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The Role of Interdependencies in Blockchain Adoption: The Case of Maritime Trade

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Abstract
Despite its many potential economic and organisational benefits, enterprise blockchain (distributed ledger) technology has still not been widely adopted. From the viewpoint of the participants, the deployment of a blockchain that links collaborating enterprises requires value creation that will exceed investment, including investment in operational and strategic change. The theory behind and practice of cross-enterprise open innovation can inform blockchain adoption. Blockchain implementation requires and creates interdependencies across collaborators, both among enterprise consortium partners and with stakeholders in the broader ecosystem. Distinguished from arm's-length forms of collaboration, interdependencies occur when organisations intentionally collaborate to become reliant upon one another. In this paper, we develop a framework of blockchain interdependencies and explore key factors that promote or inhibit interdependence. We propose a blockchain collaboration continuum with three levels: cooperation, interdependence, and mutualism. We then explore factors that influence the level of interdependence: two types of consortium-level interdependencies – socio-technical and economic, and two types of ecosystem-level interdependencies – standards and legal/regulatory. We illustrate these interdependencies and their payoffs through the example of supply chains in maritime trade. This work can be used as a starting point for diagnosing critical factors influencing adoption and for illuminating points of leverage that may sway hesitant organisations to participate in blockchain consortia.

Keywords: *blockchain adoption, collaborative innovation, consortia, ecosystems, enterprise blockchain, interdependencies, maritime trade, open innovation*

JEL Classifications: *M15, O33, O36*

1. Introduction

Blockchain technology [or distributed ledger technology (DLT)] has been touted for its ability to create commercial value in numerous industrial sectors distinct from its role in enabling cryptocurrencies [1]. Firms recognise that technology-enabled transparency and digital mediation are here to stay and will shape collaborative dynamics well into the future [2]. This reality plays to blockchain's strengths. Nevertheless, blockchain has still not been widely adopted by enterprises [3, 4], which remains a puzzle, and there is a lack of clear evidence of the benefits of its adoption [5].

Research has started to probe what contributes to blockchain adoption, moving beyond questions about compatibility of technology architectures and towards organisational and strategic considerations [6, 7, 8]. We extend this vein of the literature by examining blockchain adoption through the theoretical lens of open innovation [9, 10] coupled with transaction cost economics [11], in the context of organisations jointly pursuing innovation with positive net payoffs. From this perspective of cross-enterprise collaboration, we explore how blockchain adoption relies upon and creates interdependencies among the participants. Long-term value creation from blockchain collaboration relies on interorganisational relationships that escalate in obligation.

In this article, we develop a framework of blockchain interdependencies and explore key factors that promote or inhibit interdependence. We propose a collaboration continuum with three levels: cooperation, interdependence, and mutualism. We then explore factors that influence the level of interdependence: two consortium-level interdependencies – socio-technical and economic, and two ecosystem-level interdependencies – standards and legal/regulatory.

We illustrate blockchain interdependencies and their payoffs through the example of supply chains in maritime trade. Maritime trade includes freight forwarders, large oceangoing carriers, port operators, customs agents, inland carriers, and many other parties. Over 80% of global trade in goods is

transported by the maritime industry and transaction flows can link hundreds of organisations [12]. The maritime industry currently deploys a number of blockchain systems, and all of the largest carriers in this oligopolistic industry participate in blockchain consortia [13, 14]. Blockchain technology not only offers a way to track movement and digitise handoffs, but can automate and streamline surrounding processes, creating value as contracts between trading parties are fulfilled.

In the next section, we present the theoretical grounding of our analysis. This is followed by the development of our framework, and then an examination of the four blockchain interdependencies with examples from maritime trade. The subsequent sections discuss our findings, conclusions, and areas of future research.

2. Theoretical Grounding of Blockchain Technology Adoption

Much of the research on blockchain adoption takes the perspective of the individual firm [15, 16], as does relevant maritime trade literature (e.g., [17]). This work typically focuses on pain points or frictions and emphasises efficiencies and cost savings attributable to participation in a blockchain project, while opportunities for innovation are not widely addressed [18].

The open innovation literature can inform an understanding of opportunities for multi-party innovation. It provides a foundation for considering the gains from two or more firms intentionally cooperating to create new value. Organisations often are members of value chains where individual firms do not possess the resources to operationalise complex value propositions from start to finish [19]. They instead develop relationships and interdependencies with other organisations, forming ecosystems that support innovative projects that combine the contributions of individual firms. Enterprise blockchain adoption can facilitate such innovation, but its success can only be realised with multi-party participation.

Technology-based collaboration across enterprises requires firms to move beyond arm's-length market negotiations through cooperation to interdependence [20, 21]. Interdependent organisations intentionally collaborate and become reliant on one another. Interdependence hinges on "high levels of trust, commitment and information sharing among supply chain partners" [21].

In the case of blockchain, interdependence additionally requires agreement on governance and processes for information sharing, which lead to "industrialized trust" [22, 23]. Industrialised trust, reflecting that economic exchanges among members are verifiable, is established among the organisations participating in a blockchain project. This trust relies on the governance rules that support the decentralisation of transactions and the fidelity, transparency, and immutability of the entries in the distributed ledger. Interdependence based on industrialised trust can lead to co-created value through integrated relationships, where events are contingent on one another [24, 25, 26].

As existing literature demonstrates, the collaboration required for enterprise blockchain deployment typically occurs in a consortium setting and deepens to the point of shared governance [6], allowing participating firms to benefit from interdependencies [21, 27]. In the case of blockchain, interdependencies create value through coordinated action that companies involved in traditional transactional relationships cannot achieve. The rules governing the execution of a blockchain support interfirm data and process integration, which constitute the basis of interdependence in the blockchain setting [27].

