship has started to adopt novel analytical techniques, such as natural language processing, but has continued to take a reductionist approach to contracts.<sup>71</sup>

<sup>63</sup>See Gilson, *supra* note 46, at 254.

<sup>64</sup>See, e.g., Lisa Bernstein, *The Silicon Valley Lawyer as Transaction Cost Engineer?*, 74 OR. L. REV. 239, 251–52 (1995) (applying Gilson's framework to transactional lawyers working with startups and venture capital firms in Silicon Valley); see Marcel Kahan & Michael Klausner, *Standardization and Innovation in Corporate Contracting*, 83 VA. L. REV. 713, 736 (1997) (noting the traditional view that transactional lawyers add value by helping the parties identify the set of terms that maximize their joint value).

<sup>65</sup>See Elisabeth de Fontenay, *Law Firm Selection and the Value of Transactional Lawyering*, 41 J. CORP. L. 393, 396–97, 405–06 (2015).

<sup>66</sup>See Tess Wilkinson-Ryan, *Do Liquidated Damages Encourage Breach? A Psychological Experiment*, 108 MICH. L. REV. 633, 633–38 (2010) (finding that parties are more likely to exploit efficient breach opportunities if the contract contains a clause for liquidated damages).

<sup>67</sup>See Tess Wilkinson-Ryan, *Breaching the Mortgage Contract: The Behavioral Economics of Strategic Default*, 64 VAND. L. REV. 1547, 1573–74 (2011) (finding that transfer provisions in mortgage contracts can increase the likelihood of homeowners engaging in strategic default).

<sup>68</sup>See Robert T. Miller, *The Economics of Deal Risk: Allocating Risk Through MAC Clauses in Business Combination Agreements*, 50 WM. & MARY L. REV. 2007, 2007–09 (2009) (finding that material adverse change clauses typically allocate four types of risk: systematic risk, indicator risk, agreement risk, and business risk).

<sup>69</sup>See Spencer Williams, *Venture Capital Contract Design: An Empirical Analysis of the Connection Between Bargaining Power and Venture Financing Contract Terms*, 23 FORDHAM J. CORP. & FIN. L. 105, 149–54 (2017) (finding that the total supply of venture capital financing is statistically connected to numerous terms in venture capital contracts).

<sup>70</sup>See *id.* at 158–59.

<sup>71</sup>See, e.g., Robert Anderson & Jeffrey Manns, *The Inefficient Evolution of Merger Agreements*, 85 GEO. WASH. L. REV. 57, 64, 70–72, 80–83 (2017) (constructing "family trees" of precedent documents to visualize how M&A terms change over time); see also Bernhard Ganglmair & Malcom Wardlaw, *Complexity, Standardization, and the Design of Loan*

While alluringly simple, contractual reductionism fails to properly capture the complexity of contracts.<sup>72</sup> This traditional term-by-term approach overlooks the significance of macro-level effects and is insufficient to understand a contract as a whole.<sup>73</sup> Recent scholarship, however, has begun to challenge contractual reductionism.<sup>74</sup> This scholarship is the subject of the next section.

### B. Challenging Reductionism

A growing literature has begun to push back against contractual reductionism. This new scholarship challenges the term-by-term, reductionist approach traditionally taken by contract scholars. Thus far, this scholarship has focused on contractual modularity, multidimensionality, and structure.

The scholarship challenging contractual reductionism largely started with Henry Smith's examination of the use of modularity in contract design.<sup>75</sup> Smith identified that interaction effects between terms increase the complexity of the overall contract<sup>76</sup> and that contractual modularity can be used as a mechanism to respond to this complexity.<sup>77</sup> According to Smith, by using modular terms with limited interactions with other terms, a contract designer can limit the flow of information between different segments of the contract, thereby reducing the contract's complexity.<sup>78</sup> Smith then analyzed the role of standardized boilerplate terms, finding that the primary function of contractual boilerplate is to

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*Agreements* 5 (Apr. 13, 2017) (unpublished manuscript), [https://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=2952567](https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2952567) (applying topic model text analysis to covenants in debt contracts); see also Elliott Ash, W. Betley MacLeod & Suresh Naidu, *Optimal Contract Design in the Wild: Rigidity and Control in Collective Bargaining 2* (Jan. 29, 2018) (unpublished manuscript), <https://events.barcelonagse.eu/live/files/2366-elliottash61103pdf> (applying topic model text analysis to labor union contracts that the authors describe as "bundles of obligations and entitlements"). See *infra* Section III.C. (discussing legal technology and natural language processing).

<sup>72</sup>See Hwang & Jennejohn, *supra* note 2, at 282-84, 296.

<sup>73</sup>See Hwang & Jennejohn, *supra* note 2, at 282-84, 296.

<sup>74</sup>See *infra* Section II.B.

<sup>75</sup>See Smith, *supra* note 9, at 1176, 1179-80, 1187-99; see also Radin, *supra* note 9, at 1224 (conducting early work on contractual modularity, and continuing to take a reductionist approach to contracts, describing legal modularity as "the practice of creating a legal document by selecting and cobbling together terms from a source compendium or from different sources").

<sup>76</sup>See Smith, *supra* note 9, at 1189-90 (discussing how cross-references, dependent covenants, and definitions create interaction effects between terms).

<sup>77</sup>See Smith, *supra* note 9, at 1189-90

<sup>78</sup>See Smith, *supra* note 9, at 1189-90; see also Triantis, *supra* note 9, at 204-206 (proposing the use of technology to enhance the benefits of modularity by enabling multiple contract designers to collaborate on terms via a centralized platform).

increase the overall modularity of a contract.<sup>79</sup> In developing his theory of modularity and boilerplate, Smith recognized a critical aspect of contract design: a contract is more than just a collection of terms.<sup>80</sup> In addition to the effects of individual terms, the interaction effects between those terms have significant implications for how the contract should be designed and how it will function.

Albert Choi and George Triantis explored interaction effects in the context of vague terms.<sup>81</sup> As part of the debate about the relative merits of precise terms versus vague terms, Choi and Triantis argued that vague terms can reduce moral hazard by creating a disincentive for ex post litigation and can respond to adverse selection by incentivizing information provision at the time of contracting and/or renegotiation.<sup>82</sup> In order for vague terms to serve this function, however, the ratio of litigation costs to damages needs to fall within a particular range.<sup>83</sup> Parties can control this ratio ex ante using liquidated damages clauses to specify damages and dispute resolution provisions to limit litigation costs.<sup>84</sup> As a result, the cost-reducing function of vague terms is enabled in part by the interaction between vague terms, liquidated damages clauses, and dispute resolution provisions.<sup>85</sup>

Cathy Hwang extended the concept of modularity to transactions such as Merger and Acquisition ("M&A") deals that are effectuated by using multiple interconnected contracts.<sup>86</sup> As Hwang describes, M&A transactions are typically structured with a central acquisition agreement that is connected to numerous ancillary agreements such as confidentiality agreements, employment agreements, and intellectual property assignments.<sup>87</sup> Similar to Smith's discussion of interaction effects between terms within a contract, Hwang discusses interaction effects between contracts within a multi-contract transaction which she refers to as an "unbundled bargain."<sup>88</sup> Hwang argues that one of the key benefits of

<sup>79</sup>See Smith, *supra* note 9, at 1196-99 (arguing that boilerplate terms contribute to contractual modularity via decomposition, substitution, augmentation, exclusion, inversion, and porting).

<sup>80</sup>See Smith, *supra* note 9, at 1196-99.

<sup>81</sup>See Choi & Triantis, *supra* note 10, at 848, 852-55, 859-60, 921-24.

<sup>82</sup>See *id.* at 852-55, 859-60.

<sup>83</sup>See *id.* at 921 ("Nevertheless, to achieve this screening, verification cost can be neither too large nor too small compared to the size of the litigation stake. If the litigation cost is too large, no seller will have a credible claim against the buyer; whereas if the litigation cost is too low, all sellers will bring a lawsuit against the buyer.").

<sup>84</sup>See *id.* at 921-24.

<sup>85</sup>See Choi & Triantis, *supra* note 10, at 921-24.

<sup>86</sup>See Hwang, *supra* note 11, at 1403-27.

<sup>87</sup>See *id.* at 1410-17.

<sup>88</sup>*Id.*

simplifying a complex deal into multiple contracts is to take advantage of modularity.<sup>89</sup> For example, deal modularity enables specialists such as employment or intellectual property lawyers to focus on a particular part of the transaction in need of their expertise while having a limited effect on the overall structure of the deal.<sup>90</sup> Through her analysis of unbundled bargains, Hwang further advances a view of contracts in which interaction effects and structure matter.<sup>91</sup>

Similar to Hwang's investigation of deal modularity, Matthew Jennejohn examined the multidimensionality of contracts through a theoretical and empirical analysis of interfirm innovation alliance contracts.<sup>92</sup> Jennejohn proposes a theory of "multivalent" contracting in which contract designers use a variety of contractual mechanisms to respond to a variety of transaction costs.<sup>93</sup> According to Jennejohn, contract terms function in an integrated fashion to address the multidimensional set of challenges faced by the parties.<sup>94</sup> While certain terms are primarily intended to respond to specific transaction costs, others work in tandem and influence one another.<sup>95</sup> As a result, changes to one term to improve its functioning may impact the ability of another term to do its job.<sup>96</sup> Contrary to traditional contractual reductionism, Jennejohn's integrated approach to contract design views contracts as greater than the sum of their terms.<sup>97</sup>

Most recently, Hwang and Jennejohn collaborated on a research project examining the importance of contract structure.<sup>98</sup> The authors argue that the increasingly complex and interconnected nature of contracts necessitates a macro-level analysis of contract structure.<sup>99</sup> They propose a theory of "contractual structuralism," which they define as the "idea that how a contract is put together matters in every part of that contract's life

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<sup>89</sup>*Id.* at 1417-27.

<sup>90</sup>*See* Hwang, *supra* note 11, at 1418-23.

<sup>91</sup>*See id.* at 1418-23.

<sup>92</sup>*See* Jennejohn, *supra* note 12, at 284-94.

<sup>93</sup>*Id.* at 323.

<sup>94</sup>*Id.* ("Parties not only have to navigate more than one type of transaction[.]").

<sup>95</sup>*Id.* at 323-26.

<sup>96</sup>*See* Jennejohn, *supra* note 12, at 326 ("[G]overnance mechanisms are interdependent. A contract provision that addresses holdup problems may also affect, either positively or negatively, the mitigation of spillover and/or entropy concerns.").

<sup>97</sup>*Id.* at 292.

<sup>98</sup>*See* Hwang & Jennejohn, *supra* note 2, at 281.

<sup>99</sup>*See* Hwang & Jennejohn, *supra* note 2, at 296 ("[A]s the core parts of the deal are increasingly memorialized in multiple related contract provisions, or even in multiple related documents, moving beyond a provision-by-provision study, and into a macro-level study of contract structure, is increasingly important.").

cycle: design, performance, and enforcement."<sup>100</sup> The authors identify three primary categories of contract structure (modular, integrated, and hybrid) and provide examples of each.<sup>101</sup> The primary claim of their work is that it is critical for lawyers designing contracts and judges interpreting contracts to understand whether a contract is modular, integrated, or hybrid *before* engaging in term-level analysis.<sup>102</sup> This claim emphasizes the importance of the contractual whole and stands in stark contrast with contractual reductionism.<sup>103</sup>

A recurring theme throughout these works is that contracts are more complex than their individual terms would suggest. Fortunately, there is a field of study dedicated to understanding systems composed of numerous interacting components: complex systems theory.<sup>104</sup> While these works have implicated the systemic nature of contracts,<sup>105</sup> none have fully addressed contracts as systems. To fill this gap, this Article provides the first application of complex systems theory to contracts. This is the subject of the next section.

### III. CONTRACTS AS SYSTEMS

This section applies complex systems theory to contracts to argue that a contract is a complex system that is greater than the sum of its terms. Section III.A provides a brief overview of complex systems theory. Section III.B uses complex systems theory to model a contract as a complex system. Section III.C uses this model to discuss key properties of complex systems that are exhibited by contract systems.

#### *A. Complex Systems Theory*

Complex systems theory is an interdisciplinary field of study that examines the behaviors and properties of complex systems.<sup>106</sup> Complex

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<sup>100</sup>See Hwang & Jennejohn, *supra* note 2, at 284.

<sup>101</sup>See Hwang & Jennejohn, *supra* note 2, at 299-321. Examples of contracts with modular structure include OTC derivatives, supply chain contracts, and securities offerings. Examples of contracts with integrated structure include relational contracts and interfirm innovation alliance contracts. M&A deals are the primary example of contracts with hybrid structure.

<sup>102</sup>See Hwang & Jennejohn, *supra* note 2, at 320-21.

<sup>103</sup>See Hwang & Jennejohn, *supra* note 2, at 320-21.

<sup>104</sup>See *infra* Section III.A.

<sup>105</sup>See Smith, *supra* note 9, at 1180, 1184-85; see Jennejohn, *supra* note 12, at 321-22, 364; see also Hwang & Jennejohn, *supra* note 2, at 299-301.

<sup>106</sup>See JOHNSON, *supra* note 39, at 17 (noting that complex systems theory "looks at the complicated and surprising things which can emerge from the interaction of a collection of objects which themselves may be rather simple"); see generally MELANIE MITCHELL,

systems theory originated at the intersection of physics, biology, and computer science,<sup>107</sup> and has since made its way to the social sciences.<sup>108</sup> The genesis of complex systems theory was an effort to explain systems that could not be properly explained by traditional scientific reductionism,<sup>109</sup> much in the way that this Article seeks to expand the understanding of contracts beyond contractual reductionism. The primary goal of complex systems theory is to understand "how parts of a system and their relationships give rise to the collective behaviors of the system, and how the system interrelates with its environment."<sup>110</sup> The central theme running throughout this field is that a system is greater than the sum of its parts.<sup>111</sup> This theme is exemplified by the title of Nobel Laureate Phil Anderson's famous article: *More is Different* – systems with a large number of interacting components are not merely larger, they are fundamentally different.<sup>112</sup>

One of the biggest unresolved questions in complex systems theory may also seem like one of the most basic questions for a field dedicated to studying complex systems: "What is a complex system?"<sup>113</sup> Some scholars of complex systems have focused their definitions on the connections between the components of the system.<sup>114</sup> Others have focused on the collective behavior of the components that emerges at the system level.<sup>115</sup>

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COMPLEXITY: A GUIDED TOUR 4 (2011); *see generally* STEFAN THURNER, RUDOLF HANEL & PETER KLIMEK, INTRODUCTION TO THE THEORY OF COMPLEX SYSTEMS v. (2018); *see generally* David C. Krakauer, *Complexity: Worlds Hidden in Plain Sight*, in *WORLDS HIDDEN IN PLAIN SIGHT* 229 (David C. Krakauer ed., 2019) ("Complexity science is an effort to discern and theorize common patterns in complex systems from multiple scientific perspectives."). Complex systems theory is commonly referred to by other names such as systems theory, complexity theory, or complexity science.

<sup>107</sup>*See* MITCHELL, *supra* note 106, at 16-22 (discussing the history of complex systems theory).

