Blockchain Adoption in Life Sciences Organizations: Socio-organizational Barriers and Adoption Strategies

Chang Lu

Abstract The goal of this chapter is to reveal socio-organizational barriers for blockchain adoption in life sciences organizations and delineate the strategies that managers and executives can undertake to facilitate adoption. By drawing on the literature on innovation adoption and organizational culture and studying real-time blockchain adoption, this chapter describes the following socio-organizational barriers for blockchain adoption in life sciences organizations: (1) negative stereotypes of blockchain technology, (2) perceived technological complexity of blockchain, (3) highly institutionalized nature of life sciences organizations, and (4) lack of ecosystem mindset. The chapter also reveals strategies that can facilitate adoption: (1) holistic evaluation of blockchain life sciences use cases, (2) framing blockchain adoption as aligned with the innovative and safety-driven culture in life sciences organizations, (3) unobtrusive implementation, and (4) acting swiftly when the innovative culture gains strength. These insights draw attention to the overlooked socio-organizational aspects of blockchain adoption in life science and offer practical insights to make blockchain adoption a reality.

Keywords Blockchain adoption · Socio-organizational barriers · Adoption strategies · Organizational culture · Resources · Life sciences

1 Introduction

In recent years, blockchain is emerging as a transformative technology to address data challenges in life science. By combining cryptography and decentralized internet, blockchain makes it extremely difficult to change or erase data, producing an exceedingly high degree of data immutability, provenance, and transparency [1, 2]. Researchers have suggested that using blockchain in life sciences could help monitor compliance with regulations, improve patient and trial safety, and enhance the credibility of clinical research [3].

C. Lu (✉)
Blockchain@UBC, University of British Columbia, Vancouver, BC, Canada
e-mail: chang.lu@ubc.ca

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Despite the transformative potential of blockchain, the academic and practical discussions about blockchain in life sciences have focused on exploring new use cases and the design and technical parameters of the use cases [4, 5]. Very little attention has been paid to what life sciences organizations experience when adopting blockchain, what socio-organizational barriers they encounter, and what organizational strategies could facilitate adoption.

It is important to address these gaps. As scholars have suggested, the more an emerging technology represents a radical innovation, the more likely it will face strong socio-organizational barriers during adoption [6, 7]. Without a solid understanding of those barriers and the strategies to overcome the barriers and facilitate adoption, we cannot materialize the transformative potential of the technology, regardless of the care given to its technical design [8]. As blockchain represents a decentralized solution to data challenges in life science, radically departing from existing centralized solutions, the socio-organizational barriers and adoption strategies are likely to be crucial to the outcome of mass adoption and must be understood thoroughly.

This chapter reveals the socio-organizational barriers that hinder and the strategies that facilitate blockchain adoption in life sciences organizations. This chapter is based on an empirical study of a real-time blockchain adoption use case in a global life sciences organization. The author followed a standard qualitative case-study approach, collected 28 semi-structured interviews with managers and experts that participated in the adoption process, as well as documents and meeting minutes, and analyzed the data using a grounded theory approach [9].

Blockchain adoption may face the following socio-organizational barriers in life sciences organizations: (1) negative stereotypes of blockchain technology, (2) perceived technological complexity of blockchain, (3) highly institutionalized nature of life sciences organizations, and (4) lack of ecosystem mindset. These barriers compound the uncertainty and ambiguity of blockchain technology, making it difficult for mass adoption to occur. However, drawing from the literature on organizational culture and a real-time blockchain pilot project that gained initial success, the following strategies might increase the likelihood of adoption: (1) holistic evaluation of blockchain life sciences use cases, (2) framing blockchain adoption as aligned with both the innovative and safety-driven culture in life sciences organizations, (3) unobtrusive implementation, and (4) acting swiftly when the innovative culture gains strength. These findings fill the gap that socio-organizational understandings of blockchain adoption are limited and hold the potential to advance the practice of blockchain adoption.

2 Background Literature

Blockchain is referred to as a “distributed ledger with confirmed blocks organized in an append-only sequential chain using cryptographic links” ([1], s. 3.6). This technology represents an enabler for decentralized information systems that are superior in privacy and security while less susceptible to “single point of failure.” By using cryptography and algorithm-generated public–private key structure, blockchain can protect user privacy better than traditional password-based systems. Specifically, blockchain makes security attacks and data tampering extremely difficult through hash function and the chained structure of information blocks. Moreover, as a peer-to-peer network where each node holds a copy of all transactions, blockchain avoids the “single point of failure” inherent in centralized data systems. More importantly, these technical properties render it possible to govern information in decentralized mechanisms.

All in all, blockchain is considered to transform information management. Given the importance of information in the digital era, blockchain may bring fundamental changes to business and social systems [2]. As such, scholars and practitioners have explored blockchain use cases in a wide range of sectors, such as finance, agriculture, retail, and life sciences [10].

