The Governance of Blockchain Dispute Resolution

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Blockchain technology acts as infrastructure for self-executing smart contracts. Because contracts are incomplete and some parties are opportunistic, these new contracting possibilities create dispute resolution challenges. For instance, will smart contracts be recognized, and any disputes resolved, within the existing territorial courts? In this Article, we first map some institutional governance possibilities for contracting parties (e.g. mediation, private arbitration, and courts) to create a Dispute Resolution Possibility Frontier (DRPF). Second, we provide case studies of emerging blockchain-based dispute resolution mechanisms. Blockchain-based smart contracts create a source of new disputes requiring resolution, but also can serve as a technology that facilitates new methods of dispute resolution, including for disputes arising from traditional legal contracts. Contracting parties will subjectively make tradeoffs for their most effective dispute resolution mechanism, and the costs of dispute resolution will change over time through a process of institutional innovation.

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I. Introduction

The fundamental difference between traditional legal contracts and smart contracts is around the enforcement of contractual terms.[1] Smart contractual terms are written into an executable programming language. This means that smart contracts are "automatically executing" in the sense that the agreed transaction or exchange will take place after the happening of an event or after a specified time period, for instance. While smart contractual terms are capable of being more dynamic, contractual performance is harder to reverse. For this reason, the introduction of automatically executing blockchain-based smart contracts will generate new types of legal disputes. The idea of smart contracts as protocols formalizing relationships over computer networks predates the emergence of blockchain-based technologies.[2] Nevertheless, in this Article we consider the case of smart contracts as pieces of code that run "on top of the blockchain." The adoption of blockchain-based smart contracts will require courts and other forms of dispute resolution bodies to grapple with several difficulties when smart contract disputes arise, including the interpretation of code, jurisdictional issues, and the application of traditional contract law principles.[3]

How will smart contract disputes be resolved after smart contracts have been executed? The answer to this dispute resolution question goes beyond whether smart contracts will be recognized and enforced by jurisdiction-based courts.[4] When parties draw up a smart

1. Primavera De Filippi & Aaron Wright, Blockchain and the Law: The Rule of Code (2018), at 74-75.

2. Nick Szabo, *Formalizing and Securing Relationships on Public Networks*, 2 First Monday (1997), https://firstmonday.org/ojs/index.php/fm/article/view/548 (last visited Jan. 10, 2020).

3. De Filippi & Wright, *supra* note 1; Kevin Werbach & Nicolas Cornell, *Contracts Ex Machina*, 67 Duke L.J. 313 (2017).

4. According to Sagewise database (2019), legislation has been introduced into several state legislatures in the United States of America–including Arizona

contract, they must determine how disputes will be resolved. We view the various ways that those disputes are resolved as a question of governance. Contracting parties must choose the most effective institutional governance mechanism to resolve their contractual disputes. The ways to govern a contract—that is, to minimize the costs of contracting and facilitating the exchange—include courts and arbitration. Furthermore, the range of institutional choices that parties face is open to institutional entrepreneurship, where those choices change through time as new mechanisms of dispute resolution are discovered, including the development of online dispute resolution services, or decentralized versions of dispute resolution.[5]

Our focus in this Article is on the governance choice that contracting parties face over smart contract dispute resolution, an inquiry that sits on the boundary of law, economics, and political economy. We can analyze the choice over these alternatives using institutional economics and new comparative economics. We have two aims: first, to outline a theoretical framework to understand that dispute resolution governance choice, and second, to provide case studies of new governance possibilities. Together with the emerging field of blockchain and dispute resolution,[6] we draw on new comparative economics—or the analysis of the choices between different institutional governance structures[7]—and "institutional cryptoeconomics," an emerging theoretical framework for understanding blockchain and other distributed ledger technologies as a new kind of economic institution competing with other organizational forms such as firms, markets and governments.[8]

(HB2417), Florida (H1357), Nebraska (LB695), New York (AB8780), Ohio (SB300), Tennessee (HB1507 and SB1662), and Vermont (S135)–that seek to recognize the legal validity of smart contracts.

5. See *infra,* Part IV.

6. *E.g.*, Jake Goldenfein & Andrea Leiter, *Legal Engineering on the Blockchain: "Smart Contracts" as Legal Conduct*, 29. L. CRIT. 141 (2018); Wulf A. Kaal & Craig Calcaterra, *Crypto Transaction Dispute Resolution*, 73 BUS. LAW. 109 (2017); Rikka Koulu, *Blockchains and Online Dispute Resolution: Smart Contracts as an Alternative to Enforcement*, 13 SCRIPTED 40 (2016); Amy J. Schmitz & Colin Rule, *Online Dispute Resolution for Smart Contracts*, 2019 J. DISP. RESOL. 103 (2019); Orna Rabinovich-Einy & Ethan Katsh, *Blockchain and the Inevitability of Disputes: The Role for Online Dispute Resolution*, 2019 J. DISP. RESOL. 47 (2019); James Metzger, *The Current Landscape of Blockchain-based Crowd Sourced Arbitration,* 19 MACQUARIE L.J. 81 (2019).

7. *E.g.*, Simeon Djankov, Edward Glaeser, Rafael La Porta, Florencio Lopez-de-Silanes, & Andrei Shleifer, *The New Comparative Economics*, 31 J. COMP. ECON. 595 (2003).

8. *E.g.*, Sinclair Davidson, Primavera De Filippi & Jason Potts, *Blockchains and the Economic Institutions of Capitalism*, 14 J. INST. ECON. 639 (2018). *See also* Chris

Our analysis proceeds as follows. In Part II we outline the nature of smart contracts as a contracting technology: How do smart contracts differ from traditional contracts? What problems do they create? In Part III we consider the choices faced by contracting parties and introduce a theoretical framework called the Dispute Resolution Possibility Frontier (DRPF). In Part IV we observe dispute resolution in practice through several emerging case studies, examining novel mechanisms of dispute resolution within the blockchain ecosystem. Part V outlines findings from the case studies. Part VI discusses the implications of our framework and findings, and Part VII concludes the Article.

II. Smart Contracts

For the purpose of this Article, we broadly define smart contracts as agreements—or parts of agreements—that are coded to operate within a decentralized or distributed blockchain network, and that can be automatically executed by that network when specific conditions are validated. For instance, a particular time period or the happening of a certain event might trigger a payment from an escrow to a party. While the concept of smart contracts dates back several decades,[9] there has been a renewed interest in smart contracts following the development of blockchain technology. Blockchain technology was developed a decade ago through a combination of several technologies including peer-to-peer networks, asymmetric (public key) cryptography, time stamping, and the proof of work consensus mechanism (i.e. an algorithm requiring a relatively large amount of computing power to solve but relatively simple to prove).[10] Specifically, blockchain is a suite of "digital technologies that combine cryptographic, data management, networking and incentive mechanisms to support the checking, execution and recording of transactions between parties."[11]

Berg, Sinclair Davidson, & Jason Potts, Understanding the Blockchain Economy: An Introduction to Institutional Cryptoeconomics (2019).

9. *E.g.,* Szabo, *supra* note 5

10. Satoshi Nakamoto, *Bitcoin: A Peer-to-Peer Electronic Cash System* (2008), http://bitcoin.org/bitcoin.pdf (last visited Jan. 8, 2020).

11. Mark Staples, Shiping Chen, Sara Falamaki, Alex Ponomarev, Paul Rimba, An Binh Tran, Ingo Weber, Sherry Xu, & John Zhu, *Risks and Opportunities for Systems Using Blockchain and Smart Contracts*, Data61 1, 2 (2017). https://www.data61.csiro.au/~/media/052789573E9342068C5735BF604E7824.ash (last visited Jan. 8, 2020).