Going a level deeper to establish the theoretical grounding for the willing creation of interdependencies, transaction cost economics (TCE) provides justification for boundary-spanning collaboration. TCE considers how people and organisations interact to, in effect, fulfil a contract [11], where interactions are characterised as transactions. In the case of blockchain, participating in a DLT project and recording transactions in a shared ledger reflect collaboration.

The foundational assumptions of TCE are that people operate with bounded rationality and are prone to opportunism [11]. Regarding the former assumption, because blockchain enables the execution of smart contracts, i.e., programmed-in decision rules, it can help reduce limitations to human information processing [2]. Opportunism can be mitigated through smart contracts as well as through automation of transactions and transparency of entries.

TCE distinguishes between the types of costs incurred to engage in a transaction where *ex ante* costs can include search costs to identify an exchange partner plus the costs of drawing up the agreement, which requires negotiations and the adoption of safeguards as needed [11]. Once the agreement is finalised and the exchange proceeds, if outcomes diverge from expected outcomes, the parties might face haggling and re-contracting costs [11].

Prior to the explosion of the internet in the 1990s, Malone [28] explored hierarchical and market structures and the trade-offs between production and coordination costs related to these structures. Malone and colleagues proposed the electronic market hypothesis (EMH) which argued that information technology would reduce the *ex ante* and *ex post* transaction costs, promoting a shift from hierarchies to markets as a means of coordinating economic activity [29, 30]. This hypothesis was later used to explain and propose decentralisation of project teams and transaction networks [31], as well as the decentralisation of decision-making, both within hierarchical organisations and among market participants [32].

Because of its features, blockchain technology helps overcome both *ex ante* cooperation costs and possible *ex post* costs once coordination is underway. Hence, blockchain technologies offer a new way to establish trust in an economic exchange [1] and new areas of value creation

requiring a new approach to governance [2]. Blockchain has the potential to disrupt existing hierarchies and business models [1] and represents not only technological change but institutional change [33].

3. Progression of Value Creation through Intensity of Collaboration

Blockchain represents a paradigm shift in collaboration; it provides a new way to organise economic activity [33]. Lumineau et al. [2] explore blockchain technology as a new form of organisational governance; they argue that blockchain is among "the most disruptive technological innovations of recent times that may fundamentally change how collaborations are organized" (p.1). In a blockchain setting, increasing levels of interdependence enable engagement in blockchain-based collaborations that have the potential for increasing economic payoffs for participants. As intensity of collaboration and open innovation increases, so does the potential for value creation.

To contextualise how open innovation and the underlying TCE processes give rise to value creation in a blockchain consortium, we consider the payoffs to blockchain adoption in maritime trade. Specifically, organisations that have joined maritime trade consortia have benefited from the digitisation of trade documents, improved information sharing including more precise tracking of containers in the global supply chain, and increased speed of transactions through smart contracts [34]. These benefits have accrued to the participating organisations once they have committed to going beyond arm's length open innovation exchanges to interdependent ones as part of a consortium with their transactions captured in the digital ledger. It is the intensity of collaboration that forms the basis of our blockchain adoption framework as captured in Table 1.

Table 1. The Blockchain Collaboration Continuum

	Cooperation	Interdependence	Mutualism
Technology	3rd Party Provider	Consortium Blockchain	Consortium Blockchain Backbone + Additional Industry 4.0 Technologies
Performance outcomes	Enhanced Speed, efficiency, reliability, transparency, consortium database	Additive Shared governance, consortium goals, automated inter-company processes, shared resources	Multiplicative Shared intellectual property, new products, services, business models

The continuum characterises three types of multi-firm relationships associated with various forms of blockchain collaboration: cooperation, in which firms collaborate to integrate processes and share data; interdependence, in which the success of firms is interconnected; and mutualism, in which participating companies innovate beyond typical blockchain affordances to develop and execute new strategic initiatives. For each of these relationship types, we explain representative blockchain solutions that support them and the associated performance outcomes. We illustrate the three categories using examples from maritime trade.

Cooperation

Cooperation relationships can be supported by third-party blockchain providers. Participating organisations opt into these systems but do not typically take ownership in ongoing development and governance. These systems are akin to centralised collaborative technologies, but they offer advantages including trust, security, and privacy, which can promote achievement of existing objectives for the collaboration among its participants. These systems are typically implemented to remove transaction inefficiencies, such as reconciliation problems, or to enable multi-party information sharing. The payoffs often take the form of speed and efficiency of transacting, resulting in cost savings for participants, as well as reliability and transparency, which reduce transaction risk among participants. Information stored in the ledger can provide expanded visibility to participants with access, as well as to outside parties such as auditors and regulators.

Prior to adoption of blockchain, the maritime industry had a history of collaboration via centralised service providers. Industry members moved beyond arms-length cooperation by agreeing to follow standards and share data through centrally managed portals such as INTTRA and GT Nexus [35, 36]. Companies collaborated through these centralised portals by sharing location and booking-related data. These systems enhanced value primarily by automating and streamlining existing processes and enabling better planning through data sharing.

Currently in the maritime industry, there are many third-party blockchain solutions for a variety of issues. For example, shipping consortia have adopted technology developed by CargoX that enables participating firms to use the smart bill of lading systems based on the Smart B/L token, which can be used upon receipt of a shipment to demonstrate that it has been paid for [13]. Maritime Blockchain Labs and the Lloyd's Register Foundation's prototype for digital audit trails and due diligence for dangerous goods cargo is another example. This system is designed to reduce serious incidents aboard containerships caused by mis-declared cargo [12].

Interdependence

Interdependence relationships represent a high degree of collaboration and open innovation among participants. Collaborators agree to participate in mutually-beneficial relationships in which they share common goals and work together to achieve them often in a consortium structure. Their activities and outcomes are intertwined such that the success of

one party is dependent on the actions of other organisations in the multi-party relationship.