<sup>108</sup>*See, e.g.*, MILLER & PAGE, *supra* note 39, at 3-8 (introducing their book on computational modeling for complex social systems).

<sup>109</sup>*See* JOHNSON, *supra* note 39, at 17; *see also* MILLER & PAGE, *supra* note 39, at 3, 10, 27.

<sup>110</sup>Y. Bar-Yam, *General Features of Complex Systems*, in *ENCYCLOPEDIA OF LIFE SUPPORT SYSTEMS* 1 (2002).

<sup>111</sup>*See* DONELLA H. MEADOWS, *THINKING IN SYSTEMS* 12 (2008); *see* GEOFFREY WEST, *SCALE: THE UNIVERSAL LAWS OF LIFE, GROWTH, AND DEATH IN ORGANISMS, CITIES, AND COMPANIES* 21-23 (2017).

<sup>112</sup>P. W. Anderson, *More is Different*, 177 *SCIENCE* 393 (1972) (arguing against the widespread acceptance of reductionism in the natural sciences).

<sup>113</sup>*See* MEADOWS, *supra* note 111, at 11.

<sup>114</sup>*See, e.g.*, MEADOWS, *supra* note 111, at 11 (defining a complex system as "an interconnected set of elements that is coherently organized in a way that achieves something").

<sup>115</sup>*See, e.g.*, STEVEN JOHNSON, *EMERGENCE: THE CONNECTED LIVES OF ANTS, BRAINS, CITIES, AND SOFTWARE* 18 (2002) (defining a complex system as a system in which "agents residing on one scale start producing behavior that lies one scale above them"); *see* MITCHELL, *supra* note 106, at 13 (defining a complex system as "a system in which large



Still, others have taken a mathematically-oriented approach to defining a complex system.<sup>116</sup> After many years and many definitions, the most generally applicable definition likely remains the one provided by Nobel Laureate Herbert Simon in 1962: a complex system is "made up of a large number of parts that interact in a nonsimple way."<sup>117</sup>

Complex systems theory is closely related to network theory.<sup>118</sup> A network is a mechanism for representing how a collection of elements relate to one another.<sup>119</sup> A common example of a network is a route map for an airline.<sup>120</sup> The cities in the airline's route network are represented as dots on the map (called "nodes") and the flights are represented as lines between the dots (called "links").<sup>121</sup> For example, a network would represent an airline's flight path from New York City to Los Angeles as a link between the New York City node and the Los Angeles node. Networks can be used to represent a wide variety of relational information, including social connections between friends (a social network), transactional connections between financial institutions (a financial network), and disease transmission connections between infected individuals (an epidemiological network). Networks are particularly useful for analyzing complex systems because they can be used to represent the interactions between the components in a system.<sup>122</sup>

While complex systems theory has existed as a distinct field of study for multiple decades, it has seen a recent resurgence due to advances in

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networks of components ... give rise to complex collective behavior"); see WEST, *supra* note 111, at 21 (defining a complex system as a system that "is composed of myriad individual constituents or agents that once aggregated take on collective characteristics that are usually not manifested in, nor could easily be predicted from, the properties of the individual components themselves"); see DANIEL B. LARREMORE & AARON CLAUSET, WHY PREDICTING THE FUTURE IS MORE THAN JUST HORSEPLAY, *WORLDS HIDDEN IN PLAIN SIGHT* 340 (David C. Krakauer ed., 2019) (defining a complex system as a system "with many interacting elements whose collective behavior defies expectations based on their component parts").

<sup>116</sup>See, e.g., THURNER ET AL., *supra* note 106, at 22 (defining a complex system as a "co-evolving multilayer network"). See *infra* Section III.B. (basing its formal model of a contract system on this definition).

<sup>117</sup>Herbert A. Simon, *The Architecture of Complexity*, 106 *PROC. AM. PHIL. SOC'Y* 467, 468 (1962).

<sup>118</sup>See JOHNSON, *supra* note 39, at 97-110; see MILLER & PAGE, *supra* note 39, at 154-65; see MITCHELL, *supra* note 106, at 227-57; see THURNER ET AL., *supra* note 106, at 140-223. See *infra* Section III.B. (featuring networks prominently in this Article's modeling of a contract as a complex system).

<sup>119</sup>THURNER ET AL., *supra* note 106, at 140 ("Networks are a tool for keeping track of who is interacting with whom, at what strength, when, and in what way.").

<sup>120</sup>See MITCHELL, *supra* note 106, at 229-30.

<sup>121</sup>See MITCHELL, *supra* note 106, at 229-30.

<sup>122</sup>See THURNER ET AL., *supra* note 106, at 140.

computational power and data collection.<sup>123</sup> Increased computing power and new analytical techniques, including statistical machine learning, are enabling scholars to quantitatively examine systems that were previously too complex for meaningful computational analysis.<sup>124</sup> Furthermore, substantially improved data collection mechanisms have provided researchers with the information needed to model real-world complex systems with a high level of granularity and accuracy.<sup>125</sup> These advances have led some systems experts to suggest the possibility of a quantitative science of complexity.<sup>126</sup> Experts have cautioned, however, that any such quantitative approach must be properly informed by a cohesive theory of complex systems.<sup>127</sup>

Over the years, complex system theory has been used to examine numerous different complex systems across a wide variety of contexts. Within the life sciences, complex systems theory has been applied to systems such as living cells,<sup>128</sup> insect colonies,<sup>129</sup> the human brain,<sup>130</sup> and the immune system.<sup>131</sup> As for the social sciences, complex systems researchers have studied systems as varied as cities,<sup>132</sup> transportation systems,<sup>133</sup> romantic relationships,<sup>134</sup> and war.<sup>135</sup> Complex systems theory has been particularly useful for studying economics and finance,<sup>136</sup> as well as technology systems.<sup>137</sup> One of the key findings of complex systems theory is that complex systems exhibit a surprising degree of similarity

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<sup>123</sup>See MILLER & PAGE, *supra* note 39, at 26-27; see WEST, *supra* note 111, at 22-23; see generally THURNER ET AL., *supra* note 106, at v., 25-26.

<sup>124</sup>See THURNER ET AL., *supra* note 106, at vi., 25-26.

<sup>125</sup>See THURNER ET AL., *supra* note 106, at vi., 25-26.

<sup>126</sup>See WEST, *supra* note 111, at 427, 440-48.

<sup>127</sup>See WEST, *supra* note 111, at 427, 440-48.

<sup>128</sup>See JOHNSON, *supra* note 115, at 82-86.

<sup>129</sup>See MITCHELL, *supra* note 106, at 4-5.

<sup>130</sup>See MITCHELL, *supra* note 106, at 4-5.

<sup>131</sup>See MITCHELL, *supra* note 106, at 6-9.

<sup>132</sup>See JOHNSON, *supra* note 115, 87-97.

<sup>133</sup>See JOHNSON, *supra* note 39, at 129-45.

<sup>134</sup>See JOHNSON, *supra* note 39, at 147-58.

<sup>135</sup>See JOHNSON, *supra* note 39, at 159-76.

<sup>136</sup>See JOHNSON, *supra*, note 39, at 113-27 (applying complex systems theory to financial markets); see W. Brian Arthur, *Complexity: A Different Way to Look at the Economy*, in *WORLDS HIDDEN IN PLAIN SIGHT* 193-99 (David C. Krakauer ed., 2019) (discussing complexity economics); see also John H. Miller, *What Happens When the Systems We Rely on Go Haywire?*, in *WORLDS HIDDEN IN PLAIN SIGHT* 311-15 (David C. Krakauer ed., 2019) (applying complex systems theory to algorithmic trading).

<sup>137</sup>See JOHNSON, *supra* note 115, at 115-26 (describing the internet as a complex system); see also Seth Blumsack, *How Complexity Science Can Help Keep the Lights On*, in *WORLDS HIDDEN IN PLAIN SIGHT* 329-337 (David C. Krakauer ed., 2019) (applying complex systems theory to electric grid management).

and common behavior across diverse contexts.<sup>138</sup> This Article examines key properties of complex systems that are exhibited by contract systems in Section III.C.

Despite being applied to a variety of fields, complex systems theory remains relatively underexplored in legal scholarship. The application of complex systems theory to the law has primarily been limited by scholars to three areas of inquiry. First, scholars have examined the role of the law as a component of a broader social system.<sup>139</sup> Second, scholars have framed the entire legal system as a complex system.<sup>140</sup> Third, scholars have analyzed the presence of systemic complexity in the law.<sup>141</sup> Complex systems theory has notably been missing from contract and business law, though recent research is starting to change this trend.<sup>142</sup> This Article uses complex systems theory to argue that a contract is as a complex system that is greater than the sum of its terms. This is the subject of the next section.

### *B. Modeling a Contract as a Complex System*

A contract is a complex system composed of terms and interactions between terms.<sup>143</sup> It exists within an environment that contains external conditions such as contract law and norms. A contract system can be

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<sup>138</sup>See JOHNSON, *supra* note 39, at 13-17; see MILLER & PAGE, *supra* note 39, at 230; see MITCHELL, *supra* note 106, at 12-13; see THURNER ET AL., *supra* note 106, at v.

<sup>139</sup>See generally 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 (1996) [hereinafter Ruhl, *Complexity Theory*]; see J.B. Ruhl, *The Fitness of Law: Using Complexity Theory to Describe the Evolution of Law and Society and Its Practical Meaning for Democracy*, 49 VAND. L. REV. 1407 (1996) [hereinafter Ruhl, *The Fitness of Law*]; see also NIKLAS LUHMANN, *LAW AS A SOCIAL SYSTEM* (FATIMA KASTNER, ET AL. EDS., KLAUS A. ZIEGERT TRANS., OXFORD UNIVERSITY PRESS 2004).

<sup>140</sup>See generally Gerald J. Postema, *Law's System: The Necessity of System in Common Law*, 2014 N.Z. L. REV. 69 (2014); see also Brian Tamanaha, *Law's Evolving Emergent Phenomena: From Rules of Social Intercourse to Rule of Law Society*, 95 WASH. U. L. REV. 1149 (2018).

<sup>141</sup>See generally Peter H. Schuck, *Legal Complexity: Some Causes, Consequences, and Cures*, 42 DUKE L. J. 1 (1992); see generally R. G. Wright, *The Illusion of Simplicity: An Explanation of Why the Law Can't Just Be Less Complex*, 27 FLA. ST. U. L. REV. 715 (2000).

<sup>142</sup>See, e.g., Tamara Belinfanti & Lynn Stout, *Contested Visions: The Value of Systems Theory for Corporate Law*, 166 U. PA. L. REV. 579, 581-86 (applying complex systems theory to corporations and corporate law); see also Hilary J. Allen, *Payments Failure*, B.C. L. REV. (forthcoming 2020) (manuscript at 10 – 21), [https://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=3539797](https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3539797) (applying complex systems theory to the regulation of systemic risk in payments systems).

<sup>143</sup>Practically all real-world contracts studied by contract scholars meet the definition of a complex system. An example of a contract that is not a complex system is a simple agreement between friends in which one friend agrees to mow the other friend's lawn for \$50.

represented as a coevolving multilayer network in which the terms and the interactions between terms evolve over time in tandem.<sup>144</sup> This section models this representation of a contract system using concepts drawn from complex systems theory to provide a framework for understanding and analyzing a contract as a complex system. This model is then used as the basis for discussing key properties of a contract system in Section III.C and the implications of a complex systems approach to contracts in Section III. The components of the model are: (1) the contract terms, (2) the interactions between terms, (3) the manner in which the terms and interactions evolve over time, and (4) the environment in which the contract system exists. These components are discussed in the sections below. A formal presentation of the model is provided in the Appendix.

### 1. Terms

The first step in modeling a contract as a complex system is to represent each of the contract's terms as components of the overall contract system. For example, the force majeure clause is a common component of modern contract systems. To enable quantitative analysis of a contract system, each term is represented in the model by a function that provides information about the term at a particular point in time. These functions are referred to throughout the remainder of this Article as "state functions" because they indicate the "state" of the term in the system at a particular point in time.

The state functions can take a variety of forms. A binary state function, for example, simply represents whether the term is present in the contract at a particular point in time, with the state function equal to one if the term is present and zero if the term is not. A continuous state function, on the other hand, can be used to represent a term that takes the form of a real number, for example the price term in a sales contract or the interest rate in a mortgage. If the interest rate of a variable rate mortgage (a type of mortgage in which the interest rate fluctuates over time) was equal to five percent in January 2020, then the continuous state function representing the interest rate term would be equal to 0.05 in January 2020. A categorical state function can be used to represent a term that takes one of a limited number of forms, for example an antidilution provision in a venture capital contract, which typically comes in one of three varieties: full ratchet, broad-based weighted-average, or narrow-based weighted-

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<sup>144</sup>This representation of a complex system and the model developed in this section draw heavily on the concepts and notation used by Thurner, Hanel & Klimek. See THURNER ET AL., *supra* note 106, at 21-26.

average.<sup>145</sup> Each of these different potential forms can be assigned a number (e.g. one, two, and three, respectively). Then, for example, if a venture capital contract uses the full ratchet version of antidilution, the categorical state function representing the term would be equal to one.<sup>146</sup> If a term can take multiple independent states at the same time, the state function can take the form of a vector<sup>147</sup> that represents each of the different states simultaneously. For example, an interest rate term could be represented as a vector that indicates the rate (continuous), whether the interest is simple or compound (binary), and the accrual period (categorical: daily, monthly, quarterly, or annually).

When applying this model to real-world contracts, one will need to decide how to decompose the contract into terms. There are a number of ways to do this. First, a contract can be broken down into terms based on easily identifiable markers such as section/subsection headings and numberings. Think of this as the "Table of Contents" approach. This approach has been used in other contexts to decompose legal text into components for network analysis.<sup>148</sup> Second, contracts can be subdivided into terms that are conceptually distinct, with each term addressing a unique concept within the contract. Natural language processing is particularly useful for breaking contracts down in this way, and there are many legal technology companies currently taking this approach.<sup>149</sup> Third, a contract can be reduced to its constituent terms based on an existing understanding of the common terms in the contract. For example, law firms that deal with particular types of contracts on a repeat basis (such as venture capital or M&A) often have internal lists of the terms that make up these contracts.<sup>150</sup> In some instances, a term may be composed of several "sub-terms." For example, antidilution provisions in venture capital financing agreements are often written as a primary section containing an antidilution formula along with subsections defining the variables used in the formula.<sup>151</sup> When modeling such a term, the user of the model will need

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<sup>145</sup>See Williams, *supra* note 69, at 131-32.

<sup>146</sup>See *id.* at 131.

<sup>147</sup>See THURNER ET AL., *supra* note 106, at 22 (describing a vector as a mathematical tool that can be used to represent multidimensional data).

<sup>148</sup>See Adam B. Badawi & Giuseppe Dari-Mattiacci, *Reference Networks and Civil Codes*, in *LAW AS DATA: COMPUTATION, TEXT, AND THE FUTURE OF LEGAL ANALYSIS* 355-56 (Michael A. Livermore & Daniel N. Rockmore eds., 2019).

<sup>149</sup>See Williams, *supra* note 69, at 652-56. See *infra* Section III.C. (providing further discussion of legal technology and natural language processing).

<sup>150</sup>See de Fontenay, *supra* note 65, at 397 (describing how large law firms compile databases of deal terms).