Blockchain is an institutional governance technology that functions as an infrastructure for smart contracting platforms.[12] That is, blockchain acts as infrastructure for smart contracts to be executed across a distributed network (those nodes validating and updating the distributed ledger) rather than being executed and adjudicated by centralized organizations (such as a judicial system). Furthermore, information stored in blockchains are a new potential trusted source of information to trigger those contracts. Paul Catchlove summarizes four key features of smart contracts: (i) an electronic format, enabling functionality to be triggered digitally; (ii) a core conditional framework between contracting parties; (iii) Boolean logic providing a greater level of certainty because contract outcomes are binary; and (iv) a focus on performance that lowers the likelihood of opportunistic breaches.[13]

Smart contracts present a variety of opportunities for practical application. Philippa Ryan notes that "smart contracts can manage financial interactions between machines, vehicles, humans, regulators, government, and financial service providers."[14] Professor Joshua Fairfield discusses the potential for smart contracts for consumer protection in the online marketplace by enabling consumers to use a combination of smart contracts and automation to form and enforce contractual terms online.[15] In a recent book, two of this Article's authors, along with another colleague at RMIT University, examine the way that smart contracts could reshape political, corporate, and

12. Paul Catchlove, *Smart Contracts: A New Era of Contract Use*, SSRN (2018) https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3090226 (last visited Jan. 8, 2020); Goldenfein & Leiter, *supra* note 6; Guido Governatori, Florian Idelberger, Zoran Milosevic, Regis Riveret, Giovanni Sartor & Xiwei Xu, *On Legal Contracts, Imperative and Declarative Smart Contracts, and Blockchain Systems*, 26 ARTIFICIAL INTELLIGENCE LAW 377 (2018); Scott A. McKinney, Rachel Landy & Rachel Wilka, *Smart Contracts, Blockchain, and the Next Frontier of Transactional Law*, 13 WASH. J. L. TECH. & ARTS, 313 (2018); Reggie O'Shields, *Smart Contracts: Legal Agreements for the Blockchain*, 21 N.C. BANKING INST. 177 (2017); Max Raskin, *Law and the Legality of Smart Contracts*, 1 GEO. L. TECH. REV. 305 (2017); Philippa Ryan, *Smart Contract Relations in e-Commerce: Legal Implications of Exchanges Conducted on the Blockchain*, 7 TECH. INNOVATION MGMT. REV. 10 (2017); Werbach & Cornell, *supra* note 3.

13. Catchlove, *supra* note 12.

14. Ryan, *supra* note 12, at 15.

15. Joshua A.T. Fairfield, *Smart Contracts, Bitcoin Bots, and Consumer Protection*, 71 WASH. & LEE L. REV. 35 (2014).

organizational governance.[16] There are now a range of entrepreneurial efforts to develop smart contracting platforms for applications in regulatory technology[17] and in industries such as gambling[18] and supply chain management.[19] Smart contracts have also been proposed as an alternative to Online Dispute Resolution (ODR).[20] Smart contracts are important because greater trust from automating agreements might promote greater trade and exchange, particularly in the online environment. Indeed, Professor Joshua Gans argues that "by improving observability and reducing the costs of verification of contract obligation performance, the space of feasible contracts can be enlarged."[21]

The wide range of possible applications for smart contracts stems from their capacity to reduce opportunism. This reduction in opportunism comes from how blockchains industrialize trust.[22] Blockchains industrialize trust because their protocols convert energy into economically-valuable trust through complex computations and economic incentives. Blockchains are not trustless technologies but are better understood as trust machines. They represent the industrialization of trust, analogous to the industrial transformation. One way that blockchain-based smart contracts reduce opportunism is through stronger *ex ante* enforcement. Because the contractual obligations of smart contracts are written into code—and will be enforced in a decentralized way across a blockchain network—contracting parties can have greater confidence that performance will be carried out.

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16. Darcy W.E. Allen, Chris Berg & Aaron Lane, CRYPTODEMOCRACY: HOW BLACKCHAIN CAN RADICALLY EXPAND DEMOCRATIC CHOICE (2019); *see also* Darcy W.E. Allen et al., *Cryptodemocracy and its Institutional Possibilities,* REV. AUSTRIAN ECON. (2019).

17. Primavera De Filippi & Samer Hassan, *Blockchain Technology as Regulatory Technology: From Law is Code to Code is Law*, 21 FIRST MONDAY (2016), https://firstmonday.org/ojs/index.php/fm/article/view/7113/5657 (last visited Jan. 8, 2020).

18. Sally M. Gainsbury & Alex Blaszczynski, *How Blockchain and Cryptocurrency Technology Could Revolutionize Online Gambling*, 21 GAMING L. REV. 141 (2018).

19. Darcy W.E. Allen, Chris Berg, Sinclair Davidson, Mikayla Novak & Jason Potts, *International Policy Coordination for Blockchain Supply Chains*, 6 ASIA PAC. POL'Y STUD. 367 (2019).

20. Koulu, *supra* note 6; Pietro Ortolani, *Self-Enforcing Online Dispute Resolution: Lessons from Bitcoin*, 36 OXFORD J. LEGAL STUD. 595 (2016); Mykyta Sokolov, *Smart Legal Contract as a Future of Contracts Enforcement*, SSRN (2018), https://ssrn.com/abstract=3208292 (last visited Oct. 10, 2019).

21. Joshua S. Gans, *The Fine Print in Smart Contracts* (NBER Working Paper No. 25443), 1 (2019), http://www.nber.org/papers/w25443 (last visited Oct. 10, 2019).

22. Chris Berg, Sinclair Davidson & Jason Potts, *Bitcoin is a Three Sided Market*, SSRN (2019), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3074070 (last visited Oct. 10, 2019).

There are trade-offs in the selection of smart contracts over more traditional legal contracts. While smart contracts might limit the scope of hold-up—where one party invests in relationship-specific assets and the counterparty subsequently refuses to perform their end of the agreement unless the first party agrees to more favorable terms[23]—smart contracts also require agreements to be drafted into rules-based code. That code might have to refer to external data, provided by a third-party information source (popularly referred to as an "oracle"), to trigger the execution of the contract. Preferably those oracles—including temperature readings, prices of other goods or any other event relating to the contract—are reliable and can be predetermined in contract negotiation.

The idea of incomplete contracts recognizes that rarely is it possible for parties to consider every eventuality in contractual bargaining.[24] Given positive transaction costs, contracts are necessarily incomplete and cannot be comprehensive in nature. There are a range of underlying factors that make contracts incomplete. The main problem is limited knowledge over future states of the world (i.e. fundamental uncertainty) together with limited human cognitive power (i.e. bounded rationality).[25] Added to this underlying problem of uncertainty are potentially prohibitive transaction costs in negotiating future states of the world (it costs time and money to conceive legal risks and draft contracts accordingly), and then at the contract enforcement stage (future states might be difficult to prescribe, measure, or assess when they arise). Even when transaction costs are low, contracts may be deliberately incomplete for other strategic reasons.[26]

Any contract that is not a complete contract will potentially result in disputes if questions of performance arise. Compared to traditional contracts, smart contracts may economize on costs of enforcement, but smart contracts also impose potentially greater

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23. See, *e.g.,* Richard Holden & Anup Malani, *Can Blockchain Solve the Holdup Problem with Contracts?* (NBER Working Paper No. 25833) (2018), https://www.nber.org/papers/w25833 (last visited Jan. 1, 2020); Ryan, *supra* note 12.