The consortium of participants functions much like an organisation. Participants jointly govern the consortium and commit to a shared set of goals. Governance features of blockchains such as jointly designed and enforced membership, usage, and voting rules lead to interfirm interdependence [37]. Participating organisations share in the design, development, and deployment of these systems along with the ongoing creation and maintenance of shared governance agreements. While small participants and those joining the consortium after its implementation may play a lesser role, participants involved in governance engage in extensive open innovation as they form agreements on the strategic and operational aspects of these systems.

At the interdependence stage, value creation can be considered additive in nature. Participants can create and capture value beyond what could have been achieved through cooperation. Through interdependence relationships, participants may utilise numerous blockchain artefacts that provide new sources of value. Interorganisational processes can be coordinated and streamlined; smart contracts can be developed for the automation of processes and agreements; data generated through traditional and IoT-generated transactions can be mined to identify further opportunities for performance enhancements; and resources and competencies such as advanced know your customer (KYC) capabilities can be shared among participants.

In maritime trade, blockchain-enabled interdependence has been prevalent, resulting in performance benefits for participating firms. In 2020, TradeLens reported processing over 14 million documents involving over 30 million containers linking over 200 organisations in the maritime supply chain, including the majority of container ships worldwide [38]. Other active implementations include initiatives in trade finance and trade insurance [39].

Ancillary value has been created including the establishment of provenance and the elimination of counterfeiting through the enforcement of intellectual property rights via the blockchain, as well as other services like the execution of insurance contracts or the tracking of contaminated food [40].

Mutualism

As literature on interfirm interdependence finds, increasing the intensity of cooperation and open innovation can lead to mutualism. In these relationships, shared strategic direction arises as the partners collaborate on shared intellectual property and create new products, services, and business models. The ability to collaborate in this way is greatly enhanced for firms that have previously interacted through well-established interdependencies. Mutualism is enabled and supported by these relationships and the multi-party blockchain technology backbone.

Mutualism enables multiplicative returns for participants. When firms reach this stage, they work together towards mutual objectives, which may be novel and unique to the group. Innovations build on the resources created and supported through the blockchain system in which they engage [41]. Through their collaboration with each other on the blockchain project, participants develop and hone strategic technology partnering (STP) capabilities that enable them to more effectively organise, innovate, learn, and create value through future technology-based collaborations [42].

The potential for value creation supported by blockchain platforms can be informed by the capabilities achieved through other platform ecosystems such as those provided by Apple, Facebook, Google, and Uber [43, 44]. Along with the data, the network of participants itself can be a source of innovation, and in many situations, the greater the number of participants the more value is created through network effects [14, 45]. For example, participants could create an app for service providers seeking to collaborate with these organisations. Vetting and performance ratings could be shared, providing benefits to participants seeking to collaborate with these vendors in the future. New products that rely on shared systems and historical data could be developed, such as end-to-end products for self- or external party-insurance or financing arrangements. Experience and expertise can be drawn upon as specific needs arise, expanding the capabilities available to participants.

In the maritime space, blockchain-based mutualistic collaborations have been foundational to the development of beneficial innovations and increasingly involve other "Industry 4.0" technologies like artificial intelligence, big data, IoT, and/or machine learning. Green et al. [13] summarise a number of examples, including TradeLens, Blocklab, and BunkerTrace. TradeLens is developing a smart bill of lading technology similar to that provided by CargoX. This technology will be used by consortium participants for automated processing and actionable document flows. Blocklab, a subsidiary of Port of Rotterdam built on its blockchain relationships and experience to launch a green energy innovation that uses smart contracts to enable high-frequency energy trades, balance supply and demand, and increase clean energy use. BunkerTrace, which uses blockchain technology for digitalisation of fuel trade documents, has built on this system to develop a blockchain innovation for fuel tracking. BunkerTrace uses DNA-based tags that can be added to fuel. The tags enable the fuel to be quickly tested en route to ensure provenance and quality.

4. Identification of Adoption Factors

As we have argued, increasing the intensity of collaboration and open innovation among blockchain consortium participants can result in significant economic and other performance returns. The factors that contribute to blockchain adoption and use not only influence an organisation's

adoption but the level of interdependence they can achieve across the blockchain collaboration continuum.

To identify the contributors to blockchain adoption through the lens of interdependence, we began with a systematic analysis of the academic literature. Such an analysis provides transparent and auditable documentation of the researchers' approach to gathering and evaluating evidence. Because academic research can lag behind practice, we supplemented academic findings with factors from grey literature, particularly in international maritime trade, which we use to illustrate and validate the factors.

Our research approach followed the PRISMA-S guidelines [46]. We began with database searches narrowed to relevant literature and then expanded to related academic and trade resources. We searched the Web of Science database of high-impact journals for blockchain AND (adoption OR diffusion) within subject categories of business, management, and operations research. This search resulted in a starting sample of 156 papers, which were reviewed for relevance. We identified 16 papers from this sample and added five additional highly relevant papers that addressed factors beyond individual organisation and technological concerns. Based on the factors in these papers, we identified four areas of interdependency that affect blockchain adoption.

Interdependencies Enabled by Blockchain

Building upon our analysis of the blockchain adoption literature, we grouped the primary interdependencies enabled by blockchain technology into four categories. The first two categories, socio-technical and economic, create value by integrating the actions and objectives of blockchain participants. We refer to these as internal interdependencies. The latter two categories, standards-setting and legal/regulatory, require engagement with additional players. We refer to these as ecosystem interdependencies (Table 2).