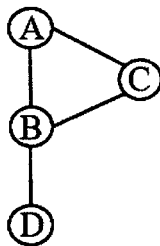
<sup>151</sup>See Nat'l Venture Capital Ass'n, §4.4.4 *Model Certificate of Incorporation* (Sept. 2020), <https://nvca.org/model-legal-documents>.

to decide whether to represent the term as a single term or as a connected set of terms.<sup>152</sup> The benefit of breaking such terms down into their constituent sub-terms is that doing so increases the granularity of the model, but this comes at the cost of making the model more complicated.

Once the terms in the contract system have been represented in the model by state functions, then next step in the model is to represent the interactions between these terms.

## 2. Interactions

The terms in a contract system frequently interact with one another. For example, the force majeure clause typically interacts with multiple other terms, including definitions and risk allocation provisions.<sup>153</sup> These interactions are represented in the model by networks, with the terms as the nodes and the interactions as the links between nodes. For example, a simple contract with four terms, A, B, C, and D, in which term A interacts with terms B and C, term B interacts with terms A, C, and D, term C interacts with terms A and B, and term D interacts with term B, can be represented by the following network:



As can be seen in the network above, the terms in the contract system are represented as nodes in the network (the circles), and the interactions between those terms are represented as links in the network (the lines between circles). For example, terms A and B are linked because they interact. On the other hand, terms C and D are not linked because they

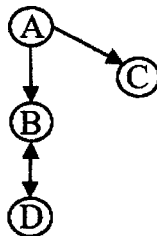
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<sup>152</sup>Thank you to Charlotte Alexander for this helpful point.

<sup>153</sup>See Robert M. Finkel, John A. Trenor & Ariel Soiffer, COVID-19: Drafting Force Majeure Clauses in Light of the COVID-19 Pandemic, WILMERHALE (Apr. 14, 2020), <https://www.wilmerhale.com/en/insights/client-alerts/20200413-drafting-force-majeure-clauses-in-light-of-the-covid-19-pandemic>.

do not interact.<sup>154</sup> The Appendix discusses how the information contained in an interaction network such as this can be represented in a form suitable for quantitative analysis.

The network above assumes that if term A interacts with term B, then term B necessarily interacts with term A. This network is an example of an undirected network. An undirected network is a network in which there is no direction to the interactions in the network.<sup>155</sup> For example, Facebook is an undirected social network because if person A is "friends" with person B on Facebook, then person B is by definition friends with person A. Certain types of interactions in a contract system, however, may be directed. For example, if term A is a definition term that is used in term B, then term A interacts with term B, but term B does not necessarily interact with term A. A change in term A would affect term B, but a change in term B would not necessarily affect term A. Directed networks are used to represent directed interactions such as these. A directed network is a network in which the interactions therein have direction.<sup>156</sup> For example, Twitter is a directed social network because person A can "follow" person B without person B following person A. The following is a directed network for a contract in which term A interacts with terms B and C, term B interacts with term D, term C does not interact with any other terms, and term D interacts with term B:



As can be seen in the network above, the interactions in the network have direction (represented by the arrows at the end of the links). For example, an arrow points from term A to term C because term A interacts with term C, but there is no arrow pointing from term C to term A because term C does not interact with term A. On the other hand, the link between

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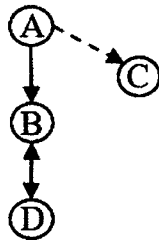
<sup>154</sup>Terms C and D do not directly interact and therefore are not directly linked in the network. They both interact, however, with term B and are therefore indirectly linked. *See infra* Section II.C.6. (providing further discussion of the potential effects of a series of linked terms).

<sup>155</sup>*See* THURNER ET AL., *supra* note 106, at 145.

<sup>156</sup>*See* THURNER ET AL., *supra* note 106, at 145.

terms B and D have an arrow on each end because term B interacts with term D and term D interacts with term B.

Thus far, the networks above have merely represented whether an interaction is present between two terms. These networks are examples of unweighted networks. An unweighted network is a network in which the interactions in the network do not have magnitude (commonly referred to as "weight") – they either exist or they do not.<sup>157</sup> An example of an unweighted network is an airline route map that simply shows whether the airline has a flight path between two cities. Some types of interactions, however, may come in different strengths. Weighted networks are used to represent interactions such as these. A weighted network is one in which the interactions in the network have magnitude.<sup>158</sup> An example of a weighted network is an airline route map that shows whether the airline has a flight path between two cities, and if so, the number of daily flights between those cities. Interactions in a contract network can sometimes be weighted. For example, a "late fee" provision in a consumer contract may increase the amount the consumer owes under the payment obligation provision by five percent if payment is thirty days late versus ten percent if payment is sixty days late. The following is a weighted, directed network for a contract in which term A interacts strongly with term B and weakly with term C, term B interacts strongly with term D, term C does not interact with any terms, and term D interacts strongly with term B:



In the network above, a solid line represents a strong interaction whereas a dashed line represents a weak interaction.

Most contract systems will have multiple different types of interactions, such as textual cross references (e.g. Section 3.4 explicitly references Section 2.8), linked definitions, conceptual interactions, and dependent promises.<sup>159</sup> In this model, each type of interaction is represented as a separate network that indicates all the interactions of that

<sup>157</sup>See THURNER ET AL., *supra* note 106, at 150.

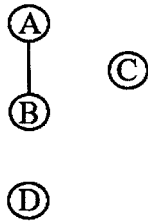
<sup>158</sup>See THURNER ET AL., *supra* note 106, at 150.

<sup>159</sup>See Smith, *supra* note 9, at 1188-90.

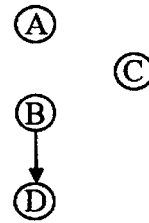


type between the terms at a given point in time. Together, the networks representing all the interaction types in the contract system make up the contractual multilayer network. The following is a multilayer network for a contract in which terms A and B have an undirected, unweighted dependent promise interaction, term B has a directed, unweighted definition interaction with term D, and terms C and D do not interact with any other terms.

### Dependent Promises



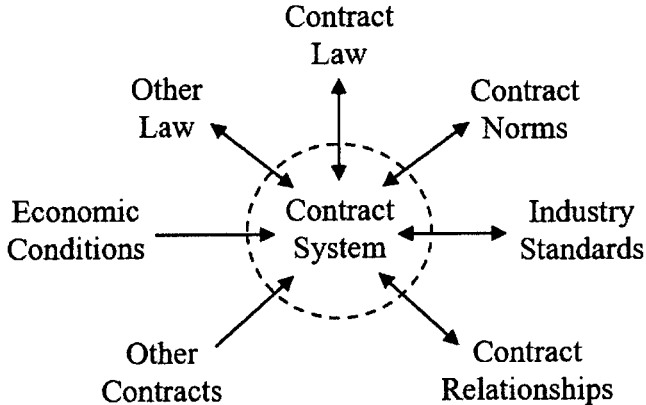
### Definitions



As can be seen above, the two different types of interactions in the contract system are each represented by a network. The combined multilayer network represents all interactions in the contract system. Once the terms and interactions in the contract system have been represented in the model, the next step in the model is to represent the system's environment.

### 3. Environment

A contract system does not exist within a vacuum. Rather, it exists within an environment that contains external conditions<sup>160</sup> such as contract law, norms, industry standards, relationships, other contracts, economic conditions, and other areas of law. The following diagram depicts a contract system within its environment:



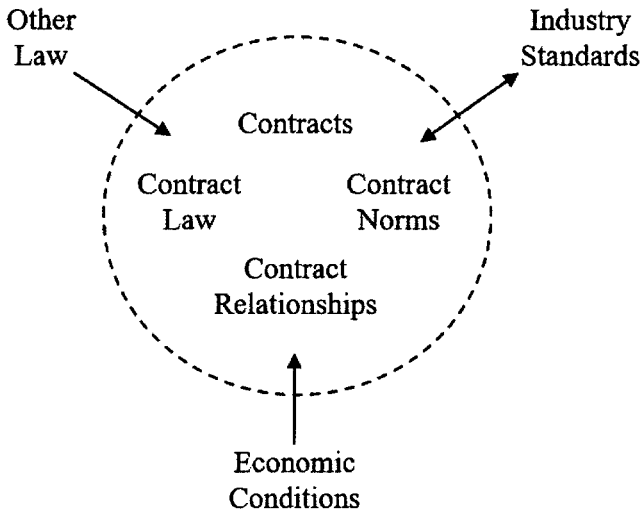
As can be seen in the diagram above, the contract system is an open system<sup>161</sup> that is influenced by its environment (represented by the arrows going into the system) and that influences its environment (represented by the arrows going out of the system). Some relationships between the system and its environment are unidirectional whereas others are bidirectional. An example of a unidirectional relationship is general economic conditions. General economic conditions can affect the terms of a contract, but the contract is unlikely to have a material effect on general economic conditions. For example, the fluctuation of overall interest rates can affect the interest rate term in a variable rate mortgage, but the mortgage is unlikely to affect overall interest rates. An example of a bidirectional relationship is the interaction between the contract system

<sup>160</sup>See Williams, *supra* note 45, at 646-47 (discussing exogenous conditions that influence contract terms and outcomes). For example, the Uniform Commercial Code situates a contract within an environment containing usage of trade, course of dealing, and course of performance. See Hwang & Jennejohn, *supra* note 2, at 313.

<sup>161</sup>An open system is a system that interacts with its environment. This is contrasted with a closed system, which does not. Most real-world systems are open systems to some extent. See MEADOWS, *supra* note 111, at 95-99; see JOHNSON, *supra* note 39, at 14; see Jennejohn, *supra* note 12, at 364 ("[C]ontract law is only one node in a broader enforcement network. In other words, the legal infrastructure supporting collaboration is an open system.").

and contract law. For example, if a contract is litigated and results in a judicial opinion that interprets the contract while also establishing precedent with respect to the issue at hand, the contract will have been influenced by the law and the law will have been influenced by the contract.

One of the key determinations to make when analyzing a complex system is where to establish the boundary between the system and its environment.<sup>162</sup> In the diagram above, the boundary is represented by the dashed circle surrounding the contract system. The boundary serves as an analytical tool for defining which elements are part of the system and which elements are part of the environment.<sup>163</sup> In this case, the system to be analyzed is the "contract"—the contractual relationship between the parties likely memorialized in a text-based document. If, however, one wanted to analyze a broader system composed of multiple contracts, contract law, contract norms, and contract relationships, one could reconceptualize the boundary between this new system and its environment.<sup>164</sup> The following diagram depicts this new arrangement:



As can be seen in the diagram above, the expanded boundary now includes additional elements in the system. These additional elements

<sup>162</sup>See MEADOWS, *supra* note 111, at 95-99.

<sup>163</sup>See MEADOWS, *supra* note 111, at 95-99.

<sup>164</sup>See Ronald J. Gilson, Charles F. Sabel & Robert E. Scott, *Braiding: The Interaction of Formal and Informal Contracting in Theory, Practice, and Doctrine*, 110 COLUM. L. REV. 1377, 1379-87. (proposing a theory of contractual "braiding" in which formal and informal contracting function in tandem).

(extra contracts, contract law, norms, and relationships) can be represented in the model by their own sets of state functions and interaction networks. For example, rules and principles of contract law can be represented by additional state functions. The interactions of these rules and principles, both with each other and with other elements in the system, can be represented by additional interaction networks in the system's multilayer network. While it may seem analytically appealing to include every potentially relevant factor in the system, such a system will quickly become unwieldy.<sup>165</sup> Furthermore, when applying this model to real-world contract systems, the larger the system, the more data necessary to properly construct the model.<sup>166</sup> As a result, it will often be necessary to limit the scope of the system for purposes of analysis and modeling.

Once the contract system and its environment have been represented in the model, the final step in the model is to represent how the system changes over time.<sup>167</sup>

#### 4. Evolution

The terms and the interactions in a contract system change over time. Evolution of the contract system can occur for a variety of reasons, including modification, renegotiation, waiver, interpretation, and redrafting.<sup>168</sup> For example, the parties to a contract may disagree over a particular term and resolve their disagreement via a formal contract modification that alters the form of the disputed term. As a result of this contract modification, the state function representing the term would change to reflect the modified form of the term. Furthermore, the modification may also affect interactions between the modified term and other terms, and as a result the interaction networks representing these interactions would change as well. Conditions out of the control of the

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<sup>165</sup>See MEADOWS, *supra* note 111, at 98.

<sup>166</sup>See Williams, *supra* note 45, at 686-87 (discussing how more complicated models typically require more data).

<sup>167</sup>Although this model has been constructed to account for change in a contract system over time, the model can also be used to analyze a contract system at a particular point in time.

<sup>168</sup>There is a rich literature on the evolution of contract terms. See, e.g., Stephen J. Choi & G. Mitu Gulati, *Innovation in Boilerplate Contracts: An Empirical Examination of Sovereign Bonds*, 53 EMORY L.J. 929, 933-36 (2004) (discussing how adverse judicial interpretations can lead to changes in steady state contract terms and providing empirical evidence from sovereign debt contracts); see also Stephen J. Choi, Mitu Gulati & Eric A. Posner, *The Dynamics of Contract Evolution*, 88 N.Y.U. L. REV. 1, 7-10, 27, 35-36 (2013) (proposing and testing a three-stage model of contract evolution that includes pre-interpretation standardization, post-interpretation innovation, and post-innovation standardization); see also Anderson & Manns, *supra* note 71, at 76-80 (constructing "family trees" of precedent documents to visualize how M&A terms change over time).

parties can also cause a contract system to change. For example, in the wake of the COVID-19 pandemic, many transactional lawyers are changing how they draft force majeure clauses to properly protect their clients in the event of a future pandemic that brings the global economy to a halt.<sup>169</sup> The state function representing the force majeure clause in a contract system and any interaction networks that include the clause would change as a result of the pandemic.

The model accounts for the evolution of terms and interactions over time using evolution functions. Each term in the contract system has an evolution function that describes how the term's respective state function changes over time. For example, assume a term is present in a contract system in 2020, but the transactional lawyer who drafts the contract removes the term in a subsequent version of the contract in 2021. If the term is represented in the model by a binary state function, then the evolution function for the term would describe how the term's binary state function changed from a value of one in 2020 (because the term was present in the contract) to a value of zero in 2021 (because the term is no longer present in the contract). The change in a term from one point in time to another can depend in part on the state of the term, the state of other terms, the state of interaction networks, and/or environmental conditions. As a result, the evolution function of a term takes these parameters into account.

Similarly, each interaction network in the contract system also has an evolution function that describes how the network changes over time. For example, assume terms A and B are linked in a contract system via a textual cross reference in 2020, but the transactional lawyer who drafts the contract removes the cross reference in a subsequent version of the contract in 2021. The evolution function for the interaction network representing textual cross references in the contract would describe how the link between terms A and B was removed from the network between 2020 and 2021. As is the case with the term evolution functions, the evolution functions for the interaction networks also take into account the states of the terms, interaction networks, and environmental conditions. Therefore, the evolution of the terms is influenced by the interaction networks and the evolution of the interaction networks is influenced by the terms. As a result, the terms and interactions in a contract system can be said to "coevolve" – they evolve over time in tandem, each influencing the evolution of the other.