24. *See, e.g.,* Sandford J. Grossman & Oliver D. Hart, *The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration*, 94 J. POL. ECON. 691(1986); Oliver D. Hart & J Moore, *Property Rights and the Nature of the Firm*, 98 J. POL. ECON. 1119 (1990).

25. *See, e.g.,* Herbert A. Simon, MODELS OF A MAN: ESSAYS IN MEMORY OF HERBERT A. SIMON, MIT Press (2004).

26. *See, e.g.,* B. Douglas Bernheim & Michael D. Whinston, *Incomplete Contracts and Strategic Ambiguity*, 88 AM. ECON. REV. 902 (1998); Sarath Sanga, *Incomplete Contracts: An Empirical Approach*, 34 J. LAW. ECON. ORG. 650 (2018).

costs of negotiating agreements. On this point, Jeremy Sklaroff proposes that "smart contracts create negotiation costs by requiring parties to fully and precisely define all future states of the contract" and "smart contracts raise the costs of responding to breach by removing enforcement flexibility."[27] Accordingly, while blockchain and smart contracts may make more contracts or parts of contracts complete, the problem of incomplete contracts will persist.

The codified nature of smart contracts does not square easily with incomplete contracts, leading to dispute resolution challenges. For example, what happens if the code does not execute in accordance with the intention of the contractual agreement due to unforeseen circumstances frustrating the agreement? What happens if the contract assumes that an event will take place that does not actually occur? What happens if an "oracle" used to measure or verify performance ends up malfunctioning or getting corrupted? What happens if there is difficulty in understanding the coding language and its implications for contractual interpretation?[28] Accordingly, there remains a fundamental question about how smart contractual disputes will be resolved *ex post*.

At present, there are two different approaches to dispute resolution for smart contracts. The first approach accepts that smart contracts can operate within the existing contract law framework, and can be adjudicated by the courts or existing Alternative Dispute Resolution (ADR) procedures.[29] In this way, a smart contract "allows parties to more credibly commit to original contracts" with the benefit of avoiding potential hold-up problems.[30] This approach could be extended to other problems of contractual performance and enforcement. This approach is supported by credible jurisprudence: ordinary contractual principles should apply unless the common law develops—and there has been no case law to date.[31]

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27. Jeremy Sklaroff, *Smart Contracts and the Cost of Inflexibility*, 166 U. PA. L. REV. 263, 277 (2017).

28. Governatori et al., *supra* note 12.

29. *E.g.,* De Filippi & Wright, *supra* note 1; Governatori et al., *supra* note 12; Holden & Malani, *supra* note 23; Raskin, s*upra* note 12; Sokolov, *supra* note 20.

30. A hold-up problem exists where one party to a contract makes a relationship-specific investment (e.g. purchasing equipment that is more valuable to the contracting parties than to non-parties to the contract) and the counterparty, opportunistically, threatens to breach the contract unless additional conditions are agreed to (e.g. a higher contract price), see Holden & Malani, *supra* note 23, at 24.

31. O'Shields, *supra* note 12; McKinney et al., *supra* note 12.

The second approach contemplates smart contracts as distinct legal tools, rather than digital alternatives to traditional legal contracts. From this perspective, blockchain technologies and smart contracts may create new legal systems, or a new *Lex Cryptographia*.[32] In this approach, Professor Wulf A. Kaal and Professor Craig Calcaterra, in a joint article, contend that several characteristics of blockchain-based technologies and smart contracts, such as its anonymity, automatic execution, and tamper-resistance, mean that "existing legal infrastructure cannot address legal challenges presented by crypto transaction disputes."[33] Instead these disputes might require a "distributed jurisdiction"—that is, blockchain-based governance.[34] Such a distributed jurisdiction would need to be developed and created through a process of institutional innovations (the case studies presented in this Article provide several examples). Smart contracts extend the possible forms of governance that contracting parties have open to them, raising questions of whether they will provide a superior contracting alternative.[35]

These two visions have advantages and limitations. While a contract law framework may provide legal certainty supported by established jurisprudence, it may not be able to capture the distinctive properties of smart contracts, such as self-execution. Conversely, a new *Lex Cryptographia* would be able to consider such properties as core elements in a new regulatory regime whose parameters are still subject to discussion and uncertainty. In the following section, we suggest a unified framework that integrates both approaches to the smart contract dispute resolution problem. This framework recognizes that individual parties to a contract face an institutional governance choice over dispute resolution alternatives. The most effective governance solution will depend on the precise nature of the contract they are facing, while the options open to them are not fixed, and are themselves open to institutional innovations.

III. The Dispute Resolution Possibility Frontier

How can we develop a coherent theoretical understanding of the range of dispute resolution governance choices available to contracting parties? We draw on new comparative economics to apply

32. De Filippi & Wright, *supra* note 1; *see also* De Filippi & Hassan, *supra* note 17; Koulu, *supra* note 10; Mark Versstraete, *The Stakes of Smart Contracts*, 50 Loy. U. Chi. L.J. 743 (2018); Werbach & Cornell, *supra* note 3.

33. Kaal & Calcaterra, *supra* note 6, at 4.

34. *Id.,* at 1.

35. Werbach & Cornell, *supra* note 3.

the Institutional Possibility Frontier (IPF)[36] to this dispute resolution governance problem. Our new framework—what we call the Dispute Resolution Possibility Frontier (DRPF)—demonstrates the governance trade-offs in terms of disorder costs (i.e. the risk that costs are imposed by private actors such as a counterparty) and dictatorship costs (i.e. the risk that costs are imposed through the exercise of state power) over dispute resolution systems and enables integration of new decentralized governance structures. This framework unifies the two visions of dispute resolution outlined above within a coherent framework. In this section we map a DRPF, before turning to new blockchain dispute resolution start-ups in Part IV.

As we have argued earlier, contracts are necessarily incomplete because of uncertainty. This incompleteness leads to *ex post* contracting problems. For centuries societies have developed mechanisms to lower the costs of contracting to facilitate voluntary exchange and coordination. From irrigation systems to fishing villages, Nobel Laureate Elinor Ostrom described a range of collectively developed institutions that helped overcome the tragedy of the commons.[37] Indeed, the tragedy of the commons can be understood as a type of coordination or contracting failure where individuals were thought to be incapable of forming institutions to prevent the overconsumption of a resource. The common property regimes that Ostrom studied suggests that individuals can create unique institutional structures—contracts—to overcome their challenges.

More recently, Edward Stringham shed light on a range of private governance mechanisms that were discovered to solve governance challenges from the earliest stock exchanges to modern credit card fraud.[38] These governance structures include the creation of companies and employment contracts, reputation mechanisms that enable social ostracism, and state-enforced common law and court systems. The institutional economics perspective on governance views different governance structures—including firms, markets, clubs, commons and blockchains—as different ways to minimize the transaction costs of exchange.[39]

While smart contracts might limit hold-up problems and some other forms of opportunism, they might also exacerbate problems of

36. *See* Djankov et al., *supra* note 7.