Table 2. Blockchain Interdependencies

Internal Interdependencies – among blockchain participants	
Socio-technical	Socio-technical interdependencies include shared language, routines, practices, and mindsets.
Economic	Economic interdependencies include synergies and trade-offs associated with costs, productivity, and market access.
External Interdependencies – with organisations in the ecosystem	
Standards	Standards interdependencies include shared technical and procedural specifications relating to transactions, workflows, and systems.
Legal/regulatory	Legal/regulatory interdependencies include rules and regulatory requirements governing the use of data and information, materials, currencies, practices, and systems.

Internal Interdependencies

Internal interdependencies refer to dependencies among firms that participate or could participate in an enterprise blockchain project. Socio-technical interdependencies include shared language and collaborative technological integration. Economic interdependencies affect the distribution of value creation from the adoption of blockchain across the collaborating parties.

Socio-technical Interdependence

Blockchain can be understood as a social technology that both requires and enables social coordination. While these systems can help to build trust and support open innovation, the manner in which they interact with existing socio-technical systems will influence adoption and effectiveness. Teece et al. [47] suggest that for individual firms, existing routines and practices as well as current endowments of technologies and relationships will affect how a firm adapts to strategic opportunities. Industries, too, have histories, practices, mindsets, and relationships that affect their trajectories. Theories about the diffusion of innovations suggest that adoption of new technology is an iterative process through which ideas affect actions that over time influence social structures. These structures, in turn, affect beliefs and actions [48]. Achieving blockchain objectives requires a cultural willingness to integrate new practices into existing socio-technical systems. Use of an "industrial age methodology and mindset" when evaluating blockchain and other advanced technologies may inhibit adoption [49]. In industries considering blockchain adoption, for example, low levels of digitalisation can create further challenges, particularly when long-established process and practices have functioned smoothly.

By way of illustration, the adoption of blockchain along the maritime supply chain was impeded to some degree by "institutional grind," where some of the supply chain players, particularly the small- and medium-sized firms, were reluctant to either replace these existing systems or integrate blockchain into them [50]. However, other organisations in the industry had already implemented precursors to blockchain-based systems through digital shipping portals like INTTRA and port community systems which enable information exchange between a port and its customers [51]. Adoption of these systems modernised industry practices and laid the foundation for future digitalisation. Participation in pre-blockchain projects also reflected potential participants' willingness to coordinate with other industry players. Collaborating via pre-blockchain systems helped establish multi-party relationships. In addition, leading industry participants gained experience managing such relationships, which could be drawn on as blockchain consortia emerged.

Like other interorganisational systems, blockchain technology holds the potential for enhanced performance through "IT-enabled coordination of interfirm processes" requiring both IT integration and communication across firm boundaries [25]. This interdependence requires shared governance along

the supply chain necessitating high-level communication about business objectives and a consensus on how to manage the relationship [25]. Value creation occurs through relational rents derived from the streamlining and improved quality of interfirm linkages that rely on self-enforcement [24].

When Maersk and IBM introduced the TradeLens blockchain, Maersk's direct competitors were hesitant to join [1]. A customer advisory board helped to improve transparency across member firms, facilitate communication and shared governance, and quell concerns of Maersk's dominance [52]. Expansion of TradeLens membership followed [36].

Economic Interdependence

Technology-based innovations can create economic benefits in a variety of ways, including cost savings through efficiency and productivity, revenue increases through market expansion, and innovation of new products and services [53]. Participation in a blockchain consortium establishes or amplifies economic interdependencies among participants. Individual firms must anticipate a net positive payoff that exceeds switching and integration costs to ensure their willingness to adopt blockchain technology. Resources required for implementation include the appropriate infrastructure and the knowledge to operate and integrate the new technology [54].

By spanning organisational boundaries and facilitating data sharing and aggregation across supply chain partners, blockchain can further enhance the performance of other technologies already deployed, such as RFID and IoT devices, and enterprise systems such as ERP, EDI, and CRM systems [55]. Direct interorganisational transactions enabled by blockchain can reduce transaction costs in ways not possible for tacit transactions [2].

In maritime trade, adoption of blockchain technology has enabled three primary areas of value creation: digitised paperwork including bills of lading and ship registry information; information sharing, ranging from commercial data such as cargo movements to technical data such as engine data; and automated processes focused on the execution of smart contracts when shipping terms are fulfilled [56]. Blockchain facilitates the integration of "granular information" and "exceptions related to physical flows" to allow supply chain partners to more effectively manage their interdependencies [25, 57]. Additional payoffs include streamlined connections among supply chain partners.

Numerous intermediaries are involved in arranging shipments in maritime trade, including freight forwarders, carriers, and brokers who link the supplier, the "shipper," with the buyer, the "consignee." Some of these intermediaries may be eliminated in the future by smart contracts enabled by blockchain, which has contributed to the hesitation of some firms to participate in the emerging consortia. For the surviving supply chain players, this will improve their return by decreasing: search costs, fees charged by intermediaries, errors and time associated with paper document exchange, and fraud and settlement transaction times [58]. Digitalisation has allowed carriers to start directly offering capacity to shippers [59]. Taking these changes into consideration, disruption and reconfiguration of existing relationships along the supply chain could be considered a countervailing cost to blockchain implementation.

Across case studies of firms in maritime trade contemplating replacement of existing digital shipping portals with blockchain technology, participants viewed confidentiality of information to be paramount in choosing interorganisational information systems [35]. In the case of TradeLens, the blockchain architecture based on Hyperledger Fabric allows information to be walled off into "channels" so only specified participants can view the information [36]. Hyperledger Fabric is open source, which provides assurance that the software will continue to improve due to a committed community of developers and that the source code of current and future versions will be transparent.

Ecosystem Interdependencies

An ecosystem can be described as a network of economically connected organisations that may span the boundaries of multiple industries [60]. Ecosystems emerge for a variety of purposes. They enable interdependent organisations to coordinate without hierarchical decision-making authority. Ecosystems support multilateral dependencies based on the unique resources and capabilities of participants [43].