To model the evolution of real-world contract systems, one would need to specify the forms of the evolution functions for each term and

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<sup>169</sup>See Finkel et al., *supra* note 153.

interaction in the system. While doing so is beyond the scope of this Article, the advent of technologies such as contract management systems that track contract data over time have made this type of modeling possible.<sup>170</sup> With sufficient data on contract terms, interactions, and environmental conditions, one could determine the set of evolution functions for a particular contract system (e.g., a law firm's venture financing contracts) and use these functions in combination with contract data to engage in predictive analysis.<sup>171</sup> For example, past data on how a contract system responded to an adverse judicial interpretation could be used to specify evolution functions that would provide insight into how the current system would respond to a future adverse interpretation.<sup>172</sup>

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The model developed in this Section describes the terms, interactions, environment, and evolution of a contract system. This model provides a framework for thinking about contracts as systems. In the next section, this Article uses the model to discuss a number of key complex systems properties that are exhibited by contract systems.

### *C. Properties of a Contract System*

Contract systems exhibit many key properties observed in other complex systems. The sections below discuss the following properties of a contract system: (1) organized complexity, (2) hierarchy, (3) emergence, (4) adaptation, (5) sensitivity to initial conditions, (6) nonlinearity, and (7) punctuated equilibria.

#### 1. Organized Complexity

Complex systems are, by their very nature, complex. While the standard meaning of "complex" is effectively the same as "complicated," complexity has a technical meaning within complex systems theory.<sup>173</sup>

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<sup>170</sup>See Williams, *supra* note 45, at 648-61 (describing sources of contract data including contract management systems, natural language processing, and computable contracts).

<sup>171</sup>See THURNER ET AL., *supra* note 106, at 25.

<sup>172</sup>See Williams, *supra* note 45, at 631-34 (proposing "predictive contracting" in which machine learning systems statistically connect contract terms to contract outcomes). See *infra* Section III.C. (providing further discussion of the implications of a complex systems approach to contracts for legal technology).

<sup>173</sup>See MILLER & PAGE, *supra* note 39, at 9, 27 (distinguishing between complex and complicated); see THURNER ET AL., *supra* note 106, at v. (distinguishing between complex and complicated). Although complexity and complicatedness are distinct, they tend to be positively correlated in complex systems.

When analyzing a complex system, complexity specifically refers to the degree of interaction between the components of the system.<sup>174</sup> The greater the interactivity of the system, the greater the complexity.<sup>175</sup> As identified by Warren Weaver in 1948, complexity can come in two varieties: disorganized and organized.<sup>176</sup> Disorganized complexity arises from a very large number of components interacting in a random, yet statistically predictable manner.<sup>177</sup> The random interactions that produce disorganized complexity typically conform to the Law of Large Numbers, and as a result their behavior can be described and modeled using probability and statistics.<sup>178</sup> An example of disorganized complexity is the behavior of molecules in a gas.<sup>179</sup> Organized complexity, on the other hand, arises from components interacting in a nonrandom (or at least not entirely random), systematized fashion.<sup>180</sup> As a result, organized complexity cannot be modeled using traditional probability and statistics, but instead must be analyzed using alternative methods such as network analysis.<sup>181</sup> Examples of organized complexity include traffic jams, stock market crashes, and earthquakes.<sup>182</sup> Complex systems theory is primarily concerned with systems that exhibit organized complexity.<sup>183</sup>

Interactions between terms within a contract system, as well as interactions between terms and environmental conditions (such as contract law), are typically nonrandom. Yet not all terms within a contract system contribute equally to the complexity of the system. The greater the number of other terms that a particular term interacts with, the greater the complexity contributed by that term. Some terms will contribute very little complexity. For example, a simple term listing the contact information of the parties is unlikely to interact in a meaningful way with many other terms. On the other hand, terms such as key definitions that interact with

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<sup>174</sup>See Bar-Yam, *supra* note 110, at 28; see MILLER & PAGE, *supra* note 39, at 9; see MITCHELL, *supra* note 106, at 233.

<sup>175</sup>See Bar-Yam, *supra* note 110, at 28.

<sup>176</sup>See Warren Weaver, *Science and Complexity*, 36 AMERICAN SCIENTIST 1, 2-7 (1948) (describing and distinguishing between disorganized and organized complexity).

<sup>177</sup>See Weaver, *supra* note 176, at 538; see JOHNSON, *supra* note 115, at 46; see MILLER & PAGE, *supra* note 39, at 47-48.

<sup>178</sup>See MILLER & PAGE, *supra* note 39, at 47-48 ("[T]he Law of Large Numbers ... provides some relatively general conditions under which a certain type of aggregate behavior can emerge from the stochastic, microlevel actions of individual agents.").

<sup>179</sup>See JOHNSON, *supra* note 115, at 46.

<sup>180</sup>See Weaver, *supra* note 176, at 4-7; see JOHNSON, *supra* note 115, at 47-49; see MILLER & PAGE, *supra* note 39, at 49-50.

<sup>181</sup>See MILLER & PAGE, *supra* note 39, at 47-48.

<sup>182</sup>See MILLER & PAGE, *supra* note 39, at 50.

<sup>183</sup>See Weaver, *supra* note 176, at 4-7; see JOHNSON, *supra* note 115, at 47-49; see MILLER & PAGE, *supra* note 39, at 49-50.

a large number of other terms will contribute a lot of complexity. Contractual modularity can reduce the complexity of a contract system by creating term "modules" in which the modular terms primarily interact with each other rather than the rest of the system.<sup>184</sup> In addition, certain terms can substantially reduce the complexity of a system by limiting the interaction of the system with parts of its environment.<sup>185</sup> For example, an integration clause typically prevents a court from examining parol evidence when interpreting a contract. In doing so, the integration clause is cutting off interaction between the contract system and parol evidence in its environment in the context of interpretation. As a result, the integration clause reduces the complexity of the contract during interpretation.

Discussion of complexity in legal scholarship has tended to view complexity as a measure of complicatedness rather than interaction.<sup>186</sup> In the context of contracts, empirical analysis of contractual complexity has typically proxied complexity either by the length<sup>187</sup> or linguistic complexity<sup>188</sup> of the contract. While length is positively correlated with complexity (because longer contracts have more terms and more terms tend to create more interactions), it is a rough proxy at best.<sup>189</sup> A better measure of contractual complexity would capture the degree of interaction in the contract system.<sup>190</sup> One such measure is the total complexity of the contract: the total number of interactions across all interaction networks in the contract.<sup>191</sup> This measure of complexity tends to increase as the number of terms (i.e., the length of the contract) increases.<sup>192</sup> An alternative

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<sup>184</sup>See Smith, *supra* note 9, at 1180.

<sup>185</sup>See Smith, *supra* note 9, at 1180.

<sup>186</sup>See, e.g., Karen Eggleston, Eric A. Posner & Richard Zeckhauser, *The Design and Interpretation of Contracts: Why Complexity Matters*, 95 NW. U. L. REV. 91, 97 (2000) (proposing a three-part definition of contractual complexity, including "the cognitive load required to understand the contract"); see also Wright, *supra* note 141, at 720 (equating legal complexity with complicatedness).

<sup>187</sup>See, e.g., John C. Coates, IV, *Why Have M&A Contracts Grown? Evidence from Twenty Years of Deals* 1 (Harvard Law Sch. John M. Olin Ctr. for Law, Econ. & Bus., Working Paper No. 333, 2016) (analyzing the growth in complexity of M&A contracts over time based on word count); see Ganglmair & Wardlaw, *supra* note 71, at 4-6 (analyzing the complexity of debt contracts based on length).

<sup>188</sup>See, e.g., Coates, *supra* note 187, at 1 (analyzing the growth in complexity of M&A contracts over time based on the Flesch-Kincaid linguistic complexity score); see Jeremy McClane, *Boilerplate and the Impact of Disclosure in Securities Dealmaking*, 72 VAND. L. REV. 191, 238-42 (2019) (analyzing the complexity of securities disclosures based on the Gunning Fog readability index).

<sup>189</sup>See Smith, *supra* note 9, at 1213.

<sup>190</sup>See *infra* Appendix B.

<sup>191</sup>See *infra* Appendix B.

<sup>192</sup>See *infra* Appendix B.



measure is the average complexity of the contract: the average number of interactions per term.<sup>193</sup> This measure does not necessarily increase with length. Another alternative for measuring complexity is the complexity density of the contract: the percentage of total possible interactions present in the contract.<sup>194</sup> This measure also does not necessarily increase with length. The Appendix provides equations for calculating each of these measures of complexity.

## 2. Hierarchy

Complex systems typically exhibit hierarchical structure, in which a system is composed of subsystems that are themselves complex systems, and these subsystems are in turn composed of even smaller subsystems, until the system is reduced to its most basic, non-system components.<sup>195</sup> Hierarchy is one of the most fundamental properties of complex systems and is evident in physical, biological, social, and technological systems.<sup>196</sup> For example, humans are complex systems that are composed of organ systems that are in turn composed of individual cells.<sup>197</sup> Similarly, the global economy is composed of national economies that are composed of regional economies that are composed of local economies that are composed of firms and individuals engaging in economic activity.<sup>198</sup> As a result of hierarchy, complex systems can be viewed as having "levels," in which lower level systems are components of higher level systems.<sup>199</sup> Complex systems benefit from hierarchy through increased stability and resilience as well as a reduction in the amount of information processing that has to be handled by any one part of the system.<sup>200</sup>

Like other complex systems, contract systems are hierarchical.<sup>201</sup> A network of interrelated contracts is composed of individual contracts, each of which is a complex system. In a hierarchical contract system, individual terms within individual contracts function as the lowest level, non-system

<sup>193</sup>See *infra* Appendix B.

<sup>194</sup>See *infra* Appendix B.

<sup>195</sup>See Simon, *supra* note 117, at 468 (describing the hierarchical structure of a complex system as "a system that is composed of interrelated subsystems, each of the latter being, in turn, hierarchic in structure until we reach some lowest level of elementary subsystem"); see MEADOWS, *supra* note 111, at 82-85; see MITCHELL, *supra* note 106, at 109; see also John H. Holland, *Complex Adaptive Systems: A Primer*, in *WORLDS HIDDEN IN PLAIN SIGHT* 1-2 (David C. Krakauer ed., 2019). Hierarchy is sometimes referred to as "nesting" or "embedding."

<sup>196</sup>See Simon, *supra* note 117, at 467.

<sup>197</sup>See MEADOWS, *supra* note 111, at 82.

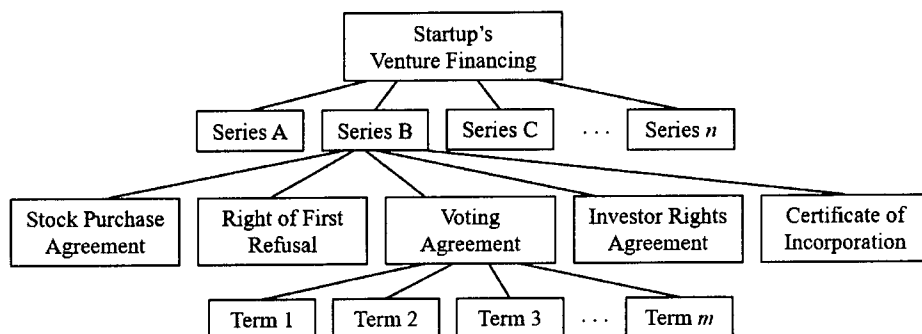
<sup>198</sup>See MEADOWS, *supra* note 111, at 82.

<sup>199</sup>See Holland, *supra* note 195, at 1.

<sup>200</sup>See MEADOWS, *supra* note 111, at 83.

<sup>201</sup>See Hwang, *supra* note 11, at 1426-27; see also Jennejohn, *supra* note 12, at 321-22.

components. Hwang's research on unbundled bargains in the M&A context is an example of contractual hierarchy.<sup>202</sup> As Hwang discusses, M&A deals are effectuated using multiple interrelated contracts.<sup>203</sup> The M&A deal is a complex system made up of contractual subsystems that are in turn made up of individual terms. The market for over-the-counter ("OTC") derivatives exhibits hierarchical structure as well.<sup>204</sup> Parties typically enter into multiple derivative transactions over a period of time, with each derivative represented by a contract.<sup>205</sup> These individual derivatives contracts are governed by a central master agreement designed by the International Swaps and Derivatives Association ("ISDA").<sup>206</sup> The derivative relationship between the parties is a contract system composed of the ISDA master agreement and the individual derivatives contracts, each of which is a contract system composed of terms.<sup>207</sup> Contractual hierarchy can also be found in venture capital contracting. The following diagram depicts a venture capital contract system.



As can be seen in the diagram above, a startup's venture capital financing contracts are typically divided into multiple "series" (Series A, B, C, etc.) associated with similarly titled classes of the company's preferred stock.<sup>208</sup> Each series of venture financing is effectuated by an

<sup>202</sup>See *supra* notes 80-87 and accompanying text.

<sup>203</sup>See *supra* notes 80-87 and accompanying text.

<sup>204</sup>See Hwang & Jennejohn, *supra* note 2, at 307-09.

<sup>205</sup>See Hwang & Jennejohn, *supra* note 2, at 307-09.

<sup>206</sup>See Hwang & Jennejohn, *supra* note 2, at 307-09.

<sup>207</sup>See Hwang & Jennejohn, *supra* note 2, at 307-09.

<sup>208</sup>See Williams, *supra* note 69, at 123, 128-30.

interrelated set of contracts.<sup>209</sup> In the U.S., the five primary contracts that make up a venture capital deal are the Stock Purchase Agreement, the Right of First Refusal, the Voting Agreement, the Investor Rights Agreement, and the Certificate of Incorporation.<sup>210</sup> Each of these contracts are in turn composed of multiple interrelated terms.

### 3. Emergence

Complex systems frequently demonstrate emergence, in which the system exhibits properties at the system level that are not found at the component level.<sup>211</sup> These properties are said to "emerge" from the interactions of the individual components and are commonly referred to as "emergent properties."<sup>212</sup> Emergence is the primary reason why a complex system is greater than the sum of its parts; mere summation of a system's components does not capture emergent properties. The concept of emergence originated in the study of evolution and has since been broadly adopted within complex systems theory.<sup>213</sup> A common example of emergence is the collective intelligence of ant colonies.<sup>214</sup> Through the actions of individual ants and the interaction effects between ants, an ant colony exhibits unique properties at the system level such as swarm logic.<sup>215</sup> Emergence contributes to a broad range of phenomena across diverse complex systems, including human consciousness, stock market crashes, cancer tumors, and climate change.<sup>216</sup>

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<sup>209</sup>See Nat'l Venture Capital Ass'n, §4.4.4 *Model Certificate of Incorporation*, <https://nvca.org/model-legal-documents>.

<sup>210</sup>*Id.* While the Certificate of Incorporation is technically not a contract but rather a corporate charter, it is typically treated and negotiated as a contract in the venture capital context. See Michael Klausner, *Corporations, Corporate Law, and Networks of Contracts*, 81 VA. L. REV. 757, 761-62 (1995) (discussing corporate charters as contracts).