37. Elinor Ostrom, Governing the Commons: The Evolution of Institutions for Collective Action (1990).

38. Edward Stringham, Private Governance: Creating Order in Economic and Social Life (2015).

39. Oliver E. Williamson, The Economic Institutions of Capitalism (1985).

dispute resolution, particularly for enforcing resolutions. Do existing governance structures effectively solve smart contract disputes? There are frictions between existing mechanisms of dispute resolution and disputes over the execution of smart contracts. For instance, how would a traditional dispute resolution outcome be enforced in code? Unless dispute resolution clauses were written into the code of a smart contract when it was drafted—for instance a clause that refers to a dispute resolution as an "oracle"—then the resolution will need to be enforced through some other mechanism. In contrast to Kaal and Calcaterra,[40] we propose that there are several ways in which existing dispute resolution mechanisms could feed into smart contracts. One possibility is the emergence of open legal or technical standards that enable external dispute resolution to trigger or reverse smart contracts (for instance, where the resolutions from dispute resolution mechanisms are released in a specified machine-readable format that can interact with the smart contracts they refer to). Such legal standards would be necessary to enable general dispute resolution clauses in smart contracts that do not rely on one specific court or jurisdiction, enabling greater flexibility.

We do not emphasize or advocate for any one institutional possibility of dispute resolution. Rather, our approach is to map and arrange some governance choices open to contracting parties. To do so we use the Institutional Possibility Frontier (IPF) framework from new comparative economics.[41] The IPF is based on the notion that all institutions trade-off between two types of costs: disorder costs and dictatorship costs. Disorder costs arise from private expropriation or a failure to coordinate. Dictatorship costs arise from public expropriation. No institutional possibility perfectly minimizes these costs, and each has comparative advantages with respect to addressing particular governance problems.

To form our Dispute Resolution Possibility Frontier (DRPF) we have mapped and described four institutional possibilities: private orderings, arbitration, courts and the regulatory state. The costs underpinning any IPF are inherently subjective because they are based on individual judgements—that is, there is not objective society-wide valuation of an IPF.[42] Therefore, the way that we have ordered these institutional possibilities is based on our subjective judgements of the

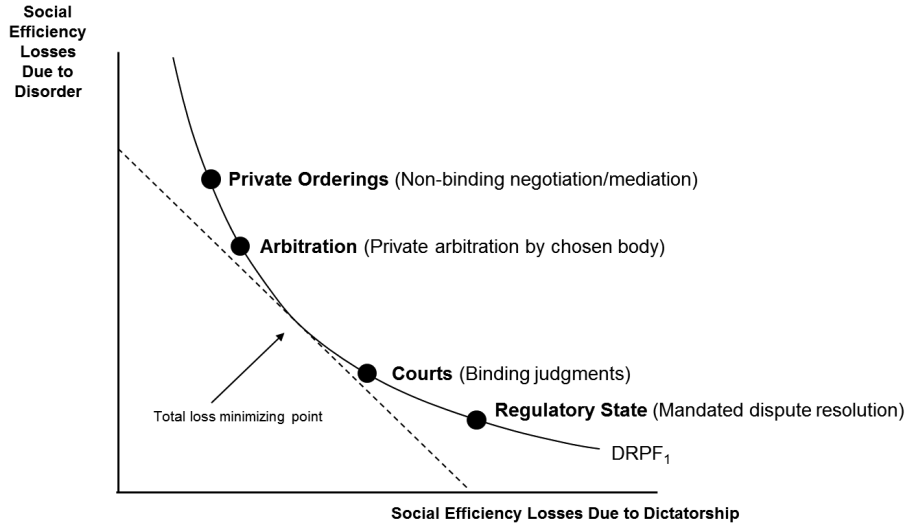
40. Kaal & Calcaterra, *supra* note 6.

41. *See* Djankov et al., *supra* note 7; Andrei Shleifer, *Understanding Regulation*, 11 Eur. Fin. Mgmt. 439 (2005); Darcy W.E. Allen & Chris Berg, *Subjective Political Economy*, 13 New Persp. Pol. Econ. 19 (2017).

42. Allen & Berg, *supra* note 41.

relative dictatorship and disorder costs of each mechanism. Analyzing these institutions in terms of disorder costs and dictatorship costs enables us to see how existing dispute resolution mechanisms assist with smart contract disputes, thereby enabling *ex post* dispute resolution, such as the splitting of escrow funds, or a full reversal of a contract. The theoretical ordering of these possibilities into a DRPF is useful because it enables us to interpret the potential governance choices of contracting parties, based on the notion that parties will choose what they perceive to be the cost-minimizing point that is closest to the origin.

FIGURE 1. The Dispute Resolution Possibility Frontier



What are some of the potential institutional dispute resolution options for smart-contracting parties?

Non-binding negotiation or mediation. Parties could insert within a smart contract that they will seek to undertake non-binding resolution mechanisms if disputes arise. This is non-binding negotiation or mediation. Negotiation is bilateral, between disputing parties, while mediation always involves a third independent party acting as a facilitator. Theoretically, there is a high level of disorder costs associated with both two-sided negotiation and third-party mediation, in particular because the agreements are non-binding (that is, the success of these mechanisms requires the mutual consent of the parties) and therefore hold-up problems remain. Furthermore, given that both mechanisms are non-binding, their outcomes would not feed back into the smart contract and execute automatically.

Binding private arbitration by a chosen body. Parties could specify an arbitrator to resolve disputes. In conventional arbitration, the arbitrator will make a ruling on issues as they see fit.[43] Interestingly, this institutional possibility could be theoretically binding because the output of the dispute could feed back into the smart contract as an "oracle." For such an approach to be effective, however, the outcomes of the arbitration would need to be standardized so that they can be executed automatically. In this way we would expect this institutional possibility to have lower disorder costs (given the reduction in capacity of individuals to hold-up or disregard the outcome of dispute resolution), but higher levels of dictatorship costs (due to the more centralized powers of the arbitrator).

Territorial courts with binding judgements. There are several ways that resolutions or judgements within traditional territorial court systems could be binding. One possibility is that if a smart contract is recognized as a contract within a court—and the contracting parties have agreed on a legal jurisdiction—then dispute resolution could be enforced through the conventional means of the state (e.g., seizure of property). We anticipate many challenges to traditional enforcement including contracting parties existing across multiple jurisdictions, that the smart contract itself was executed over a distributed network (rather than in one jurisdiction), that parties might be pseudonymous (or anonymous), and that courts may lack the technical capabilities to transfer or seize cryptocurrency without a party's consent. Rather than smart contracts relying on territorial judgements and enforcement, smart contacts could use territorial judgments as "oracles," enabling the decentralized blockchain network to compute and enforce those judgements through code. As with the "binding private arbitration" institutional possibility, outlined above, territorial courts would resolve disputes and provide input for the smart contract, lowering the potential for hold-up. However, an ongoing practical challenge is that court orders would require specific standards to be machine-readable and machine-computable so that the blockchain platform can read the judgement and execute its orders.[44] Compared to "binding private arbitration," we propose that

43. Less commonly, "pendulum" or "final offer" arbitration is another method of arbitration where the arbitrator decides the outcome by choosing between the alternatives presented by the parties. For a comparison of the two methods *see e.g.*, Cary Deck & Amy Farmer, *Bargaining Over an Uncertain Value: Arbitration Mechanisms Compared*, 23 J. LAW ECON. & ORG. 547 (2006).