Use cases in multiple business domains have been proposed in life sciences, including clinical trials, drug supply chains, payments, and consumer health records [3, 4]. So far, the literature has focused on exploring the value propositions of the use cases and prototyping application design. For example, Tseng et al. [11] showed how blockchain could enhance the traceability of drug supply chains and proposed a governance framework based on the Gcoin. Metcalf et al. [5] discussed how blockchain might enable decentralized clinical and genomic data marketplaces, laying out the key value propositions and stakeholders. Recently, the design aspect of blockchain in life sciences has become nuanced, as specific technical measures are proposed to accommodate the characteristics of health data and regulations. For instance, Dubovitskaya et al. [12] suggest storing original clinical data off-chain and only meta transaction data on-chain. Clinical data are often too large to be stored on-chain, and some instances of on-chain storage may not be compliant with the U.S. Health Insurance Portability and Accountability Act (HIPAA). They also propose Member Services as a unique node to certify and grant access to member nodes on the blockchain.

The literature has also begun to explore the adoptability of blockchain in life sciences from the originators of human data. Lu et al. [13] explored consumer attitude towards blockchain-based health records focusing on consumer health records. They demonstrated that consumers are not necessarily ready for the application because of the concerns about losing their private keys and the inability to revoke data access. Khurshid et al. [14] examined clinical data sharing behavior in a simulated setting. They found that people may initially exhibit faulty sharing behaviors and the errors decrease over time, suggesting that users can adapt to blockchain-based clinical data sharing.

Despite the advancements above, the literature lacks an understanding of the socio-organizational barriers for blockchain adoption in life sciences and the strategies that may facilitate adoption. This is a critical omission because the literature on innovation adoption [6–8], as well as on electronic laboratory records [15–20], strongly suggests that blockchain adoption is likely to encounter socio-organizational barriers. The neglect of these barriers could lead to adoption failure.

The literature on innovation adoption has long suggested that new practices or technologies encounter socio-organizational barriers when introduced into a new organization, industry, or country [6–8, 21, 22]. These barriers stem from the inertia of the "old" socio-organizational systems, whether behavioral routines, the entanglement of social networks, entrenched material interests in old systems, or taken-for-granted values and beliefs. The stronger the inertia of the "old," the more barriers new practices or technologies are likely to face [6, 7]. Research has shown that these barriers can significantly delay or change the trajectory of practice or technology adoption. For example, Barley [23] showed that the inertia of the interactions between professionals has strongly affected the adoption of body imaging technology and the technology had to adapt to local clinical practices. Dougherty and Dunne [24] found that scientists with different backgrounds were embedded in different knowledge systems that hindered their collaborative adoption of digital technologies in life sciences laboratories. As such, scholars suggested that due to socio-organizational barriers, new practices or technologies must be made to fit with local structural, cultural, and political arrangements [8].

In the literature on the Electronic Lab Notebooks (ELN), researchers have found that the implementation of ELN in life sciences labs, a technology that matured decades ago, met a variety of socio-organizational barriers. For instance, Kanza et al. [18] found that the low adoption of ELN in life sciences research institutions might be due to the behavioral inertia of lab participants, who would shift back to paper-based notebooks even after being made aware of ELN. Also, Kanza [17] and Zupancic et al. [20] suggest that scientists sometimes hesitate to adopt ELN because they believe that the implementation process would disrupt workflow. These socio-organizational barriers have delayed the adoption of ELN and contributed to the operation inefficiencies experienced by scientists [20].

Blockchain is more technically complex than ELN and represents a paradigm shift in how information is managed in life sciences. Therefore, blockchain is bound to meet more substantial socio-organizational barriers than those encountered by ELN. Without understanding those barriers and coping strategies, blockchain adoption in life sciences may suffer a more challenging path than witnessed by ELN.

3 Research Methods

The aim of this study was to understand the socio-organizational barriers for blockchain adoption and the responding strategies using a qualitative approach. A qualitative approach is well suited to explore emerging or poorly understood phenomena and is commonly used by behavioral researchers to explore the barriers to emerging technology adoption [23, 25, 26]. It can provide rich, detailed descriptions of barriers that early adopters experienced and their actions to tackle them. The qualitative approach also promises to develop more abstract, widely relatable categories of the barriers, informing both researchers and practitioners.

The primary data source involved 28 semi-structured interviews with directors, managers, and executives in the life sciences sector who have been involved in the adoption of blockchain. A purposeful sampling method was adopted [27], targeting experienced life sciences professionals with first-hand experience of blockchain adoption. A pharmaceutical company known to implement blockchain projects was contacted to provide contact information for those who have participated in the blockchain projects; the company named 15 individuals working on blockchain adoption in two locations. Twelve agreed to participate in the interview. In the meantime, interview invitations were sent to 26 individuals identified on LinkedIn after searching for "blockchain" and "life science." Ten decided to participate. In addition, the author attended three multi-day blockchain conferences with sessions discussing blockchain and reached out to the speakers and attendees, inquiring about their professional backgrounds and interest in an interview. Six individuals at those conferences agreed to the interview. All individuals work in middle-senior professional roles, such as manager, Information technology (IT) manager, blockchain consultant, enterprise innovation manager, compliance, and regulatory director. Among others, all individuals have either led or participated in blockchain life sciences projects. Table 1 shows the number of study participants in different professional roles.