<sup>211</sup>See JOHNSON, *supra* note 115, at 18; see JOHNSON, *supra* note 39, at 4; see MILLER & PAGE, *supra* note 39, at 44; see MITCHELL, *supra* note 106, at 13; see WEST, *supra* note 111, at 23.

<sup>212</sup>See JOHNSON, *supra* note 115, at 18; see JOHNSON, *supra* note 39, at 4; see MILLER & PAGE, *supra* note 39, at 44; see MITCHELL, *supra* note 106, at 13; see WEST, *supra* note 111, at 23.

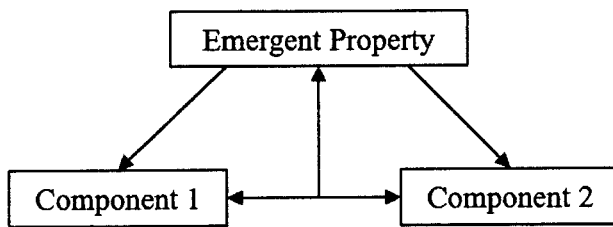
<sup>213</sup>See generally DAVID BLITZ, EMERGENT EVOLUTION: QUALITATIVE NOVELTY AND THE LEVELS OF REALITY 1 (1992) (discussing the history of emergence); see also Jeffrey Goldstein, *Emergence as a Construct: History and Issues*, 1 EMERGENCE 49, 53-55 (1999); see also Peter A. Corning, *The Re-Emergence of "Emergence": A Venerable Concept in Search of a Theory*, 7 COMPLEXITY 18, 18-21 (2002); see also Tom De Wolf & Tom Holvoet, *Emergence Versus Self-Organisation: Different Concepts but Promising When Combined*, 3464 LECTURE NOTES IN COMPUTER SCIENCE 1, 2-3 (2005).

<sup>214</sup>See JOHNSON, *supra* note 115, at 29-33, 73-82.

<sup>215</sup>See JOHNSON, *supra* note 115, at 29-33, 73-82.

<sup>216</sup>See Corning, *supra* note 213, at 18; see also JOHNSON, *supra* note 39, at 4.

Emergence is closely tied to the hierarchical structure of complex systems. As was discussed in Section III.C.2, complex systems exhibit levels of hierarchy in which lower level systems are components of higher-level systems. The interactions of the lower level systems produce the emergent properties of the higher-level systems. At the same time, these emergent properties influence the components in the lower level.<sup>217</sup> As a result, the relationship between lower level components and the higher-level emergent properties they produce is bidirectional.<sup>218</sup> The following diagram depicts this relationship.



As can be seen in the diagram above, the interaction between the lower level components produces the higher-level emergent property, which in turn influences the components. Because an emergent property is not a property of any of the components, but rather a property of the system that results from component interactions, emergence can often result in surprise and unintended consequences.<sup>219</sup> Fully understanding the properties of a system's components will not reveal emergent properties that only appear when the components interact within the system. Modeling and (potentially) predicting the emergent behavior of a complex system is one of the primary goals of complex systems theory.

Contract systems exhibit emergence. Interactions between terms in single-contract systems produce properties at the system level that are not evident at the term level. For example, two separate promises within a contract can be independent or dependent.<sup>220</sup> If the promises are independent, failure to perform promise A does not remove the obligation to perform promise B. If, however, the promises are dependent, then the performance of promise A is treated as a constructive condition of the performance of promise B and vice versa. Whether two promises are

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<sup>217</sup>See Corning, *supra* note 213, at 27; see also Tamanaha, *supra* note 140, at 1150-51.

<sup>218</sup>See Corning, *supra* note 213, at 27; see also Tamanaha, *supra* note 140, at 1150-51.

<sup>219</sup>See Ruhl, *Complexity Theory*, *supra* note 139, at 855-56.

<sup>220</sup>See Smith, *supra* note 9, at 1189.

independent or dependent depends on the interaction of the promises in the context of the contract system as a whole and therefore cannot be determined by examining the terms in isolation. As a result, the independence or dependence of two promises is an emergent property of the contract at the system level.

Interactions between individual contracts can also produce emergent properties in multi-contract systems. For example, Marcel Kahan and Michael Klausner have discussed the presence of learning benefits and network benefits in networks of contracts.<sup>221</sup> Learning benefits are associated with terms that have been commonly used in the past.<sup>222</sup> Network benefits, on the other hand, are associated with terms that are expected to be used by other parties in the future.<sup>223</sup> These externalities contribute to the prevalence of standardization in contract terms.<sup>224</sup> In both instances, terms in individual contracts (either commonly used in the past or expected to be used in the future), produce the emergent property of externalities at the multi-contract system level. The emergent externalities are created by the presence of certain terms at the individual contract level. At the same time, the externalities influence the likelihood of those same terms being used in the future. As a result, the relationship between the terms and the externalities is bidirectional. The evolution functions for the externalities are based on the states of the terms and the evolution functions for the terms are based on the externalities.

#### 4. Adaptation

Complex systems are adaptive.<sup>225</sup> The states of their components and the interactions between these components change over time in response to inputs from their environment.<sup>226</sup> The classic example of adaptation is how systems of living organisms evolve via natural selection.<sup>227</sup> Complex systems are typically viewed as having the capacity to "learn."<sup>228</sup> They iteratively revise and update themselves as they gain experience.<sup>229</sup> For example, the human immune system makes progressive improvements

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<sup>221</sup>See Klausner, *supra* note 210, at 763, 786-87; see Kahan & Klausner, *supra* note 45, at 350; see Kahan & Klausner, *supra* note 64, at 718-27.

<sup>222</sup>See Kahan & Klausner, *supra* note 64, at 718.

<sup>223</sup>See Kahan & Klausner, *supra* note 64, at 718.

<sup>224</sup>See Kahan & Klausner, *supra* note 64, at 715-17.

<sup>225</sup>See JOHNSON, *supra* note 115, at 18; see WEST, *supra* note 111, at 23-24; see also THURNER ET AL., *supra* note 106, at v.

<sup>226</sup>See WEST, *supra* note 111, at 23.

<sup>227</sup>See WEST, *supra* note 111, at 23-24.

<sup>228</sup>See Holland, *supra* note 195, at 5.

<sup>229</sup>See Holland, *supra* note 195, at 5.

when exposed to antigens, and typically becomes better-equipped to respond to future infection.<sup>230</sup>

The primary way complex systems adapt is through feedback.<sup>231</sup> Feedback mechanisms within a complex system receive inputs from the system's environment and cause the system to change its states and/or interactions accordingly.<sup>232</sup> These mechanisms are often conceptualized as "loops" because they cycle information from the environment to the system.<sup>233</sup> There are two main types of feedback mechanisms: positive and negative.<sup>234</sup> Positive feedback (also known as reinforcing or destabilizing feedback) moves a system in the direction of the input.<sup>235</sup> For example, as soil is eroded from a piece of land, fewer plants are able to establish roots to hold the soil, which leads to more erosion.<sup>236</sup> Positive feedback mechanisms tend to lead to exponential growth or loss.<sup>237</sup> Negative feedback (also known as balancing or stabilizing feedback), on the other hand, moves a system in the opposite direction of the input.<sup>238</sup> For example, a thermostat causes cold air to flow into a room if the room is too hot and causes warm air to flow into the room if the room is too cold.<sup>239</sup>

Like other complex systems, contract systems adapt via feedback mechanisms.<sup>240</sup> The primary feedback mechanism for a contract system is the transactional lawyer who designs and drafts the contract(s). The transactional lawyer responds to inputs from the contract system's environment by adding, removing, and/or modifying terms.<sup>241</sup> This feedback mechanism can be positive or negative. For example, if a lawyer identifies that a particular term has become commonplace and therefore carries less litigation risk, the lawyer will be more likely to use that term

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<sup>230</sup>See Holland, *supra* note 195, at 5.

<sup>231</sup>See JOHNSON, *supra* note 115, at 137-39; see JOHNSON, *supra* note 39, at 25-26; see MEADOWS, *supra* note 111, at 25-27; see MILLER & PAGE, *supra* note 39, at 50-53.

<sup>232</sup>See JOHNSON, *supra* note 115, at 102-03; see JOHNSON, *supra* note 39, at 33-34; see MEADOWS, *supra* note 111, at 25-27; see MILLER & PAGE, *supra* note 39, at 50-53.

<sup>233</sup>See MEADOWS, *supra* note 111, at 25-27.

<sup>234</sup>See JOHNSON, *supra* note 115, at 137-39; see MEADOWS, *supra* note 111, at 27-34; see MILLER & PAGE, *supra* note 39, at 50-53.

<sup>235</sup>See MEADOWS, *supra* note 111, at 30-32.

<sup>236</sup>See MEADOWS, *supra* note 111, at 31.

<sup>237</sup>See MEADOWS, *supra* note 111, at 30-32.

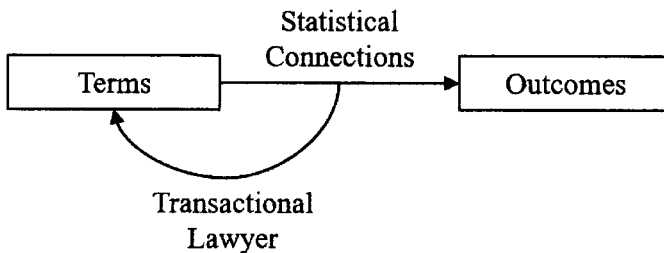
<sup>238</sup>See MEADOWS, *supra* note 111, at 27-30.

<sup>239</sup>See JOHNSON, *supra* note 115, at 138.

<sup>240</sup>See Choi & Gulati, *supra* note 168, at 931-36 (discussing the adaptation of sovereign debt contracts); see Boardman, *supra* note 51, at 1112-16 (discussing feedback loops in insurance contracts); see also Choi, Gulati & Posner, *supra* note 168, at 3-10, 27, 35 (discussing the evolutionary cycle of sovereign debt contracts and providing empirical evidence from the New York and English sovereign debt markets).

<sup>241</sup>See Choi & Gulati, *supra* note 168, at 931-36; see Boardman, *supra* note 51, at 1112-16; see also Choi, Gulati & Posner, *supra* note 168, at 3-10, 27, 35.

again.<sup>242</sup> This is a positive feedback loop that reinforces the term's prevalence. On the other hand, if a term receives an adverse judicial interpretation, a lawyer will be less likely to use the term again in its current form and will instead modify or remove the term.<sup>243</sup> This is a negative feedback loop that decreases the term's prevalence. With sufficient information, a transactional lawyer can toggle between positive and negative feedback. For example, legal technology companies are in the early stages of using machine-learning technology to statistically connect contract terms with contract outcomes.<sup>244</sup> Using a "predictive contracting" tool, a lawyer can iteratively adjust the terms of a contract based on these statistical connections.<sup>245</sup> The following diagram depicts this process:



If the predictive contracting tool demonstrates that a term increases the likelihood of a positive outcome (such as proper, on-time performance), the lawyer can increase the prevalence of the term in the future via positive feedback. On the other hand, if the term is shown to be linked to a negative outcome (such as litigation), the lawyer can decrease the prevalence of the term in the future via negative feedback.

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<sup>242</sup>See Choi & Gulati, *supra* note 168, at 931; see Kahan & Klausner, *supra* note 64, at 722-23.

<sup>243</sup>But see GULATI & SCOTT, *supra* note 51, at 2-3 (discussing the continued widespread use of a "pari passu" provision in sovereign debt contracts despite an adverse judicial ruling). See *infra* Section IV.A. (discussing the implications of failures in feedback mechanisms for contract design).

<sup>244</sup>See Williams, *supra* note 45, at 631-34. See *infra* Section IV.C. (discussing the impact of complex systems on legal technology).

<sup>245</sup>See Williams, *supra* note 45, at 631-34.

### 5. Sensitivity to Initial Conditions

Complex systems are sensitive to their initial conditions.<sup>246</sup> The initial conditions of a complex system include the states of the system's components, interaction networks, and environment at the time the system is formed.<sup>247</sup> These conditions can be thought of as the "starting point" of the system.<sup>248</sup> The evolution of a system from time  $t$  to time  $t+1$  depends on the conditions of the system at time  $t$ .<sup>249</sup> Therefore, a system's evolutionary trajectory depends on the system's original starting point.<sup>250</sup> Modifying a system's initial conditions can change its evolution. For example, starting a snowball at the top of a hill with relatively little snow will result in a much smaller snowball at the bottom of the hill than a snowball that is started at the top of a hill packed with snow. Similarly, an organism that begins its life in an environment rich with resources will likely evolve differently than an organism that starts in a sparse environment.

The sensitivity of a complex system to its initial conditions is closely related to the concept of the "adjacent possible."<sup>251</sup> "[T]he adjacent possible of a system at time  $t$  is the set of all potential states (or configurations) of that system that can be reached in the next time step  $t+1$ ."<sup>252</sup> For example, the adjacent possible for a traveler who finds themselves at the fork in a road includes four possible states: 1) go left, 2) go right, 3) turn around, and 4) remain in place.<sup>253</sup> The following diagram depicts the adjacent possible for a system that begins in state A at time  $t=1$ .

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<sup>246</sup>See JOHNSON, *supra* note 39, at 32-34; see MITCHELL, *supra* note 106, at 34; see THURNER ET AL., *supra* note 106, at vi.

<sup>247</sup>See MITCHELL, *supra* note 106, at 38.

<sup>248</sup>See MITCHELL, *supra* note 106, at 31.

<sup>249</sup>See MITCHELL, *supra* note 106, at 31.

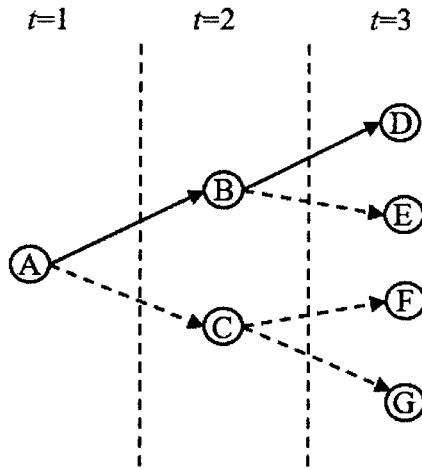
<sup>250</sup>See JOHNSON, *supra* note 39, at 32-34; see MITCHELL, *supra* note 106, at 34; see THURNER ET AL., *supra* note 106, at vi.

<sup>251</sup>See THURNER ET AL., *supra* note 106, at 229-30.

<sup>252</sup>See THURNER ET AL., *supra* note 106, at 230.

<sup>253</sup>See THURNER ET AL., *supra* note 106, at 230.





As can be seen in the diagram above, the set of adjacent possible states at time  $t=1$  includes states B and C. The system evolves into state B (represented by the solid arrow), but it could have evolved into state C (represented by the dashed arrow). Once the system is in state B at time  $t=2$ , the set of adjacent possible states become states D and E. Had the system evolved into state C instead of state B, the set of adjacent possible states would be states F and G. The diagram therefore demonstrates an important point regarding the evolution of complex systems: the set of adjacent possible states for a system at a given point in time depends on the state of the system at that point, which in turn depended on the state of the system in the previous time period, all the way back to the initial state of the system. As a result, the initial conditions of a system determine all future adjacent possible states.