44. The International Organization for Standardization has a technical committee for developing standards for blockchain and distributed ledger technologies, including a working group on smart contracts. *See, e.g.*, International Organization for

the substantial uncertainty around how territorial courts could consider and recognize blockchain smart contracts represents an increase in dictatorship costs.[45] For smart contract enforcement, the magnitude of such dictatorship costs is widely unknown. This uncertainty stems from the fact that, to date, there has not been any substantive judicial consideration of smart contract disputes around the world. Despite the "inevitability" of such disputes arising,[46] a decision in one jurisdiction will not necessarily be binding in another.[47]

Nevertheless, this institutional possibility features comparatively higher dictatorship costs because judges and other judicial officers are appointed by the state (as opposed to the agreement of the parties) and legal proceedings are governed by the state's prescribed civil procedure and evidentiary rules (as opposed to more informal and flexible ADR procedure). Fundamentally, dictatorship costs are comparatively higher because territorial courts exercise state power through compelling witnesses and documents under the threat of detention and through the expropriation of private property.

Our final demonstrative institutional possibility is the **regulatory state**. Under this option, an existing administrative body could mandate one type of dispute resolution mechanism. For instance, an existing territorial government could require smart contracts that are agreed to within their jurisdiction to include code that mandates dispute resolution in a territorial court. Essentially, this approach uses a government agency to affect the way that smart contracts operate (in code). There are parallels here to contemporary debates around encryption and governments creating a "back-door" to encrypted data. In the United States, several state jurisdictions have passed specific regulations around blockchain and smart contracts[48] and it is possible that mandated terms may become a feature of future regulatory regimes.[49] However, there are several costs relating to this institutional possibility of governments mandating dispute resolution clauses. The first is the potential for government abuse.

Standardization, *TC/307 Blockchain and Distributed Ledger Technologies* (2019), https://www.iso.org/committee/6266604.html (last visited Sep. 26, 2019).

45. O'Shields, *supra* note 12; Kaal & Calcaterra, *supra* note 6.

46. Rabinovich-Einy & Katsh, *supra* note 6.

47. *E.g.*, Mortimer N. S. Sellers, *The Doctrine of Precedent in the United States of America*, 54 Am. J. Comp. L. 67 (2006).

48. *See e.g.,* Kaal & Calcaterra, *supra* note 6.

49. Presently, it appears that the intention of specific smart contract legislation is to provide legal certainty as part of "crypto-friendly" policy settings. *See, e.g.,* Mikayla Novak & Anastasia Pochesneva, *Toward a Crypto-Friendly Index for the APEC Region,* 2 JBBA 1 (2019).

Governments requiring code within smart contracts (including the possibility to reverse automatically executing contracts) represent a kind of dictatorship costs (including the potential for government expropriation of digital assets). The second cost is that government mandates around dispute resolution represent a "one-size-fits-all" solution to the problem of dispute resolution, prohibiting entrepreneurial experimentation around other institutional possibilities and hindering the potential for discovery and innovation in dispute resolution.

We have outlined a range of potential paths forward for disputes arising from blockchain-based smart contracts. Each of these governance structures has different characteristics and will be suited to different types of contacts. Indeed, the contracting parties must themselves choose what dispute resolution mechanism will best satisfy the nature of their contract when they draft a smart contract. Drawing on the DRPF we have outlined, they will choose mechanisms that they believe minimize both dictatorship and disorder costs. However, the institutional possibilities for dispute resolution are not fixed, and the invention and application of new technologies enable new points closer to the origin (that is, a governance solution that minimizes both dictatorship and disorder costs) to be discovered. In the following section we turn to the potential for new institutional possibilities of dispute resolution enabled through blockchain.

IV. Blockchain Dispute Resolution Start-Ups

Blockchain might not just create economic and legal challenges—through the tensions of code and incompleteness of contracting—but might also incentivize and facilitate new dispute resolution institutional possibilities. For instance, there is the potential to create new private decentralized dispute resolution mechanisms. Below we outline brief case studies that build on the work of other scholars who have examined blockchain protocols for Online Dispute Resolution (ODR).[50] We also rely on available information from the websites of the start-ups we examine below (Mattereum, LTO Network, Sagewise, Kleros, Blockchain Arbitration Forum, Jury.Online, Enigma, and Monetha), which varies in analytical quality. While the purpose of most of the literature is predominantly promotional, some of these organizations have released concept papers that provide case studies and scenarios for dispute resolution.

50. *See, e.g.*, Kaal & Calvaterra, *supra* note 6; Schmitz & Rule, *supra* note 6; Rabinovich-Einy & Katsh, *supra* note 6; Metzger, *supra* note 6.

A. *Mattereum*

Mattereum—a legal-tech firm comprised of lawyers, cryptographers and software engineers—presents itself as providing "the legal, technical and commercial infrastructure layer for the on-chain property transfer and control."[51] On-chain transactions are those that take place and value is exchanged on the blockchain network. Mattereum supports a decentralized commercial law system, the Smart Property Register, that executes through automated smart contracts that ensure property rights, as well as dispute resolution and enforcement. This register facilitates the "on-chain property transfer" through a smart contract that in effect becomes a "legal contract" without the need for legislative support.

The contract protocol is based on the notion of "Ricardian Contracts,"[52] defined as "smart APIs for the legally-enforceable transfer of property rights" that "serve as the glue between the complex and bureaucratic legal world and the fast-moving digital world of data."[53] The focus is on dispute avoidance by setting a system whereby an "automated custodian" becomes the legal owner and registrar of an asset for the duration of the contract which makes enforcement easier. Nevertheless, Mattereum also acknowledge that issues with enforcement will remain and therefore propose that "technically competent mediators" will resolve any remaining disputes.[54] In another post in 2017, Mattereum's CEO Vinay Gupta announced the establishment of a "decentralized commercial arbitration court" that "is recognized as an arbitration court under the 1958 New York Convention, and can therefore make legally binding awards that will be enforced by national courts in nearly all of the countries in the world."[55]

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51. Mattereum, *Summary White Paper* (2018), https://mattereum.com/upload/iblock/784/mattereum-summary_white_paper.pdf (last visited Jan. 8, 2020).

52. *See* Ian Grigg, *The Ricardian Contract*, PROCEEDINGS OF THE FIRST INTERNATIONAL WORKSHOP ON ELECTRONIC CONTRACTING (2004), https://ieeexplore.ieee.org/document/1319505 (last visited Jan. 8, 2020).

53. Liza Simonova, *What Will the Partnership Between Mattereum and Ocean Protocol Foundation Involve and Why is it Important*, MEDIUM (Dec. 20, 2017) https://medium.com/humanizing-the-singularity/what-will-the-partnership-between-mattereum-and-ocean-protocol-foundation-involve-and-why-is-it-aa97c3c4664e (last visited Jan. 8, 2020).

54. *Id*.

55. Vinay Gupta, *The First Mattereum Briefing*, MEDIUM (Dec. 15, 2017), https://medium.com/humanizing-the-singularity/the-first-mattereum-briefing-11a67c75d840 (last visited Jan. 8, 2020).