Adoption of blockchain technology affects and is affected by the broader ecosystem within which the consortium operates. Blockchain workflows require coordination in areas such as terminology, codes, transaction features, processes, and timing. While some industries and ecosystem have well-established standards and regulations in place, it is more common for them to be lacking or inconsistent. This is particularly problematic when consortium partners operate in multiple jurisdictions or across industry lines. Thus, the consortium and its ecosystem stakeholders have interdependent relationships regarding standards, laws, and regulations.

Standards Interdependence

Standards are technical specifications that enable consistency across processes, products, and systems. Open standards can be characterised as public goods that all of the players in the industry can use at the same time without diminishing their usefulness for any one player, whether or not they contributed to the development of the standards [61, 62].

Effective deployment of blockchain technology may require broad agreements on workflows and sequencing or small agreements about the timing, identification, or contents of specific transactions. Standards and standardisation thus play a key role in blockchain adoption to facilitate these agreements [63]. To help spur technology adoption, the creation of

standards has become prevalent in high tech sectors through interfirm cooperation and the participation of international standard-setting organisations [61, 62, 64, 65, 66, 67].

For standards interdependence in maritime trade, a fundamental requirement is shared terminology. This is challenging due to the cross-border nature of trade involving multiple governmental jurisdictions [40]. The United Nations has created a library of core components of the semantics of trade information from which reference data models facilitate the exchange of business data [68]. The International Organization for Standardization (ISO) and the International Chamber of Commerce (ICC) have also been active in digital trade standards [40].

The Digital Container Shipping Association (DCSA), which counts nine of the ten largest ocean carriers among its members [69] initiated implementation of Track & Trace standards to provide a common data model and standards for interfaces and API definitions to create a common understanding of the process flow [70]. Additional standards are emerging in a coordinated fashion. For example, DCSA members are pursuing Just-In-Time port call standards consistent with the work of the International Maritime Organization (IMO), and cybersecurity standards in keeping with an IMO resolution [71, 72].

Legal/Regulatory Interdependence

Similar to standards, collaboration with legal and regulatory authorities in the broader ecosystem is critical for blockchain adoption. Adoption of blockchain requires clarification of the legal status of blockchain transactions and the manner in which data can be gathered, stored, and used. Variation in laws across jurisdictions can impede blockchain adoption [3]. Governments and trade organisations around the world are working on legislation governing blockchain trade and finance, but rules can be inconsistent and do not yet exist in many domains. Consortium participants, regulators, agencies, and others have interdependent interests and responsibilities that will affect whether and how blockchain is implemented.

Maritime trade provides a rich example of this type of interdependence. Extensive rules and regulations governing international trade have been developed over centuries, and are difficult to change. Since 2010, the European Union has sought to harmonise the electronic reporting of import and export documents and customs clearance [73]. This intensive process will inform the multilateral efforts to deploy blockchain technology including "legal certainty and establishment of interoperability standards" [58]. Blockchain holds promise as the vehicle by which to implement single windows across the 164 signatories of the 2017 Trade Facilitation Agreement [74]. UNCITRAL's MLETR digital/physical document equivalency project will contribute to global harmonisation [75].

Collaboration can also cause legal problems, however. If close collaboration is viewed as constricting downstream competition, antitrust regulations may come into play. Blockchain consortia in the maritime industry that wish to operate in the US must secure antitrust exemption by filing a cooperative working agreement with the Federal Maritime Commission [76]. This type of agreement forbids sharing vessel capacity and customer-sensitive information including terms and conditions and rates charged. However, it allows collaboration on information/data exchange including documents and events along the supply chain. Further, it can support mutualism among participants by allowing derivation of products and services from this information/data and the marketing of these products and services [77].

5. Conclusion

Building on theory and research, we identify and explicate key points of leverage affecting blockchain adoption as firms move across the collaboration continuum towards mutualism. These insights can be used by individual firms, consortia, and other ecosystem stakeholders to better understand the forces affecting adoption from within and outside of the consortium and to identify issues that promote adoption and those that inhibit it. These inhibiting factors can slow or halt adoption even in the context of clear net positive value creation for the consortium and its stakeholders. A better understanding of the interdependencies required for and created by blockchain-related relationships can influence both the short-term and long-term viability of blockchain solutions.

Our exploration of integration strategies and actions in the maritime trade industry demonstrates how interdependencies have contributed to adoption and have resulted in net value creation. From a socio-technical perspective, industry participants have been collaborating on supply chain efficiency projects for decades, and this history of collaboration provides the foundation for the higher level of integration required for interdependence and mutualism. Economically, these organisations are highly interdependent, as reflected by the container shortages during the COVID pandemic. Standards organisations and initiatives in maritime trade have long been active, and modernisation efforts for digitalisation are progressing rapidly due to the players in the maritime industry as well as in global trade organisations. Legal and regulatory frameworks associated with electronic documents, electronic payments, cybersecurity, and the storage of private information are being developed, and global framework templates are being shared [40].

Previous research focuses in large part on technological barriers to the adoption of blockchain and takes the perspective of the individual firm, particularly at the point of decision-making around adoption. In this article, we shifted focus to a multi-firm perspective and non-technological barriers for two reasons. First, individual firms do not make adoption decisions in a vacuum, and successful enterprise blockchain solutions require buy-in and participation from

multiple firms. Second, technological barriers are well-covered in the business, computer science, and other literatures [78], and technological innovations are moving rapidly to solve critical problems such as integration, scalability, and interoperability [79]. It has been frequently stated that blockchain is a team sport. The literature on open innovation and interorganisational information systems provides a theoretical foundation from which to understand blockchain adoption from a value-creation perspective. Building on this theoretical foundation and the extant body of research on blockchain adoption and diffusion drivers, we have developed our framework of organisational interdependencies.