Contract systems are sensitive to their initial conditions. For example, terms in venture financing contracts are often "sticky" – a term is more likely to appear in a later round of financing if it appeared in an earlier round.<sup>254</sup> In contracts scholarship, this property has typically been described as "path dependence."<sup>255</sup> Path dependence in contracting has been linked to a variety of causes, including learning benefits,<sup>256</sup> network benefits,<sup>257</sup> agency costs,<sup>258</sup> herd behavior,<sup>259</sup> and cognitive biases such as

<sup>254</sup>See Williams, *supra* note 69, at 152.

<sup>255</sup>See, e.g., Kahan & Klausner, *supra* note 45, at 348.

<sup>256</sup>See Kahan & Klausner, *supra* note 45, at 350-52.

<sup>257</sup>See Kahan & Klausner, *supra* note 45, at 350-52.

<sup>258</sup>See Kahan & Klausner, *supra* note 45, at 353-55.

<sup>259</sup>See Kahan & Klausner, *supra* note 45, at 356-58.

status quo bias, anchoring bias, and conformity bias.<sup>260</sup> Empirical studies have shown that path dependence can persist in contracts over decades.<sup>261</sup> The evolution functions that determine how a contract system's terms and interactions change from time  $t$  to time  $t+1$  depend on the states of the terms, interactions, and environment at time  $t$ .<sup>262</sup> As a result, the set of adjacent possible states at time  $t$  depends on the state of the system at time  $t$ , which can be traced all the way back to the initial state of the system at time  $t=1$ .<sup>263</sup> Consequently, modifying a contract system's initial conditions affects the possible states that the system can take in the future.

## 6. Nonlinearity

Complex systems often exhibit nonlinearity, in which the system does not respond linearly to an input.<sup>264</sup> A linear relationship has constant proportionality between cause and effect.<sup>265</sup> For example, doubling the rate at which water comes out of a faucet will make a pot fill twice as quickly while tripling the rate will make the pot fill three times as quickly. A nonlinear relationship, on the other hand, does not have constant proportionality between cause and effect.<sup>266</sup> For example, increasing the amount of fertilizer on a piece of farm land from ten pounds to twenty pounds may increase the yield of the land, whereas increasing the amount of fertilizer to one hundred pounds may actually decrease the yield by damaging the soil with too much fertilizer.<sup>267</sup> The primary sources of nonlinearity in a complex system are the interactions between the system's components. As a result of these interactions, an input from the system's environment that initially affects one component will often end up affecting many more. This propagation of the input throughout the system can lead to nonlinear and unexpected results.

One of the most serious of these unexpected results is a phenomenon known as cascade failure.<sup>268</sup> A cascade failure occurs when the failure of

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<sup>260</sup>See Kahan & Klausner, *supra* note 45, at 359-64; see also Russell Korobkin, *Inertia and Preference in Contract Negotiation: The Psychological Power of Default Rules and Form Terms*, 51 VAND. L. REV. 1583, 1586 (1998).

<sup>261</sup>See, e.g., Anderson & Manns, *supra* note 71, at 58-61 (finding path dependence in merger agreements over a twenty-year period).

<sup>262</sup>See THURNER ET AL., *supra* note 106, at 227-28.

<sup>263</sup>See THURNER ET AL., *supra* note 106, at 227-28.

<sup>264</sup>See JOHNSON, *supra* note 39, at 40; see MILLER & PAGE, *supra* note 39, at 216; see MEADOWS, *supra* note 111, at 91-94; see MITCHELL, *supra* note 106, at 22-27; see WEST, *supra* note 111, at 17-19; see THURNER ET AL., *supra* note 106, at 23.

<sup>265</sup>See MEADOWS, *supra* note 111, at 91.

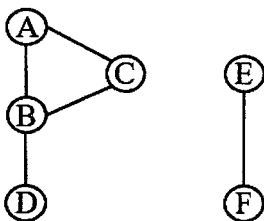
<sup>266</sup>See MEADOWS, *supra* note 111, at 91.

<sup>267</sup>See MEADOWS, *supra* note 111, at 91.

<sup>268</sup>See MITCHELL, *supra* note 106, at 255-57.

one component (or a small number of components) results in the failure of connected components, which in turn cause the failure of additional connected components until there is a system-wide failure.<sup>269</sup> Visually, a cascade failure looks like a classic set of domino tiles being toppled by a single piece. Cascade failures can occur in a variety of different complex systems. For example, in 2003, a power plant in Ohio shutdown unexpectedly.<sup>270</sup> Electricity demand normally served by that plant was shifted to other plants, causing them to overload and shut down.<sup>271</sup> In the end, over fifty million people lost power throughout the United States and Canada.<sup>272</sup> Cascade failures can be particularly severe in the finance industry in which interconnected financial entities can produce high levels of systemic risk.<sup>273</sup> Scholars have begun to use complex systems theory to advocate for more effective financial regulation aimed at preventing cascade failures.<sup>274</sup>

Contract systems can have nonlinear responses to inputs from their environment as a result of the interactions between terms. For example, a judicial interpretation of a particular term may impact numerous other terms as well. The extent to which an interpretation will have a nonlinear, system-wide effect depends on the structure of the interaction networks in the contract. The following network represents a contract system with multiple interconnected terms.



As can be seen in the network above, terms A, B, C and D are connected via interactions, as are terms E and F. All else equal, an interpretation that changes the meaning of term A is more likely to result in a nonlinear response than an interpretation that changes the meaning of term E because term A is connected to more terms than term E. If the interpretation were to render the term ineffective, the interpretation could potentially result in a cascade failure that would render the entire contract

<sup>269</sup>See MITCHELL, *supra* note 106, at 255-57.

<sup>270</sup>See MITCHELL, *supra* note 106, at 256.

<sup>271</sup>See MITCHELL, *supra* note 106, at 256.

<sup>272</sup>See MITCHELL, *supra* note 106, at 256.

<sup>273</sup>See MITCHELL, *supra* note 106, at 256.

<sup>274</sup>See, e.g., Allen, *supra* note 142, at 10-21.

ineffective.<sup>275</sup> Once again, all else equal, term A is more likely to cause a cascade failure than term E.

As this example demonstrates, the "connectedness" of a term is a critical characteristic for understanding the role of the term in the overall contract system. The simplest measure of the connectedness of a term is the "degree" of the term: the number of interaction links connected to the term.<sup>276</sup> In the network above, the degree of term A is two whereas the degree of term E is one. An alternative measure of the connectedness of a term is the "nearest-neighbor degree" of the term: the average degree of all the terms with which the term in question is connected.<sup>277</sup> In the network above, the nearest-neighbor degree of term A is 2.5<sup>278</sup> whereas the nearest-neighbor degree of term E is one. By either measure, term A is more "connected" than term E. The Appendix provides equations for calculating these measures of connectedness.<sup>279</sup>

## 7. Punctuated Equilibria

Complex systems often evolve via punctuated equilibria, in which long periods of equilibrium with relatively little change are periodically punctuated by shorter periods of substantial change.<sup>280</sup> These periods of change typically come in the form of extreme "boom" and "bust" events precipitated by environmental shocks to the system.<sup>281</sup> Theories of punctuated equilibria originated in the 1960s and 1970s as criticisms of the prevailing "gradualist" view of evolution.<sup>282</sup> According to punctuated equilibria models of evolution, complex systems exhibit multiple equilibria.<sup>283</sup> These multiple equilibria do not last forever.<sup>284</sup> Rather, they

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<sup>275</sup>See *infra* Section IV.B. (discussing the implications of cascade failure for contract interpretation).

<sup>276</sup>See THURNER ET AL., *supra* note 106, at 150-51.

<sup>277</sup>See THURNER ET AL., *supra* note 106, at 152.

<sup>278</sup>Term A has two neighboring terms, B and C. The degree of term B is three and the degree of term C is two. The nearest-neighbor degree of term A is therefore  $(3+2)/2 = 2.5$ .

<sup>279</sup>There are other potential measures of connectedness that are beyond the scope of this Article, including centrality, clustering, and community. See THURNER ET AL., *supra* note 106, at 154-58, 177-83.

<sup>280</sup>See MITCHELL, *supra* note 106, at 84-85; see THURNER ET AL., *supra* note 106, at 224-25.

<sup>281</sup>See THURNER ET AL., *supra* note 106, at 224.

<sup>282</sup>See MITCHELL, *supra* note 106, at 84-85.

<sup>283</sup>See JOHNSON, *supra* note 39, at 20-21; see also Richard Palmer, *Can Physics Contribute to Economics?*, in *WORLDS HIDDEN IN PLAIN SIGHT* 26 (David C. Krakauer ed., 2019); see MILLER & PAGE, *supra* note 39, at 83.

<sup>284</sup>See THURNER ET AL., *supra* note 106, at 233-34.

are said to be "metastable."<sup>285</sup> As a result, the evolution of a complex system is an open-ended progression "from one metastable equilibrium to the next."<sup>286</sup> Empirical evidence of punctuated equilibria can be found in a broad range of complex systems, including biological, social, and technological systems.<sup>287</sup>

The evolutionary trajectories of contract systems frequently feature punctuated equilibria.<sup>288</sup> A period of substantial change in a contract system is often driven by a shock from the system's environment.<sup>289</sup> For example, Stephen Choi and Mitu Gulati have described how "interpretive shocks" (adverse judicial interpretations that substantially alter the meaning of a term) can disrupt periods of contract standardization (i.e., equilibrium) and lead to innovation.<sup>290</sup> Together with Eric Posner, Choi and Gulati have proposed a "three-stage" model of contract evolution: 1) pre-shock standardization, 2) post-shock innovation, and 3) post-innovation standardization.<sup>291</sup> They empirically support this model with evidence from the New York and English sovereign debt markets.<sup>292</sup> Their model describes how a sovereign debt contract system moves from one metastable equilibrium to another as the result of an environmental shock.<sup>293</sup>

Inflection points in a contract system's evolution can be identified by measuring the change in the system's terms and interactions between time periods.<sup>294</sup> Large shifts in terms and interactions represent key periods of evolutionary change.<sup>295</sup> The change in a term between two points in time can be measured by the difference in its state functions at those points.<sup>296</sup> For example, assume that the state function for term A is a binary function that is equal to one if term A is present in the contract and zero if term A is not present. If the difference between term A's state function in 2021 and 2020 is equal to one, this means that term A was present in 2021 but not in 2020. On the other hand, if the difference is equal to negative one, this means that term A was not present in 2021 but was present in 2020. If

<sup>285</sup>See THURNER ET AL., *supra* note 106, at 233-34.

<sup>286</sup>See THURNER ET AL., *supra* note 106, at 233-34.

<sup>287</sup>See THURNER ET AL., *supra* note 106, at 232-36.

<sup>288</sup>Mark C. Niles, *Punctuated Equilibrium: A model for Administrative Evolution*, 44 J. MARSHALL L. REV. 353, 353-54 (2011).

<sup>289</sup>*Id.* at 356.

<sup>290</sup>See Choi & Gulati, *supra* note 168, at 933.

<sup>291</sup>See Choi, Gulati & Posner, *supra* note 168, at 10.

<sup>292</sup>See Choi, Gulati & Posner, *supra* note 168, at 27, 35.

<sup>293</sup>See generally Choi, Gulati & Posner, *supra* note 168.

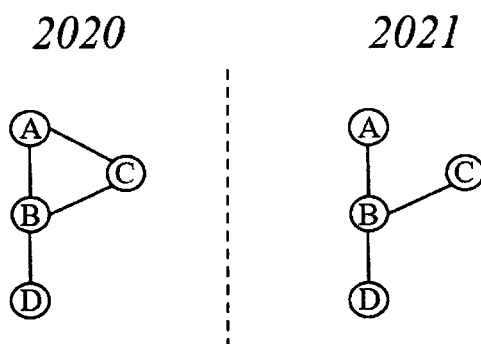
<sup>294</sup>See Choi, Gulati & Posner, *supra* note 168, at n.15 (quoting Barak Richman, *Contracts Meet Henry Ford*, 40 HOFSTRA L. REV. 77, 77 (2011)).

<sup>295</sup>See Choi, Gulati & Posner, *supra* note 168, at 4.

<sup>296</sup>See Choi, Gulati & Posner, *supra* note 168, at 5.

the difference is equal to zero, this means that the presence of term A did not change between 2020 and 2021.<sup>297</sup> The overall change in a system's terms can be measured by the aggregate change in its individual terms. The Appendix provides equations for calculating the change in individual terms as well as the aggregate change in a system's terms.

As for changes in a system's interactions, the change in a particular interaction type between two points in time can be measured by the difference in its interaction networks at those points. For example, assume that interaction type X is represented by the following interaction networks in 2020 and 2021:



As can be seen in the diagram above, the interaction between terms A and C was present in 2020, but not in 2021. The difference in these networks (the removal of the interaction between terms A and C) represents the change in interaction type X between 2020 and 2021. The overall change in a system's interactions can be measured by the aggregate change in its interaction networks. The Appendix provides equations for calculating the change in individual interaction networks as well as the aggregate change in a system's interactions. Key periods of punctuated change in a contract system will typically display above-average degrees of change in terms and interactions.

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The previous section modeled a contract as a complex system and identified key properties of a contract system. The next section draws on the model and properties discussed here to examine the implications of a complex systems approach to contracts.

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<sup>297</sup>This would be true if either term A was present at both times or was not present at both times.

#### IV. IMPLICATIONS FOR CONTRACT DESIGN, INTERPRETATION, AND ANALYSIS

This section discusses the implications of a complex systems approach to contracts for contract design, interpretation, and analysis. Section IV.A discusses design, Section IV.B discusses interpretation, and Section IV.C discusses analysis.

##### *A. Design*

Viewing a contract as a complex system has significant implications for how transactional lawyers design contracts. First, by taking a complex systems approach to contracts, lawyers can design more efficient, effective, and resilient contracts. While transactional lawyers are often aware that individual terms can often have broader effects,<sup>298</sup> complex systems theory provides a robust framework for considering the systemic effects of *ex ante* design decisions. For example, much of modern contract drafting is form-based; lawyers begin with a precedent contract and tweak it based on the specifics of the transaction at hand.<sup>299</sup> Yet adding, removing, and/or modifying individual terms in a precedent contract can have effects on other terms throughout the contract due to interaction effects between terms. Furthermore, altering terms can affect emergent properties that are only evident at the contract system level. For example, if terms A and B interact as dependent promises, then changing either term could potentially remove this dependency from the system. Making contract design decisions without considering the impact on interaction networks and emergent properties can lead to unintended consequences such as cascade failure.<sup>300</sup> As a result, it is critical for transactional lawyers to understand the systemic nature of the contract they are designing. When engaging in form-based drafting, the drafter should be aware of the connectedness of the terms they are modifying. All else equal, modifying a more connected term is more likely to result in a nonlinear response. Quantitative measures of connectedness such as the degree or nearest-neighbor degree of a term can help a drafter determine which terms in the contract are most connected.<sup>301</sup> The drafter can then use this information to modify the contract in a manner that is conscious of the effects of

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<sup>298</sup>See Klausner, *supra* note 210, at 762; see Hill, *supra* note 51, at 59-63; see Choi, Gulati & Posner, *supra* note 168, at 3; see Anderson & Manns, *supra* note 71, at 64-65.