Mattereum reports a case study in partnership with Ocean Protocol (OP), the artificial intelligence data and services provider platform, demonstrating the integration (rather than add-on) of a dispute resolution mechanism within the smart contract itself. First, the study maps out the stakeholders and functions of the OP ecosystem. Then, it presents a newly created role (the "adjudicator") and details how adjudication processes can be positioned within the system. As such, dispute resolution becomes a layer of governance that coheres with already-established charters, mission, goals and principles. The established OP ecosystem had five actors, or stakeholders, to which the Adjudicator role was added. These Adjudicative roles were given four "elements" to decide disputes: (i) evidence including contract verification data; (ii) escalation options ranging from mediation to adjudication; (iii) decision-making; and (iv) enforcement (e.g. the redistribution of "staked tokens"). The fundamental function of this built-in dispute resolution system is to provide a "layer of governance over rules and code" that can be added in a flexible way to markets and sub-markets.[56]

B. *LTO Network*

LTO network is a Dutch start-up launched in 2014.[57] The LTO platform creates a Ricardian "live contract" on a private blockchain.[58] A live contract is similar to a smart contract as embedded in the Ethereum platform in that the code follows an automated logic and can be executed in a "trustless and verifiable" way.[59] It differs from a smart contract in that smart contracts contain the exchange of value that is "unlocked" when conditions are met, while live contracts do not contain value but outline how two or more parties may "interact."[60] For example, a non-disclosure agreement is performed differently under a live contract as it would be impractical to retain the full penalty for breach of such an agreement as a deposit.[61]

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56. Reuben Thomas, *Mattereum Adds Dispute Resolution to Ocean Protocol's Distributed Data Marketplace*, MEDIUM (Aug. 17, 2018), https://medium.com/humanizing-the-singularity/mattereum-adds-dispute-resolution-to-ocean-protocols-dsitributed-data-marketplace-de474b617c9b (last visited Jan. 8, 2020).

57. LTO Network, *About LTO Network* (2019), https://lto.network/ (last visited Jan. 8, 2020).

58. LTO Network, *Blockchain for Decentralized Workflows* (2018), https://lto.network/documents/LTO%20Network%20-%20Technical%20Paper.pdf (last visited Jan. 8, 2020).

59. *Id*.

60. *Id*.

61. *Id*.

Another important difference between live contracts and smart contracts running on blockchains lies in the logic of oracles. Oracles feeding data to smart contracts are not part of the internal logic of the contract. In live contracts, however, oracles are embedded in the LTO workflow system of contract execution workflow so they "may be validated, and possibly disputed, by all parties involved."[62] In addition, the LTO workflow enables the creation of "deviations" (subflows in a given scenario) by any of the parties. These deviations may be proposed "to dispute the correctness of a previous event and present a solution on how to correct that," so in practical terms they "can be used to resolve disputes" if parties agree on them.[63] The platform also foresees off-chain dispute resolution (i.e. outside the blockchain network) via negotiation or intervention of an authoritative third party (mediation, and adjudication by an arbiter or judge).

C. *Sagewise*

Sagewise is a dispute resolution service founded in 2017. Sagewise's selling point is that smart contracts could be jeopardized by a lack of an amendment facility, providing hypothetical scenarios where underlying code inadequacies can generate disputes. Sagewise leverages an SDK (Software Development Kit) protocol embedded into the smart contract.

The Sagewise SDK offers an amendment software in anticipation of issues such as: (i) the variable quality of smart contract code; (ii) the lack of technical knowledge by contract stakeholders; (iii) grey areas and unforeseen complications, and (iv) potentiality for conflict and requirement for arbitration.[64]

SDK provides systematic alerts by monitoring the stages of contract execution. It provides notifications of milestones and has a mechanism for "freezing and upgrading defective or outdated smart contracts."[65] Parties can use the Sagewise toolkit to resolve coding errors and security vulnerabilities, and to amend, terminate or dispute smart contracts. Disputes can be resolved by the third party established in the smart contract. The third party first decides who

62. *Id*.

63. *Id*.

64. See Jonathan Sheiber, *Sagewise Pitches a Service to Verify Claims and Arbitrate Disputes Over Blockchain Transactions*, TechCrunch (Aug. 3, 2018), https://techcrunch.com/2018/08/03/sagewise-pitches-a-service-to-verify-claims-and-arbitrate-disputes-over-blockchain-transactions/.

65. *Id*.

bears the loss in the event of a dispute and then enables the immediate execution of the resolution.

D. *Kleros*

Kleros, founded in 2017, proposes Crowdsourced Online Dispute Resolution (CODR) as a justice mechanism combining the "technologies of crowdsourcing, blockchain and game theory."[66] Noting historical practices of justice such as the Athenian *kleroterion* of randomized crowdsourcing, Kleros advocates for an opt-in court platform that uses "crowdsourced jurors," a precedent for which can be found on eBay Community Court.[67]

Kleros operates as a decentralized third-party platform built on top of Ethereum.[68] First, smart contracts have to designate Kleros as their arbitrator in case of dispute, including the type of court (Kleros is developing an ecosystem of specialized courts) and the number of jurors to be involved.[69] When a dispute arises, Kleros randomly assigns the dispute to a jury of crowdsourced, self-selected experts, who will analyze the evidence and vote for a verdict. A smart contract will then transfer the money to the winning party. Oracles are engaged to provide real-world data to assist dispute resolution.

The platform also relies on anonymity and procedures that are information-based, with in-built mechanisms to correct bias and provide decision rationales. As such, their framework emphasizes: (i) adjudicator expertise in dispute resolution and law; (ii) independence (neutral and anonymous adjudicators); (iii) impartiality (random selection of judges without vested interests); and (iv) transparency (all procedures are documented and rationalized).

E. *Blockchain Arbitration Forum*

The Blockchain Arbitration Forum (BAF), founded by a group of law and technology experts in 2018, is a stand-alone service that provides template smart contracts (with arbitration and mediation clauses) in addition to a pool of Forum members with the expertise to arbitrate disputes. BAF frames these services as ADR mechanisms as

66. Clément Lesaege & Federico Ast, *Kleros: Short Paper v.1.0.6* (2018), https://kleros.io/assets/whitepaper.pdf (last visited Jan. 8, 2020).

67. Colin Rule & Chittu Nagarajan, *Crowdsourcing Dispute Resolution Over Mobile Devices, in* MOBILE TECHNOLOGIES FOR CONFLICT MANAGEMENT: ONLINE DISPUTE RESOLUTION, GOVERNANCE, PARTICIPATION, 93 (Marta Poblet ed., 2011).

68. Lesaege & Ast, *supra* note 66.

69. *Id*.

they offer a flexible approach to tailoring dispute formats and allocating judges based on the prevailing conditions and needs of counterparties to a contract.[70]

BAF also offers a "Smart Contract Arbitration Library" which consists of a set of coded rules (based on United Nations Commission on International Trade Law (UNCITRAL) arbitration rules) that allow counterparties to pause, resume, modify and terminate a smart contract.[71] Additionally, the Arbitration Library connects the software with human beings acting as arbitrators. The breach of a contract provides an example of how the automated mechanism works:

> One party which considers the other party to be in a breach of the legal contract pauses the execution of the Smart Contract by triggering a function *pauseAndSendToArbitrator* in the Arbitration Library. This function automatically notifies a so-called Appointing Authority defined in the Blockchain Arbitration Rules.[72]

F. *Jury.Online*

Jury.Online supports investments in Initial Coin Offering projects (a form of capital fundraising using cryptocurrency) by essentially providing a decentralized escrow service accompanied with a mechanism for digital mediation.[73] This facility is a smart contract that executes and addresses potential disputes according to predefined specifications.

The dispute resolution component operates as follows: when counterparties agree to a contract, the conditions and funding (as well as cost allocations) for potential disputes are also agreed upon. When disputes arise, a "panel of jurors," judge(s), or a single arbitrator is called upon and selected from a "pool" of experts. Potential judges are "experts" who have submitted their qualifications to be part of a "pool." These are continuously updated to contain "active

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70. *See* "Dispute Resolution," BLOCKCHAIN ARBITRATION FORUM (2018), http://blockchainarbitrationforum.org/ (last visited Jan. 8, 2020).