Lumineau et al. [2] argue, "Organization scholars may run the risk of underappreciating the vast social implications of this important empirical phenomenon [of blockchain adoption] …" (p.1). We contribute to this understanding in three primary ways. First, we combine existing theories and re-cast them from the lens of interdependent organisational relationships in a blockchain context. Prior research has identified how the resulting interdependence lends support to the electronic market hypothesis [22], whereby advances in information technology have been expected to revolutionise the structure of industrial activity [28, 29, 30]. It has taken the features of blockchain to create a new industrial structure, the so-called "V-form organisation," whereby blockchain consortium governance enables independent firms to, in effect, behave like a vertically integrated firm through the coordination of their transactions along the value chain through a distributed ledger [1, 80]. Second, we provide actionable insights that can help illuminate adoption costs and benefits, enabling ecosystem participants, as well as solution providers and consultants, to identify where change is needed and where pressure can be applied to increase adoption. Third, we demonstrate the application of a framework of interdependence in the context of the maritime trade ecosystem, drawing on existing studies that illustrate the interorganisational requirements to make blockchain deployment successful.

The need for future research on adoption and its potential benefits is great. Viewing adoption through the lens of interdependence provides new insights into adoption and its net benefits. Additional research on successful movement along the collaboration continuum and, in particular, on how mutualism can and has been achieved will provide important future contributions towards realising the full potential of enterprise blockchain.

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References

[1] C. Berg, S. Davidson, and J. Potts, Understanding the blockchain economy: An introduction to institutional cryptoeconomics. Cheltenham, UK: Edward Elgar Publishing, 2019.

[2] F. Lumineau, W. Wang, and O. Schilke, "Blockchain governance—A new way of organizing collaborations?," Organization Science, vol. 32, no. 2, pp. 500-52, 2021. Available: https://pubsonline.informs.org/doi/epdf/10.1287/orsc.2020.1379

[3] M. Janssen, V. Weerakkody, E. Ismagilova, U. Sivarajah, and A. Irani, "A framework for analysing blockchain technology adoption: Integrating institutional, market and technical factors," International Journal of Information Management, vol. 50, pp. 302-309, 2020.

[4] H. S. Sternberg, E. Hoffman, and D. Roeck, "The struggle is real: insights from a supply chain blockchain case," Journal of Business Logistics, vol. 42, no. 1, pp. 71-87, 2021.

[5] N. Naqvi and M. Hussain, "Evidence-based blockchain: Findings from a global study of blockchain projects and start-up companies," Journal of the British Blockchain Association, vol. 3, no. 2, pp. 68-77, 2020.

[6] R. Ziolkowski, F. Miscione, and G. Schwabe, "Decision problems in blockchain governance: old wine in new bottles or walking in someone else's shoes?," Journal of Management Information Systems, vo. 37, no. 2, pp. 316-348, 2020.

[7] T. T. Kuo, H. E. Kim, and L. Ohno-Machado, "Blockchain distributed ledger technologies for biomedical and health care applications," Journal of the American Medical Informatics Association, vol. 24, no. 6, pp. 1211-1220, 2017.

[8] S. Ølnes, J. Ubacht, and M. Janssen, "Blockchain in government: Benefits and implications of distributed ledger technology for information sharing," Government Information Quarterly, vol. 34, no. 3, pp. 355-364, 2017.

[9] H. W. Chesbrough, Open Innovation: The New Imperative for Creating and Profiting from Technology, Boston, MA: Harvard Business School Press, 2003.

[10] H. Chesbrough, W. Vanhaverbeke, and J. West, eds., Open Innovation: Researching a New Paradigm, Oxford University Press on Demand, 2006.

[11] O. E. Williamson, The Economic Institutions of Capitalism, New York: The Free Press, 1985.

[12] MI News Network, "LR Foundation and bloc launch blockchain consortium to tackle mis-declaration of dangerous goods," Marine Insight, December 2, 2020.

[13] E. H. Green, E. W. Carr, J. J. Winebrake, and J. J. Corbett, "Blockchain technology and maritime shipping: A primer," US Maritime Administration, 2107, 2020.

[14] S. Heister, M. Kaufman, and K. Yuthas, "Consortium capabilities for enterprise blockchain success," Journal of The British Blockchain Association, vol. 4, no. 2, pp. 34-42, 2021.

[15] H. Wang, K. Chen, and D. Xu, "A maturity model for blockchain adoption," Financial Innovation, vol. 2, no. 1, pp. 1-5, 2016.

[16] E. Toufaily, T. E., Zalan, T., and S. B. Dhaou, "A framework of blockchain technology adoption: An investigation of challenges and expected value," Information & Management, vol. 58, no. 3, pp. 1-17, 2021.

[17] IBM Corporation, The founder's handbook: An introduction to building a blockchain solution, Third Edition, USA, IBM Corporation, June, 2020.

[18] K. Yuthas, Y. Sarason, and A. Aziz, "Strategic value creation through enterprise blockchain," Journal of The British Blockchain Association, vol. 4, no. 1, pp. 18-25, 2021.

[19] H. W. Chesbrough and M. M. Appleyard, "Open innovation and strategy," California Management Review, vol. 50, no. 1, pp. 57-76, 2007.

[20] A. Harrison, R. I. Van Hoek, Logistics management and strategy: competing through the supply chain. Harlow, England: Pearson Education Limited, 2011.

[21] R. E. Spekman, J. W. Kamauff, and N. Myhr, "An empirical investigation into supply chain management: a perspective on partnerships," Supply Chain Management: An International Journal, vol. 3, no. 2, pp. 53-67, 1998.

[22] C. Berg, S. Davidson and J. Potts, "Blockchain technology as economic infrastructure: Revisiting the electronic markets hypothesis," Frontiers in Blockchain, vol. 2, pp. 1-6, 2019.

