

Blockchain: A Coordination Mechanism

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Abstract

Blockchain technology is firmly established in the public awareness as a revolutionary new technology underpinning cryptocurrency. However, its potential applications can be found across sectors and industries in providing a novel way of producing coordination necessary to transact online, making it a timely invention in the age of progressing digitalization and increasing demands for efficiency and security of online transactions, and a promising research topic addressing the growing academic interest in the coordination aspect of the contract scholarship. The aim of this conceptual paper is to model blockchain as a coordination mechanism for online transactions. Three key aspects of coordination with blockchains are identified and examined – (1) producing consensus about the facts relevant to a transaction, (2) coding contracts, and (3) autonomously executing transactions. They are argued to be integral parts of the mechanism, jointly enabling blockchains to function as a complete mechanism of coordination for online transactions. The model is intended to inform debates on the prospects for the blockchain technology and can be further used to integrate coordination and contract scholarship.

Keywords: algorithmic coordination, blockchain, consensus, contract, coordination mechanism

JEL classification: D23, D26, D86, L14, L23, L86, M11

Introduction

Coordination is prevalent in the business world, as it is required whenever various tasks must be employed together to produce desirable outcomes (Malone et al., 1990). This also concerns carrying out transactions, as they involve two or more parties who need to interact for the transaction to take place. However, as transactions differ in their coordination needs and associated costs, they call forth various mechanisms of coordination (and their combinations). Blockchain technology, extolled as the most significant technological breakthrough since the diffusion of the internet in 1990s (Tapscott et al., 2016), provides a novel approach and a new mechanism of coordination for transactions. Albeit associated primarily with cryptocurrencies, blockchain technology should be viewed more broadly as a foundational technology that has the potential to dramatically reduce the cost of transactions (Iansiti et al., 2017). It specifically addresses and revolutionizes one key aspect of coordination, namely producing consensus about facts relevant to the transaction ("the state of the world"), and integrates this capacity with the contract coding and transaction execution aspects of coordination. Thus, blockchain technology operates and coordinates at the ontological as well as the activity level.

The aim of this paper is to model blockchain as a coordination mechanism for online transactions. The topic of coordination has appeared regularly in the blockchain literature – it has been conceived in terms of aligning blockchain participants' incentives (i.e. as a precondition of good governance) (e.g. Davidson et al., 2018; Piazza, 2017) and related contexts, e.g. participants' behavior related to adaptation and change (network splits) (Arruñada et al., 2018; Biais et al., 2018).

Symptomatically, references to coordination have been limited to the consensus protocols, i.e. providing consensus about facts, while other aspects of coordination have not been recognized.

In the present paper we take a broader view and consider consensus protocol as but one component of a composed mechanism of coordination formed by blockchains. In doing so, we depart from the dominant governance (transaction cost economics – TCE) perspective on blockchains and recognize that transaction characteristics (i.e. asset specificity, transaction frequency and uncertainty) are not the only determinants of how transactions are coordinated, as the TCE stipulates. Rather, as suggested by Schepker et al., (2014), transactions differ also along other dimensions. Specifically, these authors point at the purpose transactions serve, which is not only safeguarding against economic risk (as the TCE would have it), but also coordination and adaptation.

The present paper proposes yet another perspective on transactions, beyond their external purpose, namely how they are coordinated (i.e. internal focus). We posit that any transaction must be internally coordinated. Given space limitations, we focus more on substantiating the need for and indicating the place of the new approach to studying blockchains among the established perspectives than on detailing how individual components of the new coordination mechanism of blockchain are designed and work.

The concept of coordination and its application to the production of transactions

Although the term *coordination* is widely used and intuitively understood, it evokes a variety of domain-specific definitions, making it meaning highly contextualized. In management science, coordination had historically been considered one of the five key functions of management, together with planning, organizing, commanding and controlling (Fayol, 1917). More recently, management scholars defined it as the organization of individuals' efforts toward achieving common and explicitly recognized goals (Blau et al., 1962), the integration or linking together of different parts of an organization to accomplish a collective set of tasks (Van de Ven et al., 1976), bringing into a relationship otherwise separate activities or events, typically with the goal of increasing efficiency (Frances et al., 1991), and managing dependencies among activities (Malone et al., 1994; 2012).

The managerial definitions of coordination revolve around two components – organization of separate tasks or activities and orientation at achieving an overall, common or mutually beneficial goal (Pietrewicz, 2019). It follows that tasks must be performed in such a way as to help achieve the goal, making their performance interdependent (Malone et al., 1990), which takes the form of one task or activity being controlled or contingent upon performance of another (Victor et al., 1987). Organizational responses to interdependencies take the form of coordination mechanisms (e.g. Malone et al., 1990; 2012; Thompson, 1967; Van de Ven et al., 1976), which have attracted many conceptualizations and categorizations (see Table 1.).