<sup>299</sup>See Klausner, *supra* note 210, at 762; Hill, *supra* note 51, at 59-63; Choi, Gulati & Posner, *supra* note 168, at 3; Anderson & Manns, *supra* note 71, at 64-65.

<sup>300</sup>See MITCHELL, *supra* note 106, at 256; see *infra* Section III.B.

<sup>301</sup>See *supra* Section III.C.6.

individual terms on the contract as a whole. This *ex ante* modification process can be supplemented with software tools that visualize the contract's interaction networks and enable the computation of connectedness measures.

Second, complex systems theory enables contract designers to make better-informed tradeoffs during the design process. Robert Scott and George Triantis have described how contract designers balance front-end design costs against back-end litigation costs.<sup>302</sup> Investing in greater term specificity on the front-end reduces the likelihood (and therefore cost) of litigation on the back-end.<sup>303</sup> Yet Scott and Triantis frame cost balancing as a decision that contract designers make on a term-by-term basis.<sup>304</sup> While the design of an individual term does affect front-end and back-end costs, it also affects other terms within the contract as well as emergent properties at the system level. As a result, contract designers should consider the effects on interaction networks and emergent properties when engaging in cost balancing.

Contract designers also make tradeoffs between terms when designing a contract that must respond to a variety of transaction costs.<sup>305</sup> As discussed by Matthew Jennejohn, transactional lawyers use different kinds of terms to respond to different kinds of transaction costs.<sup>306</sup> This is a critical aspect of a transactional lawyer's role as a transaction cost engineer seeking to reduce overall transaction costs associated with a contract.<sup>307</sup> Yet individual terms can often conflict with one another, therefore, a lawyer must frequently make tradeoffs in how to respond to transaction costs.<sup>308</sup> For example, the use of a committee in an interfirm innovation alliance contract can assist with the division of intellectual property rights, yet also cause holdup concerns for other parts of the deal.<sup>309</sup> Consequently, having a qualitative and quantitative understanding of the interactions between terms can better-equip a lawyer to make these tradeoffs. For example, assume that a lawyer uses term A to respond to cost X and term B to respond to cost Y and that terms A and B are linked via term C. Assume as well that in the contract's current form, strengthening term A's ability to respond to cost X weakens term B's ability to respond to cost Y and vice versa. Equipped with the knowledge

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<sup>302</sup>See *supra* note 50 and accompanying text.

<sup>303</sup>See *supra* note 50 and accompanying text.

<sup>304</sup>See Hwang & Jennejohn, *supra* note 2, at 323-24.

<sup>305</sup>See Jennejohn, *supra* note 12, at 294.

<sup>306</sup>See Jennejohn, *supra* note 12, at 294.

<sup>307</sup>See Gilson, *supra* note 46, at 241.

<sup>308</sup>See Jennejohn, *supra* note 12, at 326.

<sup>309</sup>See Jennejohn, *supra* note 12, at 327.



that terms A and B interact via term C, the lawyer could potentially restructure the contract by disconnecting term A and/or term B from term C, thereby enabling terms A and B to respond to their respective costs without interfering with one another.

Third, modeling a contract as a complex system advances the understanding of contract structure and its importance. Cathy Hwang and Matthew Jennejohn have compellingly argued that the structure of a contract plays a significant role in contract design.<sup>310</sup> Yet Hwang and Jennejohn primarily frame contract structure as whether a contract is modular, integrated, or hybrid.<sup>311</sup> While these are three broad categories of contract structure, systems analysis can add a substantial amount of detail and granularity. The multilayered networks that represent a contract's interactions provide interaction information for every pairwise combination of terms for every type of interaction in the contract system. This information can be used to visually represent the contract's structure as a multilayered set of network maps. A contract designer can then use these maps to better understand where the contract's structure falls along the modular-integrated spectrum. A contract on the modular end of the spectrum will have maps of terms that primarily interact with other terms in the same cluster. On the other hand, a contract on the integrated end up the spectrum will have much more interaction between clusters. A designer can also use quantitative connectedness measures to identify the most critical terms in the contract's structure, such as central terms in conceptual subsystems.<sup>312</sup> For example, the term in a venture financing that governs the sale of preferred stock from the company to investors is a highly connected term that is critical to the structure of the overall deal system.<sup>313</sup>

Fourth, framing a contract as a complex system highlights the significance of factors outside of the contract for the contract's design. Complex systems theory emphasizes the importance of a system's environment, and this holds true in the context of contract systems as well. When designing a contract, a contract designer should take into account potential inputs from the contract's environment and how the contract will respond to those inputs. For example, a transactional lawyer drafting a force majeure clause should be aware of the set of triggering events that could potentially render either party unable to perform under the contract.

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<sup>310</sup>See Hwang & Jennejohn, *supra* note 2, at 281.

<sup>311</sup>See Hwang & Jennejohn, *supra* note 2, at 281.

<sup>312</sup>See Nat'l Venture Capital Ass'n Model Stock Purchase Agreement § 1.1, *Model Legal Documents* (July 2020), <https://nvca.org/recommends/nvca-2020-stock-purchase-agreement-2/>.

<sup>313</sup>*Id.*

Furthermore, systems analysis can aid contract designers in drafting contracts that are more resilient to exogenous shocks such as adverse judicial interpretations.<sup>314</sup> Restructuring a contract to eliminate unnecessary interactions between terms reduces the likelihood of an undesirable nonlinear response to an interpretive shock. Using interaction networks, a contract drafter can minimize the potential for cascade failure and thereby better protect their client.<sup>315</sup> Taking a systems approach to contract design also encourages contract designers to consider how an individual contract fits into the hierarchy of a higher order system, such as a network of interrelated contracts.<sup>316</sup> In M&A and venture capital deals, for example, transactional lawyers should design contracts not as standalone documents, but rather as components of multi-contract deal systems.<sup>317</sup>

Fifth, complex systems theory brings to light the critical role of transactional lawyers as the primary feedback mechanism in most contract systems.<sup>318</sup> Contract systems evolve as transactional lawyers update the design of the system based on environmental inputs.<sup>319</sup> If, however, the transactional lawyer does not update the contract based on environmental inputs, then the contract system's primary method of adaptation breaks down. For example, Mitu Gulati and Robert Scott documented how transactional lawyers in the sovereign debt industry continued to use a "pari passu" provision in sovereign debts contracts despite an adverse judicial interpretation that negatively changed the meaning of the term.<sup>320</sup> In addition, other scholars have noted that many modifications made to contracts by transactional lawyers are inefficient or harmful to client interests.<sup>321</sup> Framing transactional lawyers as feedback mechanisms in a contract system can help identify common systems solutions for responding to feedback issues. For example, one of the most common problems with a feedback mechanism is that the mechanism is not properly receiving the input from the environment and therefore cannot update the system accordingly.<sup>322</sup> This problem is evident in contract systems because the transactional lawyers who draft contracts are not the same lawyers who

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<sup>314</sup>See *infra* Sections IV.B and IV.C.

<sup>315</sup>See MITCHELL, *supra* note 106, at 255-57.

<sup>316</sup>See *supra* Section III.C.2.

<sup>317</sup>See *supra* Section III.C.2.

<sup>318</sup>See *supra* Section III.C.4.

<sup>319</sup>See *supra* Section III.C.4.

<sup>320</sup>See GULATI & SCOTT, *supra* note 51, at 2-3.

<sup>321</sup>See, e.g., Hill, *supra* note 51, at 60; see Anderson & Manns, *supra* note 71, at 61 (finding a high level of inefficient "editorial churning" in the evolution of merger agreements).

<sup>322</sup>See MEADOWS, *supra* note 111, at 51-58 (discussing the impact of information delays on feedback mechanisms).

litigate contracts. Scholars have noted that there is little interaction between drafters and litigators,<sup>323</sup> and that transactional lawyers lack the incentive to follow up with the litigation outcomes of contracts they draft.<sup>324</sup> As a result, providing transactional lawyers with better information on litigation outcomes and better incentives to stay informed would improve their ability to function as effective feedback mechanisms for contract systems.

### *B. Interpretation*

Judges who interpret contracts should take a complex systems approach to contract interpretation. First, as is the case with transactional lawyers who design contracts, judges will benefit from understanding a contract's systemic nature, including the interactions between terms and unique properties that emerge at the system level. When a judge interprets a term in a contract, the judge is not just interpreting that term. Rather, the judge is interpreting a component of a contract system that is potentially connected with many other terms via interaction networks and possibly yields one or more emergent properties. In most cases, the judge's interpretation decision will affect much more than the term at hand. For example, the interpretation of a term in a M&A or VC deal will likely affect other terms and even other contracts in the overall deal system. Interpreting interconnected deal documents as components of a higher-order deal system will increase the stability of individual terms because judges will be more mindful of potential ripple effects of term-level interpretation.<sup>325</sup> Furthermore, any contract law precedent that a judge establishes during interpretation will become part of the environment for future contract systems.

Fortunately, judges already engage in quasi-systems analysis on a regular basis. For example, when a judge is faced with a decision regarding whether two promises in a contract are independent or dependent, the judge is essentially analyzing whether the two terms are linked in the interaction network that represents constructive conditions within the contract system. Complex systems theory supplements current interpretive principles by providing an established and methodical framework for viewing contracts as complex systems. Framing interpretation within a systems context will help judges make decisions that more accurately reflect the systemic nature of contracts.

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<sup>323</sup>See GULATI & SCOTT, *supra* note 51, at 4.

<sup>324</sup>See Hill, *supra* note 51, at 69.

<sup>325</sup>Thank you to Cathy Hwang for this helpful point.

Second, the presence of interaction networks within a contract system is particularly important for judges making severability determinations. If a judge determines that a particular term is not enforceable, the judge can either invalidate the contract as a whole or "sever" (i.e., remove) the unenforceable term and enforce the remainder of the contract.<sup>326</sup> Severability determinations often turn on whether the unenforceable term in question is seen as integral to the contract.<sup>327</sup> If the term is too important to the overall contract, the judge will typically invalidate the entire contract.<sup>328</sup> On the other hand, if the term is relatively unimportant, the judge will often sever the offending term.<sup>329</sup> Contracts frequently contain a severability provision that states that the terms of the contract are severable and that a judge should always uphold the remainder of the contract in the event a term is found to be unenforceable.<sup>330</sup> Enforcing a contract without a critical term, however, can lead to cascade failure in which the absence of that term renders the remainder of the contract unable to function. Consequently, having an understanding of the interaction networks in a contract system and the connectedness of the terms can enable judges to make better severability determinations. All else equal, a more connected term is more likely to lead to cascade failure and is therefore less suitable for severance. Quantitative measures of connectedness, such as the degree or nearest-neighbor-degree of a term, can therefore help judges determine which terms can be properly severed and which terms cannot. Network analysis can also assist judges in determining whether to enforce a severability clause. If a severability clause would require a judge to enforce the remainder of a contract destined for cascade failure due to the removal of a key term, the judge should instead refuse to enforce the severability clause and invalidate the entire contract.

Third, complex systems theory informs the ongoing debate between textualist and contextualist interpretation.<sup>331</sup> Proponents of textualism argue for a "four corners" approach to contract interpretation in which judges should only consider the written text of the contract when making interpretation decisions.<sup>332</sup> Proponents of contextualism, on the other hand, believe that judges should look beyond the written contract to sources of

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<sup>326</sup>See DOUGLAS J. WHALEY & DAVID HORTON, CASES, PROBLEMS, AND MATERIALS ON CONTRACTS 704 (8<sup>th</sup> ed., 2019).

<sup>327</sup>*Id.*

<sup>328</sup>*Id.*

<sup>329</sup>*Id.*

<sup>330</sup>See Hwang & Jennejohn, *supra* note 2, at 325.

<sup>331</sup>See *supra* notes 43-45 and accompanying text.

<sup>332</sup>See *supra* notes 43-45 and accompanying text.

extrinsic evidence including industry standards and reputational norms.<sup>333</sup> In the context of complex systems, the textualism versus contextualism debate can be framed in terms of the boundary between the contract system and its environment. In this framing, textualism can be seen as a requirement that judges limit their interpretive analysis to the contract system and that any sources of evidence beyond the system's boundary be ignored. As a result, textualism views a contract as a closed system for purposes of interpretation.<sup>334</sup> Contextualism, on the other hand, allows judges to go beyond the contract system's boundary to consider environmental conditions.<sup>335</sup> In this way, contextualism views a contract as an open system for purposes of interpretation.<sup>336</sup> Given that contract systems are primarily open systems, contextualism allows judges to interpret contract systems as they exist in the real-world. Furthermore, contextualism enables judges to consider the role a contract system may play as a component of a higher order system, such as a venture capital or M&A multi-contract deal system. Textualism, however, requires a judge to artificially close an otherwise open system for interpretive analysis. As a result, contextualism is more closely aligned with the systemic nature of contracts.

Fourth, modeling a contract as a complex system provides a vehicle for using historical contract data to inform interpretation. Choi and Gulati have proposed a theory of contract interpretation in which judges consider a contract's history in a manner akin to statutory interpretation.<sup>337</sup> The evolution of a contract system's term state functions and interaction networks provide critical historical context for this theory of interpretation.<sup>338</sup> This historical data can be used to identify key periods of evolutionary change in the contract's history.<sup>339</sup> A contract system's evolution functions can offer valuable insights into how a contract's terms and interactions developed over time.<sup>340</sup> Furthermore, judges can examine the system's initial conditions to better understand the context in which the contract system was initially formed.<sup>341</sup> Historical analysis of a contract

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<sup>333</sup>See *supra* notes 43-45 and accompanying text. The Uniform Commercial Code explicitly adopts a contextualist approach to the interpretation of goods contracts. See *supra* note 55.

<sup>334</sup>See *supra* note 160 and accompanying text.

<sup>335</sup>See *supra* note 160 and accompanying text.

<sup>336</sup>See *supra* note 160 and accompanying text.

<sup>337</sup>See Choi & Gulati, *supra* note 58, at 1131-32, 1160-61.

<sup>338</sup>See *id.*

<sup>339</sup>See *id.*

<sup>340</sup>See *id.*

<sup>341</sup>See Choi & Gulati, *supra* note 58, at 1131-32, 1160-61.

system's initial conditions and evolution can assist judges in making historically informed interpretation decisions.<sup>342</sup>

### C. Analysis

In addition to contract design and interpretation, complex systems theory has implications for contract analysis, particularly for technologically enabled methods of contract analysis used by legal technology companies. This section discusses the implications of a systems approach to contracts for the following three contract analysis technologies: natural language processing, prediction, and computable contracts.

First, natural language processing ("NLP") is a form of statistical machine learning technology that enables computers to understand natural language communication, such as documents written in English.<sup>343</sup> NLP models are typically "trained" on large data sets of natural language documents.<sup>344</sup> Via this training, NLP models "learn" "to understand natural language text based on statistical relationships between components of the text such as individual words, groups of words, word sequencing, and physical layout features like paragraph breaks and page positioning."<sup>345</sup> Once trained, an NLP model can be applied to natural language documents outside the training set.<sup>346</sup> Numerous legal technology companies are using NLP to break natural language contracts down into their constituent terms.<sup>347</sup> While current NLP models are highly effective at decomposing natural language contracts, these models are often built from a reductionist perspective.<sup>348</sup> The goal of these technologies is to deconstruct otherwise unwieldy natural language contracts into structured term data.<sup>349</sup> Yet the individual terms of a contract system only tell part of the system's story. Without properly reflecting term interactions and emergent properties, NLP-based contract analysis technologies are inaccurately representing contract systems. Instead, legal technology companies should build NLP models from a systems perspective. Individual terms should not be viewed only as terms, but rather as components of the overall contract system. In

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<sup>342</sup>See *id.*

<sup>343</sup>See Williams, *supra* note 45, at 653.