[23] C. Berg, S. Davidson, and J. Potts, "Proof of work as a three-sided market," Frontiers in Blockchain, vol. 3, pp. 1-5, 2020.

[24] J. H. Dyer and H. Singh, "The relational view: Cooperative strategy and sources of interorganizational competitive advantage," Academy of Management Review, vol. 23, no. 4, pp. 660-679, 1998.

[25] A. Rai, P. Pavlou, G. Im, and S. Du, "Interfirm IT capability profiles and communications for cocreating relational value: evidence from the logistics industry," MIS Quarterly, pp. 233-262, 2012.

[26] J. D. Thompson, Organizations in Action: Social Science Bases of Administrative Theory. New Jersey: Transaction Publishers, 2003.

[27] N. Kostić and T. Sedej, "Blockchain technology, inter-organizational relationships and management accounting: A synthesis and a research agenda," Accounting Horizons, Online Early Accepted Manuscript, 2021.

[28] T. W. Malone, "Modeling coordination in organizations and markets," Management Science, vol. 33, no. 10) pp. 1317-1332, 1987.

[29] T. W. Malone, J. Yates, and R. Benjamin, "Electronic markets and electronic hierarchies," Communications of the ACM, vol. 30, no. 6, pp. 484-497, 1987.

[30] T. W. Malone, J. Yates, and R. Benjamin, "The logic of electronic markets," Harvard Business Review, May-June pp. 166-172, 1989.

[31] T. W. Malone and K. Crowston, "The interdisciplinary study of coordination," ACM Computing Surveys (CSUR) vol. 26, no. 1, pp. 87-119, 1994.

[32] T. W. Malone, "The future of work," in Designing Ubiquitous Information Environments: Socio-Technical Issues and Challenges, pp. 17-20. Springer, Boston, MA., 2005.

[33] S. Davidson, P. De Filippi, and J. Potts, "Blockchains and the economic institutions of capitalism," Journal of Institutional Economics, vol. 14, no. 4, pp. 639-658, 2018.

[34] G. Bavassano, C. Ferrari, and A. Tei, "Blockchain: How shipping industry is dealing with the ultimate technological leap," Research in Transportation Business & Management, vol. 34, pp. 1-8, 2020.

[35] F. Zeng, H. K. Chan, and K. Pawar, "The adoption of open platform for container bookings in the maritime supply chain," Transportation Research Part E: Logistics and Transportation Review, vol. 141, pp. 1-16, 2020.

[36] T. Jensen., J. Hedman, and S. Henningsson, S., "How TradeLens delivers business value with blockchain technology," MIS Quarterly Executive, vol. 18, no. 4, 2019.

[37] L. Pietrewicz, "Coordination in the age of industry 4.0," International Journal of Management Science and Business Administration, vol. 6, no. 2, pp. 24-32, 2020.

[38] M. del Castillo, "Blockchain 50," Forbes, Feb. 2, 2021. Accessed March 1, 2022. [Online]. Available: https://www.forbes.com/sites/michaeldelcastillo/2021/02/02/blockchain-50/?sh=8e43988231cb.

[39] D. Patel and E. Ganne, "Blockchain & DLT in Trade: Where do we stand?," White Paper, Trade Finance Global, 2020. ccessed on March 1, 2022. [Online]. Available: https://www.wto.org/english/res_e/booksp_e/blockchainanddlt_e.pdf .

[40] E. Ganne, E., Can Blockchain Revolutionize International Trade? Geneva: World Trade Organization, 2018.

[41] R. Alzahrani, S. J. Herko, J. M. Easton, "Blockchain-hosted data access agreements for remote condition monitoring in rail," Journal of the British Blockchain Association, vol. 4, no. 2, pp. 27-33, 2021.

[42] I. Kilubi, "Strategic technology partnering capabilities: a systematic review of the empirical evidence over two decades," Journal of Strategy and Management, vol. 9, no. 2, pp. 216-255, 2016.

[43] M. G. Jacobides, C. Cennamo, and A. Gawer, "Towards a theory of ecosystems," Strategic Management Journal, vol. 39, no. 8, pp. 2255-2276, 2018.

[44] U. Pidun, M. Reeves, and E. Wesselink, "How healthy is your business ecosystem?," MIT Sloan Management Review, vol. 62, no. 3, pp. 31-18, 2021.

[45] R. Shi, "Blockchain network as a platform: Conceptualizing its adapted layered architecture design," Journal of the British Blockchain Association, vol. 4, no. 2, pp. 18-22, 2021.

[46] M. L. Rethlefsen, S. Kirtley, L. Waffenschmidt, A. P. Ayala, D. Moher, M. J. Page, and J. Koffel, "PRISMA-S: an extension to the PRISMA statement for reporting literature searches in systematic reviews," Systematic Reviews vol. 10, no. 1): pp. 1-19, 2021.

[47] D. J. Teece, G. Pisano, and A. Shuen, "Dynamic capabilities and strategic management," Strategic Management Journal, vol. 18, no. 7, pp. 509-533, 1997.

[48] S. L. Vargo, M. A. Akaka, and H. Wieland, "Rethinking the process of diffusion in innovation: A service-ecosystems and institutional perspective," Journal of Business Research, vol. 116, pp. 526-534, 2020.

[49] Shahaab, R. Maude, and C. Hewage, "Blockchain-a panacea for trust challenges in public services? A socio-technical perspective," The Journal of the British Blockchain Association, vol. 3, no. 2, pp. 53-60, 2020.

[50] K. Jabbar and P. Bjørn, "Infrastructural grind: Introducing blockchain technology in the shipping domain," In Proceedings of the 2018 ACM Conference on Supporting Groupwork, pp. 297-308, January, 2018.