Table 1
Selected Coordination Mechanism Categorizations

Framework author(s)	Coordination mechanisms
Thompson (1967)	<ul style="list-style-type: none"> • Standardization of tasks • Plan • Mutual adjustment
Van de Ven et al. (1976)	<ul style="list-style-type: none"> • Impersonal (plans and rules) • Personal (vertical supervision) • Group (formal and informal meetings)
Mintzberg (1979)	<ul style="list-style-type: none"> • Mutual adjustment, • Direct supervision • Standardization (of work processes, outputs, norms and skills)
Espinosa et al. (2004)	<ul style="list-style-type: none"> • Explicit (task programming and communicating) • Implicit (cognition-based on shared knowledge)
Fugate et al. (2006)	<ul style="list-style-type: none"> • Price • Non-price • Flow coordination
Malone et al. (2012)	<ul style="list-style-type: none"> • Budgets, market-like bidding • Notification, sequencing, tracking • Standardization, ask users, participatory design • Scheduling, synchronization • Goal selection, task decomposition

Source: partially based on Pietrewicz (2019)

We posit that the concept of coordination (and thus coordination mechanism) can be applied to transactions. As coordination literature concerns primarily value-adding activities along the value chains (both within firms and in interactions between firms), applying its conceptual apparatus to transactions requires that transactions be modeled as end products that must be produced, similarly to goods or services, using sets of discrete value-adding tasks (or activities) which must be coordinated in order to deliver a desirable outcome. Thus, *production of transactions* can be studied with the same conceptual apparatus as any other kind of business activity, deflecting from TCE and, more generally, incomplete contracts theory. To be sure, we do not call for discarding such established perspectives, rather, we argue for complementing them with a new approach.

Coordinating with blockchains

Coordination in computer science

Advances in information and communication technologies (ICT) have long been known to reduce coordination costs (Malone et al., 1987) by shifting constraints on certain types of communication and coordination (Malone et al., 2012). At the same time, computer systems have faced their own coordination problems, inviting research on coordination games, a branch of game theory.

In computer science, *coordination mechanisms* generalize scheduling (task allocation) policies for computer workload with the goal of improving the overall system performance (e.g. Christodoulou et al., 2009; Immorlica et al., 2009), and are used particularly in the context of decentralized coordination of self-interested agents' jobs in so-called congestion games (Ackermann et al., 2009; Rosenthal, 1973). In essence, coordination mechanism is a decentralized algorithm (Christodoulou et al. 2009), or – given a variety of task environments – a family of algorithms based on recognizing and reacting to the characteristics of certain coordination relationships,

i.e. dependencies that occur between tasks, and related uncertainties (Decker et al., 1994). Many computer science researchers have found that there is no single best coordination mechanism (scheduling policy) for all task environments (e.g. Decker et al., 1994; Durfee et al., 1991), in line with the findings of the general coordination literature.

Blockchains as coordination mechanisms

Blockchain is a set of technologies developed around the concept of distributed ledgers. The term refers to a chain of blocks of information stored on a decentralized network of computers which verifies and records every transaction in a shared, encrypted ledger. Each new block of information is verified using a consensus protocol and linked to the one preceding it, thus forming a chain. Once created, the block (i.e. the information contained within) cannot be changed, giving blockchain the quality of immutability. The use of consensus protocols replaces intermediaries providing contract fulfillment services with a peer-to-peer clearing system, where anything of value can be transacted online (Pietrewicz, 2018).

Blockchain is widely recognized in the academic literature to provide a new way of coordinating economic activity by producing consensus about the state of the world, verifying authenticity of transactions in a novel way, and thus providing governance structure for blockchain-based applications (e.g. Davidson et al., 2016; 2018; Piazza, 2017). Although this alone justifies categorizing blockchains as coordination mechanisms, the topic of coordination in blockchains should not be limited to their consensus protocols.

To make the view of coordination in blockchain-based transactions more complete, consensus protocols should be considered together with other aspects of the transaction processes (i.e. the *production of transactions*) requiring coordination. For a transaction to take place, a contract must be signed, its conditions fulfilled, and transaction successfully executed, creating a situation of interdependency requiring some sort of coordinated actions.

Contracts in themselves are coordination mechanisms (Schepker et al. 2014). Blockchain technology enables so-called smart contracts to be recorded on a given blockchain (ledger), enabling autonomous execution of transactions when conditions stipulated in the contract are met (Iansiti et al., 2017). Thus, smart contracts effectively integrate (and autonomously coordinate) recognition of conditions fulfillment and contract execution aspects of transaction coordination.