71. Michael Reuter, *CodeLegit Conducts First Blockchain-based Smart Contract Arbitration Proceeding* (2017), http://codelegit.com/2017/07/16/codelegit-conducts-first-blockchain-based-blockchain-arbitration-proceeding/ (last visited Jan. 8, 2020).

72. CodeLegit, *CodeLegit White Paper on Blockchain Arbitration* (2017), https://www.academia.edu/36257030/CodeLegit_White_Paper_on_Blockchain_Arbitration (last visited May 23, 2019).

73. Jury.Online (2020), https://jury.online (last visited Jan. 8, 2020).

judges." When a dispute emerges, potential jurors or judges are randomly selected and anonymously and independently consider the relevant evidence. Each judge makes a decision which is encrypted and then aggregated to form a majority decision. Counterparties have the option to only select one appropriately qualified judge to consider a decision. The system is invoked in order to ensure confidence and impartiality in blockchain protocols. As they argue, "bad code" does not convey human intentions, so the Jury.Online protocol combines human and machine expertise to arbitrate emerging disputes.

G. *Monetha*

Monetha is an electronic commerce platform launched in 2017 that leverages blockchain technology to facilitate decentralized, peer-to-peer transactions between merchants and customers. The platform offers a "decentralized reputation framework" that allows "participants to evaluate the trustworthiness of one another by securely accessing context-relevant information."[74] The payment system of the platform ("payment layer") includes a dispute resolution workflow where a participant can initiate a claim on the blockchain, which will then be handled automatically by a smart contract.[75] The workflow includes a step where the parties are given 72 hours to solve the claim "off-chain." If the resolution of the claim is not satisfactory, a new claim can be registered by any of the parties to re-start the process with a smart contract.

H. *Enigma*

Enigma, started in 2015 as a research project at MIT, is a "decentralized computation platform" built on the principle of privacy by design.[76] The Enigma platform offers a protocol that enables users to create privacy-preserving smart contracts, known as "secret contracts," on a distributed network.[77] In secret contracts, as Enigma developers put it, "the key difference [is] that the data itself (inputs and outputs to the contract) is concealed from the nodes that execute the computations. This enables app developers to include sensitive

74. Monetha, *Reputation Layer* (2020), https://github.com/monetha/reputation-layer (last vistied Jan. 8, 2020).

75. Monetha, *Dispute Resolution* (2020), https://github.com/monetha/payment-layer#dispute-resolution (last vistied Jan. 8, 2020).

76. Guy Zyskind, Nathan Oz, & Alex Pentland, *Enigma: Decentralized Computation Platform with Guaranteed Privacy*, arXiv (May 10, 2015), https://arxiv.org/abs/1506.03471 (last visited Jan. 8, 2020).

77. Enigma, *Enigma* (2019), https://enigma.co/ (last visited Jan. 8, 2020).

data in their smart contracts, without moving off-chain to centralized (and less secure) systems."[78]

Enigma does not specifically address dispute resolution for smart contracts but highlights the problems involved with exposing sensitive or confidential data on a decentralized blockchain environment. Code executed on Enigma ensures that these data can be used as inputs for smart contracts, since the code "is executed both on the blockchain (public parts) and on Enigma (private or computationally intensive parts)."[79] In the latest available update of the project (November 20, 2019), the Enigma team emphasizes the ultimate goal of building the "privacy" layer of the decentralized web ("when you run a secret node, you are helping Enigma secure the decentralized web").[80] The cryptoeconomics underpinning the sustainability of secret nodes is based on a protocol still under development at the time of publication.[81]

V. FINDINGS

The findings from these eight case studies are summarized in Table 1 below, where we identify, for each organization, both its distinctive dispute resolution modality and the specific method deployed to implement the selected mechanism. In essence, we have identified two main discernible approaches to dispute resolution in the blockchain ecosystem: (i) alternative dispute resolution as a standalone service, and (ii) embedded dispute resolution mechanisms coded into contracts. The embedded forms of dispute resolution use differing methods of adjudication and expertise to arrive at decisions. These two different approaches are not necessarily exclusive because, in some cases, they can be combined in successive steps of an automated workflow.

78. Enigma Project, *New to Enigma? Start Here*, MEDIUM (Jan. 6, 2020), https://blog.enigma.co/welcome-to-enigma-start-here-e65c8c9125ef (last visited Jan. 8, 2020).

79. Zyskind et al., *supra* note 76.

80. Enigma Project, *Secret Nodes — Everything You Need to Know!*, MEDIUM (Nov. 20, 2019), https://blog.enigma.co/secret-nodes-everything-you-need-to-know-2c75c72046e2 (last visited Jan. 8, 2020).

81. See Enigma Project, *Announcing the Launch of Enigma's First Networked Testnet!* MEDIUM (Dec. 24, 2019), https://blog.enigma.co/announcing-the-launch-of-enigmas-first-networked-testnet-359fd816cb69 (last visited Jan. 8, 2020).

TABLE 1. Dispute resolution modalities and methods

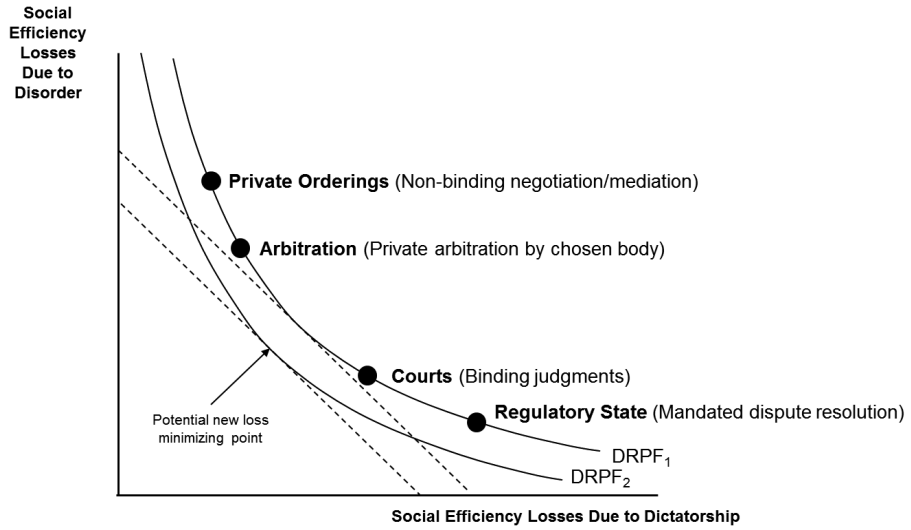
Organization	**Dispute Resolution Modality**	**Method**
Mattereum	Adjudication embedded into organizational structure	Adjudication as a standard governance protocol
LTO Network	Embedded in 'live contract'	Agreed 'deviations' in workflows and off-chain arbitration
Sagewise	Pre-agreed smart contract monitoring agent	Monitors and freezes smart contracts to pre-empt disputes
Kleros	Independent online dispute resolution mechanism	Crowdsourced jury system
Blockchain Arbitration Forum	Stand-alone dispute resolution service	Smart contract arbitration library and independent arbitration
Jury.Online	Embedded in smart contract	Randomly selected jury pool
Monetha	Embedded in smart contract	Smart contract workflow and off-chain dispute resolution
Enigma	Secret contracts	Privacy-enforcing computation

The issue of how to enforce contract dispute rulings has not yet been addressed and is a major factor in evaluating the efficacy of dispute resolution protocols. To date, the above organizations have not provided enough empirical data to demonstrate the effectiveness of their processes. Moreover, the issue of online dispute resolution on a blockchain is still theoretical because reports remain largely promotional. What is evident is that the implementation of smart contracts engenders new types of disputes that require new forms of dispute resolution. In most cases, such disputes will continue to require human intervention. In the following Part, we examine the implications of these new blockchain-based governance mechanisms for the enforcement of both blockchain smart contracts and traditional legal contracts.