<sup>344</sup>See Williams, *supra* note 45, at 653.

<sup>345</sup>See Williams, *supra* note 45, at 653.

<sup>346</sup>See Williams, *supra* note 45, at 653.

<sup>347</sup>See Williams, *supra* note 45, at 653-54. These companies include Contract Standards, eBrevia, Kira Systems, LawGeex, Legal Robot, and LegalSifter.

<sup>348</sup>See Williams, *supra* note 45, at 653-54

<sup>349</sup>See Williams, *supra* note 45, at 653-54.

addition to breaking natural language contracts down into their constituent terms, NLP models should be trained to identify the contract's interaction networks and emergent properties. Explicit textual interactions, such as cross-references and definitions, will be relatively easy to identify.<sup>350</sup> Conceptual interactions and emergent properties will be more difficult to identify, but NLP models are technologically capable of this task given that existing models are already being used to identify conceptual connections in natural language documents.<sup>351</sup> For example, researchers have developed NLP models for automatically detecting implicit semantic connections between civil code sections.<sup>352</sup> Systems-oriented NLP models will paint a more accurate picture of contract systems.

Second, complex systems theory can be used to improve machine learning-enabled contract prediction technologies. These technologies use machine learning models to statistically connect contract terms with contract outcomes such as litigation or arbitration.<sup>353</sup> These statistical insights can then be used to inform future contract design.<sup>354</sup> For example, if a term is identified to be more likely to result in costly litigation than similar alternatives, a contract drafter can replace the term with a less risky term in future iterations of the contract. While contract prediction technologies are still in a nascent stage of development, legal technology companies are actively building systems that identify connections between terms and outcomes.<sup>355</sup> As is the case with NLP models, however, statistical prediction models need to account for the systemic nature of contracts. Identifying statistical connections between individual terms and outcomes is insufficient and can potentially lead to inaccurate conclusions. For example, assume a prediction technology identifies that terms A and B are shown to increase the likelihood of a particular negative outcome (such as litigation). Using this information, a contract drafter may decide to remove term A and/or B from a future version of the contract. It may be the case, however, that neither term A nor term B is individually causing the negative outcome. Instead, the outcome could be caused by an

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<sup>350</sup>See Morayo Adedjouma, Mehrdad Sabetzadeh & Lionel Briand, *Automated Detection and Resolution of Legal Cross References: Approach and a Study of Luxembourg's Legislation*, 1-7 (2014).

<sup>351</sup>See Williams, *supra* note 45, at 670-71.

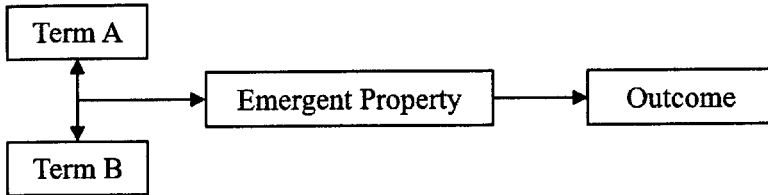
<sup>352</sup>See Jorg Landthaler, Bernhard Waltl & Florian Matthes, *Unveiling References in Legal Texts: Implicit Versus Explicit Network Structures*, 4-7 (2016).

<sup>353</sup>See Williams, *supra* note 45, at 631-34.

<sup>354</sup>See Williams, *supra* note 45, at 631-34.

<sup>355</sup>For example, Sirion Labs, a contract management technology company, enables its users to quantitatively track terms in their contracts that are linked to disputes, as well as the outcomes of those disputes and any associated costs. See Williams, *supra* note 45, at 651-52.

emergent property that results from the interaction of terms A and B as depicted in the following diagram.



As can be seen in the diagram above, the negative outcome is being driven by the emergent property. As a result, the contract drafter could reduce the likelihood of the outcome while still keeping terms A and B in the contract by removing the interaction between terms A and B that gives rise to the emergent property.

In addition to improving the accuracy of contract prediction technologies, complex systems theory can also help explain the statistical results produced by such models. Statistical machine learning models often take a "black box" approach in which they identify statistical connections between independent variables (terms) and dependent variables (outcomes) without specifying the nature of the relationship between these variables.<sup>356</sup> While black box models are useful for identifying statistical connections between contract terms and outcomes, they do not necessarily help contract drafters understand why these connections exist.<sup>357</sup> Modeling a contract as a complex system can shed light on statistical connections identified by prediction models. By modeling the nature and behavior of a contract system, a contract drafter will be better equipped to understand why the system produces certain results. Furthermore, with sufficient data on terms, interactions, and environmental conditions, a drafter can specify the contract system's evolution functions. These evolution functions will demonstrate how the contract system responded to past environmental shocks during key periods of system change. They can then be used as the starting point for predicting how the system will respond to future shocks.

Third, a complex systems approach to contracts promotes the development and adoption of computable contracts. Computable contracts (commonly referred to as "smart" contracts) are contracts that are both

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<sup>356</sup>See Williams, *supra* note 45, at 635.

<sup>357</sup>See Williams, *supra* note 45, at 688-89.



machine-readable and machine-executable.<sup>358</sup> Unlike natural language contracts, computable contracts are written in computer languages that are interpretable by machines.<sup>359</sup> Computable contracts can be thought of as pieces of software written to represent a contract in a machine-readable form. These contracts are becoming increasingly common with the advent of blockchain-enabled computable contracting platforms, such as Ethereum.<sup>360</sup> Computable contracts are an ideal method of representing the systemic nature of contracts. Each term in a contract can be coded as a function that represents the term's role in the overall contract system. Interactions between term functions can be directly and clearly represented in the contract's code, as can any resulting emergent properties. Unlike a traditional contract in which the system's architecture has to be deduced from imprecise natural language, the entirety of a computable contract system can be discerned from the contract's source code. With sufficient *ex ante* testing and debugging, a computable contract drafter can substantially reduce the likelihood of unintended consequences, such as cascade failure. The relationship between complex systems theory and computable contracts is mutually beneficial. Computable contracts are the most effective and accurate way of representing contracts as systems. At the same time, complex systems theory can inform the design of computable contracts so that drafters can fully harness the systems capabilities of contracts.

## V. CONCLUSION

Contracts have long been described as collections of terms that can be understood through their constituent parts. Yet this traditional reductionist approach has failed to accurately capture the systemic nature of contracts. A contract is much more complex than its individual terms would suggest. Seeking to paint a more accurate picture, this Article applied complex systems theory to contracts for the first time, arguing that a contract is a complex system that is greater than the sum of its terms. The article began by modeling a contract system using concepts drawn from complex systems theory. In this model, a contract system was represented as a coevolving multilayer network that exists within an

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<sup>358</sup>See Williams, *supra* note 45, at 656 (describing a contract as machine-readable if it is written in a language that is interpretable by a computer); see also Williams, *supra* note 45, at 656-58 (describing a contract as machine-executable if a computer can automatically execute the contract when supplied with real-world performance data).

<sup>359</sup>See Williams, *supra* note 45, at 657.

<sup>360</sup>See Williams, *supra* note 45, at 660-61. Ethereum enables users to "draft" computable contracts using Ethereum's contract-oriented programming language, Solidity.

environment that contains external conditions, such as contract law and norms. The Article then used this model to identify and discuss key properties of complex systems that are exhibited by contract systems, including organized complexity, hierarchy, emergence, adaptation, sensitivity to initial conditions, nonlinearity, and punctuated equilibria. The Article ended by discussing the implications of a complex systems approach to contracts for contract design by transactional lawyers, contract interpretation by judges, and contract analysis by legal technology companies.

This Article has laid the groundwork for further research on contract systems. First, empirical research is needed to demonstrate the applicability of the model developed in this Article to real-world contracts. For example, it would be illustrative to empirically construct the set of interaction networks that make up the multilayer network of a real-world contract system and then analyze the networks using network analysis techniques. In addition, historical contract data could be used to specify the evolution functions for a real-world contract to better understand how contracts evolve. Furthermore, empirical analysis of the complexity of different categories of contracts would shed light on what makes certain types of contracts more complex than others. Second, many of the contract system properties identified in the Article would benefit from additional attention and theorization. Third, further research into how complex systems theory can be applied to natural language processing, contract prediction, and the design of computable contracts would advance the implementation of these valuable contract technologies.

## VI. APPENDIX

Section A of the Appendix provides a formal presentation of the model discussed in Section III.B. Section B of the Appendix provides equations for the measures discussed in Section III.C.

## A. Model

Assume a contract system with  $n$  discrete terms. Each term  $i$  is represented in the model by a state function  $\sigma_i$  that gives the state of the term at time  $t$ :

$$\sigma_i(t) \text{ for all terms } i, 1 \dots n$$

There are  $m$  interaction types in the contract system. Each interaction type  $\alpha$  is represented in the model by an interaction network with a corresponding adjacency matrix  $M^\alpha$  that gives the state of the interaction network at time  $t$ :<sup>361</sup>

$$M_{ij}^\alpha(t) \text{ for all interaction types } \alpha, 1 \dots m$$

The contract is an open system that exists within an environment  $E$  that changes over time.

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<sup>361</sup>See THURNER ET AL., *supra* note 106, at 145-46. An adjacency matrix is a tool that can be used to quantitatively represent a network. An adjacency matrix is a grid in which the rows and columns correspond to the nodes in the network. If the network has  $n$  nodes, the corresponding adjacency matrix will have  $n$  rows and  $n$  columns. The element located in the matrix in the  $i$ th row and the  $j$ th column (indicated as  $(i,j)$ ) represents the interaction between node  $i$  and node  $j$ . For an undirected, unweighted network, if there is an interaction between node  $i$  and node  $j$ , the elements located in positions  $(i,j)$  and  $(j,i)$  will be equal to 1. If there is no interaction between node  $i$  and node  $j$ , then the elements located in positions  $(i,j)$  and  $(j,i)$  will be equal to 0. For example, assume an undirected, unweighted network with four nodes in which node One interacts with node Two, node Two interactions with node One, and nodes Three and Four do not interact with any nodes. The following adjacency matrix represents this network:

$$M = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

As can be seen above, the matrix has four rows and four columns corresponding to the four nodes in the network. The element located in the first row and the second column equals 1 because node One interacts with node Two. Similarly, the element located in the second row and the first column also equals 1 because node Two interacts with node One. All other elements in the matrix are equal to 0 because nodes Three and Four do not interact with any nodes and none of the nodes interact with themselves.

The initial conditions of the contract system at time  $t=1$  include the following:

- The states of the terms given by  $\sigma_i(t = 1)$  for all terms  $i, 1 \dots n$
- The states of the interactions given by  $M_{ij}^\alpha(t = 1)$  for all interaction types  $\alpha, 1 \dots m$
- The state of the environment given by  $E(t = 1)$

The term state function for each term  $i$  evolves according to an evolution function  $F_i^{Terms}$  that has as its parameters the states of the terms, interaction networks, and environment at time  $t$ :<sup>362</sup>

$$\frac{d}{dt} \sigma_i(t) = F_i^{Terms} \left( \sigma_1(t), \dots, \sigma_n(t), M_{ij}^1(t), \dots, M_{ij}^m(t), E(t) \right)$$

for all terms  $i, 1 \dots n$

The state of term  $i$  at time  $t+1$  is therefore given by:

$$\sigma_i(t + 1) = \sigma_i(t) + F_i^{Terms}(t) \text{ for all terms } i, 1 \dots n$$

The interaction network for each interaction type  $\alpha$  evolves according to an evolution function  $F_\alpha^{Interactions}$  that has as its parameters the states of the terms, interaction networks, and environment at time  $t$ :

$$\frac{d}{dt} M_{ij}^\alpha(t) = F_\alpha^{Interactions} \left( \sigma_1(t), \dots, \sigma_n(t), M_{ij}^1(t), \dots, M_{ij}^m(t), E(t) \right) \text{ for all interaction types } \alpha, 1 \dots m$$

The interaction network for interaction type  $\alpha$  at time  $t+1$  is therefore given by:

$$M_{ij}^\alpha(t + 1) = M_{ij}^\alpha(t) + F_\alpha^{Interactions}(t) \text{ for all interaction types } \alpha, 1 \dots m$$

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<sup>362</sup>The derivative notation used here should not be interpreted as an actual derivative, but rather as the change between discrete time periods. See THURNER ET AL., *supra* note 106, at 24.

### B. Measures

All of the following measures assume undirected, unweighted networks.

The total complexity of the contract system at time  $t$  is given by:<sup>363</sup>

$$\text{Total Complexity}(t) = \frac{\sum_{ij\alpha} M_{ij}^{\alpha}(t)}{2}$$

The average complexity of the contract system at time  $t$  is given by:

$$\text{Average Complexity}(t) = \frac{\sum_{ij\alpha} M_{ij}^{\alpha}(t)}{2n}$$

The complexity density of the contract system at time  $t$  is given by:

$$\text{Complexity Density}(t) = \frac{\sum_{ij\alpha} M_{ij}^{\alpha}(t)}{n(n-1)}$$

The degree of term  $i$  at time  $t$  is given by:

$$\text{Degree}_i(t) = \sum_{j\alpha} M_{ij}^{\alpha}(t)$$

The nearest-neighbor degree of term  $i$  at time  $t$  is given by:

$$\text{Nearest - Neighbor Degree}_i(t) = \frac{\sum_{j \text{ is neighbor of } i} \text{Degree}_j(t)}{\sum_{j \text{ is neighbor of } i} 1}$$

The change  $\Delta_i$  in term  $i$  between time  $t$  and time  $t'$  is given by:

$$\Delta_i(t' - t) = \sigma_i(t') - \sigma_i(t)$$

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<sup>363</sup>The following measures of complexity only account for complexity arising from interactions between terms. These measures do not account for interactions between the system and its environment.

Assuming that all terms in a contract system are represented by binary state functions, the total change in terms  $\Delta_{Terms}$  between time  $t$  and time  $t'$  is given by:<sup>364</sup>

$$\Delta_{Terms}(t' - t) = \sum_i |\Delta_i(t' - t)|$$

The change  $\Delta_\alpha$  in interaction type  $\alpha$  between time  $t$  and time  $t'$  is given by:

$$\Delta_\alpha(t' - t) = M_{ij}^\alpha(t') - M_{ij}^\alpha(t)$$

The total change in interactions  $\Delta_{Interactions}$  between time  $t$  and time  $t'$  is given by:

$$\Delta_{Interactions}(t' - t) = \frac{\sum_{ij} \sum_\alpha |\Delta_\alpha(t' - t)|}{2}$$

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<sup>364</sup>If the terms are represented by different types of state functions (binary, continuous, categorical, etc.), the changes in terms would need to be normalized before being aggregated. This is beyond the scope of this Article.