Smart contracts are computer programs encoded on a blockchain which trigger an automatic execution of contracts once conditions detailed on the contract are recognized as met. Since smart contracts are of binary nature, the encoded conditions must be very precise, leaving no room for interpretation and contestation (Pietrewicz, 2018). As smart contracts are programmable, they can cover a variety of contracts and multiple provisions detailing parties' obligations in various possible states of the world. If a state of the world is not provided for, the transaction will not be executed, and the interested parties have no obligations to each other, as they agreed on using a specific smart contract beforehand.

Discussion

Transacting requires coordination. Coordination can be achieved using multiple coordination mechanisms or, as the present study suggests, a composite mechanism of coordination. Traditionally, part of coordination needed for interfirm transactions has been ceded to a third party of a trusted intermediary who guaranteed

transactions. Blockchain technology enables doing away with trusted third parties, replacing such institutions with algorithms. Coordinating transactions with algorithms, i.e. algorithmic coordination, automates the interactions between parties to a transaction by establishing "objective" set of rules encoded on a blockchain protocol. Blockchain automates consensus mechanism, i.e. the process of producing consensus about facts necessary for transacting (state of the ledger), thus replacing intermediaries; it also implements business rules in the form of so-called smart contracts. Smart contracts, recorded on a blockchain, detail contract conditions triggering transactions; once conditions are met, transactions are executed on the blockchain automatically and autonomously, without the need for human involvement. Although consensus protocols and smart contracts play different functions, they complement each other in giving blockchain a potential to revolutionize transactions.

The present contribution presents a simplified model of blockchain as a coordination mechanism for online transactions. More detailed take on the topic is certainly needed, extending the model and confronting it with both traditional coordination mechanisms and established approaches to coordinating online transactions.

The present study raises a number of research questions including the relation between smart contracts and law, subjectivity of algorithms, completeness of smart contracts, data privacy and security, transaction pricing models, standardization of data and systems and, more generally, the limits of algorithmic coordination.

Arguably the most theoretically promising research question, with obvious implications for the advancement of the blockchain technology, is the nature of the relation between the purpose of a transaction and its coordination mechanism. Schepker et al. (2014) identify and describe three such purposes: safeguarding against economic risks, coordination, and adaptation. Further studies should determine to what extent the choice of transaction coordination mechanism(s) reflects the purpose a transaction serves, and to what extent the transaction coordination mechanisms are yet another dimension along which transactions can be described, designed and optimized.

Conclusion

Blockchains blend together several technologies to establish coordination necessary for transacting online. Consensus protocols and smart contracts jointly coordinate the "production of transactions" in its three aspects: coding contracts on the blockchain, providing consensus on the facts relevant to transactions, and actually executing transactions, making blockchain a composite mechanism of coordination. Thus, blockchain goes beyond its basic functions of a digital ledger replacing the established double-accounting technique, and the "internet of value" (Tapscott et al., 2016), i.e. a technology for transferring digital assets online, to provide a composite algorithm-based mechanism for coordinating transactions online. It gives blockchains the potential to revolutionize transactions. Whether the potential will be realized, depends on successfully dealing with a number of issues, including the relation between smart contracts and law, subjectivity of algorithms, completeness of smart contracts, data privacy and security, transaction pricing models, standardization of data and systems, and the limits of algorithmic coordination. All these issues merit increased academic attention. Further studies should also address the nature of the relation between the purpose of transactions and their coordination mechanisms, advancing an important aspect of the contract scholarship.