VI. Discussion

Our case studies suggest new institutional possibilities within the DRPF space that extend beyond existing dispute resolution systems. These entrepreneurial applications are leveraging blockchain as a tool for new governance possibilities of dispute resolution. The question, then, is whether the dispute resolution problem can be more effectively solved through blockchain-based mechanisms (e.g. Mattereum or Jury.Online), or by leveraging existing governance solutions (e.g. courts). Using our DRPF framework, we would expect smart contracting parties to choose a governance solution that sits closest to the origin—that is, a governance solution that minimizes both dictatorship and disorder costs. If new forms of blockchain-based dispute resolution better minimize the costs of disorder and dictatorship—and therefore contracting parties begin to adopt them—we can represent this as an inward shift in the DRPF as outlined in Figure 2 below.

Figure 2. Shifting the Dispute Resolution Possibility Frontier



There are three reasons why we cannot pinpoint the precise relationship between the new institutional possibilities outlined in Part V and existing dispute resolution mechanisms. First, as we outlined above, the points we have described are both explanatory and theoretical. The location of different institutional possibilities within the DRPF will only be revealed to contracting parties through a process

of discovery and testing. As these new mechanisms continue to develop, there are significant opportunities for future empirical research comparing alternatives using the DRPF framework.

Second, and more fundamentally, the dictatorship and disorder costs that contracting parties perceive—that is, the trade-offs between different institutional alternatives—are subjectively perceived.[82] Contracting parties must perceive, under uncertainty, the potential costs of dictatorship and disorder for given institutional possibilities. Because of this nature of subjective costs, there is no way to objectively determine a society-wide cost-minimizing institution within the DRPF space. Uncertainty will always exist over the precise location and relationships between institutional possibilities.

Third, the DRPF space changes through time—it is unstable. As we have shown, entrepreneurs are creating new institutional possibilities that change the scope of choice for contracting parties. The expansion of institutional possibilities will undergo an evolutionary selection process where contracting parties make institutional choices. This suggests a new competitive dynamic across dispute resolution institutions. This competitive dynamic over different dispute resolution systems will be contingent on many factors, including the perceived level of contract incompleteness.

There are two main approaches to understanding these new competitive dynamics in the DRPF: first, by observing historical examples of innovations in governance; and second, by analyzing other areas of institutional innovation using blockchain. Through history we can see various examples of institutional innovations.[83] Many of these innovations in governance have come through demand to reduce costs and facilitate exchange. For instance, merchant courts emerged to overcome disputes of international trade, and private companies have developed institutions to settle disputes or facilitate exchange.[84] The growing need for decentralized dispute resolution to service blockchain-based smart contracts creates demand for new and innovative solutions. Entrepreneurs are incentivized to create mechanisms of dispute resolution that complement blockchain-based

82. Allen & Berg, *supra* note 41; Darcy W. E. Allen, *The Private Governance of Entrepreneurship: An Institutional Approach to Entrepreneurial Discovery* (Aug. 31, 2017) (unpublished Ph.D. dissertation, RMIT University) (on file with authors).

83. *See* Berg, Davidson & Potts, *supra* note 8, which situates blockchain technology within the historical development of institutional technologies.

84. *See* David Skarbek, THE SOCIAL ORDER OF THE UNDERWORLD: HOW PRISON GANGS GOVERN THE AMERICAN PENAL SYSTEM (2014); Edward Stringham, *Market Chosen Law*, 14 J. LIB. STUD. 53 (1999); Edward Stringham (2011), ANARCHY AND THE LAW: THE POLITICAL ECONOMY OF CHOICE, VOL. 1; Stringham, *supra* note 38.

platforms.[85] The second way we can understand the emergence of new dispute resolution mechanisms is to observe other areas of blockchain innovation. For instance, one example of blockchain disruption in another sector is voting. Blockchain is currently disrupting the way that votes are recorded and verified through cryptodemocratic governance.[86] This new decentralized voting infrastructure competes with existing government-operated hierarchical voting infrastructure.[87] The way that this competitive process plays out may provide insights into how old and new dispute resolution mechanisms will interact and evolve together.

Blockchain-based dispute resolution systems might not only service the blockchain industry and smart contracts, but also extend into servicing dispute resolution for traditional legal contracts. Contracting parties in a more conventional contract might determine that some blockchain-based form of dispute resolution economizes on the costs of dictatorship and disorder. In other words, new blockchain-based dispute resolution might also expand the DRPF for conventional contracts.

VII. Conclusion

Innovations in blockchain and smart contracting technologies present new challenges for dispute resolution. This Article offers a coherent framework to compare new and existing institutional mechanisms of dispute resolution. We began with presenting the legal challenges that smart contracts create for dispute resolution, observing how entrepreneurs are using blockchain technology to create new dispute resolution mechanisms, and concluded with how these mechanisms might also be comparatively effective at servicing traditional legal contracts.

First, we applied the Institutional Possibility Frontier (IPF) to examine the trade-offs between existing dispute resolution mechanisms, thereby forming the Dispute Resolution Possibility Frontier (DRPF). From this perspective, different forms of dispute resolution—from non-binding negotiation to binding court judgements—can be understood as trading-off between the costs of dictatorship

85. *See* Allen & Berg, *supra* note 81. Darcy W.E. Allen, *Entrepreneurial Exit: Developing the Cryptoeconomy, in* Blockchain Economics: Implications of Distributed Ledgers, Markets, Communications Networks, and Algorithmic Reality, 197 (Melanie Swan, Jason Potts, Soichiro Takagi, Frank Witte & Paola Tasca, eds., 2019).

86. Allen, Berg & Lane, *supra* note 16; Allen et al., *supra* note 16.

87. Allen, Berg & Lane, *supra* note 16, at 133-139.

and disorder. Our DRPF framework not only incorporates existing mechanisms of dispute resolution, but also enables us to integrate new innovative governance structures. Existing mechanisms of dispute resolution that might feed into blockchain-based smart contracts can therefore be arrayed alongside new blockchain-based dispute resolution mechanisms.

Second, we used case studies to demonstrate entrepreneurial efforts to leverage blockchain technology to develop novel mechanisms of dispute resolution. These case studies showed that while blockchain-based smart contracts have raised new issues regarding dispute resolution—namely, through problems of contract incompleteness and automatic execution—the technology has also opened up new institutional possibilities for those challenges. These new dispute resolution mechanisms are both facilitated and enabled by blockchain technology, and service the growing blockchain-based smart contract industry.

And third, we outlined some of the challenges these new dispute resolution mechanisms raises for legacy dispute resolution. Given that the dispute resolution process and its enforcement are not limited to one single institutional possibility, we anticipate a new competitive dynamic between existing dispute resolution mechanisms and new blockchain-based dispute resolution systems. How this evolutionary process will unfold ultimately comes from choices of contracting parties over the costs of dictatorship and disorder.[88] We can also understand this process as institutional competition between conventional jurisdictional dispute resolution and blockchain-based dispute resolution.

The DRPF framework that we have developed and applied in this Article provides a new theoretical foundation to understand new institutional competitive dynamics in dispute resolution, and presents opportunities for further empirical analysis as blockchain-based dispute resolution mechanisms continue to emerge and compete.

88. Allen & Berg, *supra* note 41.