[51] A. Moros-Daza, R. Amaya-Mier, and C. Paternina-Arboleda, C. "Port Community Systems: A structured literature review," Transportation Research Part A: Policy and Practice, vol. 133, pp. 27-46, 2020.

[52] M. Lacity and R. Van Hoek, "What we've learned so far about blockchain for business," MIT Sloan Management Review, vol. 62, no. 3, pp. 48-54, 2021.

[53] N. O'Connor, P. B. Lowry, and H. Treiblmaier, "Interorganizational cooperation and supplier performance in high-technology supply chains," Heliyon, vol. 6, no. 3, e03434, pp. 1-16, 2020.

[54] M. L. Markus, "Toward a 'critical mass' theory of interactive media: Universal access, interdependence and diffusion," Communication Research, vol. 14, no. 5, pp. 491-511, 1987.

[55] R. Cole, M. Stevenson, and J. Aitken, "Blockchain technology: implications for operations and supply chain management," Supply Chain Management: An International Journal, vol. 24, no. 4, pp. 469–483, 2019.

[56] S. Pu and J. S. L. Lam, "Blockchain adoptions in the maritime industry: a conceptual framework", Maritime Policy & Management, pp. 1-18, 2020.

[57] World Bank Group, "Accelerating digitalization: critical actions to strengthen the resilience of the maritime supply chain," The World Bank, 2021.

[58] M. Perkušić, Š. Jozipović, and D. Piplica, "The need for legal regulation of blockchain and smart contracts in the shipping industry," Transactions on Maritime Science, vol. 9, no. 2, pp. 365-373, 2020.

[59] J. Sotelo and Z. Fan, "Mapping TradeTech: Trade in the fourth industrial revolution," World Economic Forum Insight Report, October 2020.

[60] M. Iansiti, and R. Levien, "Strategy as ecology," Harvard Business Review, vol. 82, no. 3, pp. 68–78, 2004.

[61] M. Weiss and C. Cargill, "Consortia in the standards development process," Journal of the American Society for Information Science, vol. 43, no. 8, pp. 559-565, 1992.

[62] P. Olk and J. West, "The relationship of industry structure to open innovation: cooperative value creation in pharmaceutical consortia," R&D Management, vol. 50, no. 1, pp. 116-135, 2020.

[63] M. Jović, E. Tijan, D. Žgaljić, and S. Aksentijević, "Improving maritime transport sustainability using blockchain based information exchange," Sustainability, vol. 12, no. 21, pp. 1-19, 2020.

[64] H. Delcamp and A. Leiponen, "Innovating standards through informal consortia: The case of wireless telecommunications," International Journal of Industrial Organization, vol. 36, pp. 36-47, 2014.

[65] R. M. Ham, G. Linden, and M. M. Appleyard. "The evolving role of semiconductor consortia in the United States and Japan," California Management Review, vol. 41, no. 1, pp. 137-163, 1998.

[66] R. Hawkins, "The rise of consortia in the information and communication technology industries: emerging implications for policy," Telecommunications Policy, vol. 23, no. 2, pp. 159-173, 1999.

[67] A. E. Leiponen, "Competing through cooperation: The organization of standard setting in wireless telecommunications," Management Science, vol. 54, no. 11, pp. 1904-1919, 2008.

[68] UN Economic and Social Council, "White paper on a reference data model," 2017.

[69] DCSA, "Eight need-to-know facts about DCSA," 2021. Accessed June 1, 2021. [Online]. Available: https://dcsa.org/wp-content/uploads/2021/02/202101-DCSA-factsheet.pdf.

[70] DCSA, "DCSA Track & Trace Standards Adopted by Majority of Member Carriers," April 7, 2021. Accessed June 1, 2021. [Online]. Available: https://dcsa.org/resource/dcsa-track-trace-standards-adopted-member-carriers/.

[71] DCSA "Standards for a just-in-time port call," October 20, 2020. Accessed June 1, 2021. [Online]. Available: https://dcsa.org/wp-content/uploads/2020/10/20201020-DCSA-P6-JIT-Port-Call-Publication-Release1-V1.0-FINAL-1.pdf.

[72] DCSA, "Mitigating cyber risks on board ships," 2021. Accessed June 1, 2021. [Online]. Available: https://dcsa.org/initiatives/cyber-security/.

[73] European Commission, "European Maritime Single Window environment," European Commission, Mobility Transport, 2021. Accessed June 1, 2021. [Online]. Available: https://ec.europa.eu/transport/modes/maritime/digital-services/e-maritime_en.

[74] World Economic Forum "Windows of opportunity: facilitating trade with blockchain technology," World Economic Forum, July 2019.

[75] Trade Finance Global "Standardisation 2.0 - ICC DSI's 5 year plan - Fireside chat with Oswald Kuyler," https://www.youtube.com/watch?v=YXsd4PFXlgU, Trade Finance Global, Mar 7, 2021.

[76] Federal Maritime Commission, "The TradeLens agreement: A cooperative working agreement," FMC Agreement No. 201328, 2017.

[77] Federal Maritime Commission, "The Global Shipping Business Network agreement: A cooperative working agreement," FMC Agreement No. 201344, 2017.

[78] S. Seebacher, R. Schüritz, and G. Satzger, "Towards an understanding of technology fit and appropriation in business networks: evidence from blockchain implementations," Information Systems and e-Business Management, vol. 19, no. 1, pp. 183-204, 2021.

[79] S. Johnson, P. Robinson, and J. Brainard, "Sidechains and interoperability," arXiv preprint arXiv:1903.04077, 2019.

[80] D. W. E. Allen, A. Berg, and B. Markey-Towler, "Blockchain and supply chains: V-form organisations, value redistributions, de-commoditisation and quality proxies," The Journal of the British Blockchain Association, vol. 2, no. 1, pp. 1-8, 2019.