References

1. Ackermann, H., Röglin, H., Vöcking, B. (2009), "Pure Nash equilibria in player-specific and weighted congestion games", *Theoretical Computer Science*, Vol. 410, No. 17, pp. 1552-1563.
2. Arruñada, B., Garicano, L. (2018), "Blockchain: The Birth of Decentralized Governance", Pompeu Fabra University, Economics and Business Working Paper Series, 1608.
3. Biais, B., Bisiere, C., Bouvard, M., Casamatta, C. (2018), "The Blockchain Folk Theorem", *Swiss Finance Institute Research Paper No. 17-75*.
4. Blau, P., Scott, W. (1962), *Formal organizations*. San Francisco, Scott, Foresman.
5. Christodoulou, G., Koutsoupias, E., Nanavati, A. (2009), "Coordination mechanisms", *Theoretical Computer Science*, Vol. 410 No. 36, pp. 3327-3336.
6. Davidson, S., De Filippi, P., Potts, J. (2016), "Economics of Blockchain", available at: <http://dx.doi.org/10.2139/ssrn.2744751> (2 May 2019).
7. Davidson, S., De Filippi, P., Potts, J. (2018), "Blockchains and the economic institutions of capitalism", *Journal of Institutional Economics*, Vol. 14, No. 4, pp. 639-658.
8. Decker, K., Lesser, V. (1994), "Designing a Family of Coordination Mechanisms", *AAAI Technical Report WS-94-02*, pp. 32-51.
9. Durfee, E., Montgomery, T. (1991), "Coordination as distributed search in a hierarchical behavior space", *IEEE Transactions on Systems, Man, and Cybernetics*, Vol. 21, No. 6, pp. 1363-1378.
10. Espinosa, J., Lerch, F., Kraut, R. (2004), "Explicit versus implicit coordination mechanisms and task dependencies: One size does not fit all", in Salas, E. Fiore, S. (Eds.), *Team cognition: Understanding the factors that drive process and performance*, Washington, DC, American Psychological Association, pp. 107-129.
11. Fayol, H. (1917), *General and Industrial Management*, Dunod et E. Pinat.
12. Frances, J., Levacić, R., Mitchell, J., Thompson, G. (1991), "Introduction" in Thompson, G., Frances, J., Levacić, R., Mitchell, J. (Eds.), *Markets, Hierarchies & Networks: The Coordination of Social Life*, London, Thousand Oaks, New Delhi, Sage Publications.
13. Fugate, B., Sahin F., Mentzer, J. (2006), "Supply Chain Management Coordination Mechanisms", *Journal of Business Logistics*, Vol. 27, No. 2, pp. 129-161.
14. Iansiti, M., Lakhani, K. (2017), "The Truth About Blockchain", *Harvard Business Review*, Jan-Feb, pp. 118-127.
15. Immorlica, N., Li, L., Mirrokni, V., Schulz, A. (2009), "Coordination mechanism for selfish scheduling", *Theoretical Computer Science*, Vol. 410, No. 17, pp. 1589-1588.
16. Malone, T., Crowston, K. (1990), "What is Coordination Theory and How Can It Help Design Cooperative Work Systems", in the *Proceedings of the Conference on Computer Supported Cooperative Work*, Los Angeles, CA, ACM, pp. 357-370.
17. Malone, T., Crowston, K. (1994), "The Interdisciplinary Study of Coordination", *ACM Computing Surveys*, Vol. 26, No. 1, pp. 87-119.
18. Malone, T., Crowston, K. (2012), "The Interdisciplinary Study of Coordination", in Olson, G., Malone, T., Smith, J. (Eds.), *Coordination Theory and Collaboration Technology*, New York and Hove, Psychology Press. pp. 7-50.
19. Malone, T., Yates, J., Benjamin, R. (1987), "Electronic Markets and Electronic Hierarchies", *Communications of the ACM*, Vol. 30, No. 6, pp. 484-497.
20. Mintzberg, H. (1979), *The Structuring of Organizations*, Englewood Cliffs, Prentice-Hall.
21. Piazza, F. (2017), "Bitcoin and the Blockchain as Possible Corporate Governance Tools: Strengths and Weaknesses", *PennState Journal of Law & International Affairs*, Vol. 5, No. 2, pp. 262-301.
22. Pietrewicz, L. (2018). "Token-based blockchain financing and governance: A transaction cost approach", paper presented at Entrepreneurship for the XXI Century. Images and Perspectives conference, Warsaw, Poland, available at: https://www.researchgate.net/profile/Leslaw_Pietrewicz/publication/327946607_Token-based_blockchain_financing_and_governance_A_transaction_cost_approach/links/5baec6e892851ca9ed2e542f/Token-based-blockchain-financing-and-governance-A-transaction-cost-approach.pdf (2 May 2019).

23. Pietrewicz, L. (2019), "Coordination in the age of Industry 4.0", in the Proceedings of the 38th International Scientific Conference on Economic and Social Development, Varazdin Development and Entrepreneurship Agency, Varazdin, pp. 264-274.
24. Rosenthal, R. (1973), "A class of games possessing pure-strategy Nash equilibria", *International Journal of Game Theory*, Vol. 2, No. 1, pp. 65-67.
25. Schepker, D., Oh, W.-Y., Martynov, A., Poppo, L. (2014), "The Many Futures of Contracts: Moving Beyond Structure and Safeguarding to Coordination and Adaptation", *Journal of Management*, Vol. 40, No. 1, pp. 193-225.
26. Tapscott, D., Tapscott, A. (2016), *Blockchain revolution: how the technology behind bitcoin is changing money, business, and the world*, New York, Penguin.
27. Thompson, J. (1967), *Organizations in Action: Social Science Bases of Administrative Theory*, New York, McGraw-Hill.
28. Van de Ven, A., Delbecq, A., Koenig, R. (1976), "Determinants of Coordination Modes within Organizations". *American Sociological Review*, Vol. 41, No. 2, pp. 322-338.
29. Victor, B., Blackburn, R. (1987), "Interdependence: An alternative conceptualization", *Academy of Management Review*, Vol. 12, No. 3, pp. 486-498.

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