Participants were interviewed by following a semi-structured format. Participants were first asked to describe their involvement in the adoption of blockchain in life science. Based on their different levels of involvement, questions were tailored about their socio-organizational barriers to adoption and how they have overcome those barriers. The interviews took between 30 min and one hour. Except for three interviews where notes were taken, all others were recorded and transcribed. Apart from the 28 primary interviews, the author also collected 13 secondary, publicly available interviews were evaluated that broadly discussed the adoption of blockchain in life sciences and health. Blockchain advocators often interview each other and publish the interviews on social media (e.g., YouTube or Vimeo) as part of the effort to prompt adoption. These interviews contain information that helps to understand the nature of blockchain and touch on the barriers for blockchain in life sciences organizations. In addition, the author collected 193 news articles from major blockchain websites (e.g., coinbase.com, blockchain.news.com, cointelegraph.com) that cover

Table 1 Professional roles of primary interview participants

Professional role	Number of participants (n = 28)
Middle managers in life sciences	11
Senior Executives in life sciences	2
Blockchain + life sciences start-up leaders (co-founder or CEO)	9
Blockchain + life sciences experts or consultants	5

blockchain adoption in life sciences or health. The secondary interviews and newspaper articles constitute a rich, comprehensive pool of background information to support the understanding of the primary interviews.

Data were analyzed using the grounded theory method, following the steps commonly used in the literature [28, 29]. The first step was to extensively read the secondary interviews and documents, by which a general understanding of blockchain technology was gained and its applications in life sciences settings. Next, the author conducted thematic coding of the 28 primary interviews in Nvivo 12.0, summarizing the surface meaning of words, phrases, and sentences concerning the socio-organizational behavioral barriers to adopting blockchain in life sciences organizations. This step generated 812 first-order codes. Axial coding was then conducted to aggregate first-order codes that share underlying meanings into second-order categories. The author then moved back and forth between the first-order codes and second-order categories to continuously adjust the categorization of the first-order codes. When the second-order categories captured the meaning structure of the first-order codes, the second categories were aggregated into the third-order dimensions through multiple iterations.

4 Findings

To understand the barriers of blockchain adoption in life sciences organizations, it is essential to first understand the current state of the blockchain + life sciences ecosystem since the ecosystem is the context in which the barriers are experienced. As such, the findings on the key characteristics of the ecosystem are presented.

4.1 The State of the Blockchain + Life Sciences Ecosystem

The concept of "ecosystem" refers to "a group of interacting firms that depend on each other's activities" ([30], p. 1). According to the literature, a business ecosystem comprises ecosystem boundaries, governance structures, relational networks among participants, and shared practices [7, 31]. Thus, we can understand the nature of a business ecosystem by examining its components.

The qualitative coding suggests that the components of the blockchain + life sciences ecosystem have the following characteristics:

4.1.1 The Ecosystem Boundary is in Constant Flux

Boundaries are conceptual and group distinctions made by individuals and organizations to categorize reality [32]. In the context of a business ecosystem, the system's boundary demarcates legitimate members from those who are not. Boundaries can exist as formal membership rules or informal shared understandings of the resources and identities of new entrants. In the blockchain + life sciences ecosystem, however, such boundaries are in a state of constant flux. New entrants can almost freely claim their participation in the system, regardless of their resource base or organizational identity. As undistinguished entrants crowd into the system, they tend to misinterpret or misuse terminology, ideas, and concepts, increasing the system's opaqueness. As shown by the following field note and interview excerpts:

> The conference is organized in a different format from academic conferences. Many speakers are start-up leaders. I went to the information desk of a start-up whose leader spoke 15 min ago. The information booklet is incomplete. It states the company focuses on blockchain and genomic data marketplace, but there is no business model. (Field note, 20190407)
>
> I'm invited to speak at many conferences. You can say you are a blockchain company and you get to speak. (Interview, blockchain start-up founder)

4.1.2 The Governance Structure is Developing but as yet to Form

The governance structure of a business ecosystem consists of "governance organizations or associations within the field whose sole job is to ensure the routine stability and order of the field" and the rules that these organizations enact ([33], p. 77). The governance organizations formalize rules and regulations, designate power structures, oversee practices, ensure compliance, and penalize misconduct.

In a blockchain + life sciences ecosystem, some organizations are attempting to develop governance structures. For example, there are discussions in the Institute of Electrical and Electronics Engineers about setting industry standards for blockchain in health and life sciences, organizing industry associations (e.g., various consortiums such as MELLODDY), and creating industry-wide task forces. However, all these efforts seem to be at an early stage. No evidence suggests that a mature government structure has been established in the blockchain + life sciences ecosystem.

4.1.3 The Relational Network is Forming but Thin in Content

Relational networks are the backbone of an ecosystem [30, 31]. It consists of relationships among participants, resources, information, and trust exchanged through the relationships—in other words, the content of ties [7, 34]. The higher degree of interconnectedness among system participants, the more stable the system. Besides, with ties characterized by trust, the system is more likely to optimize the utilization of resources [30, 35].

This analysis shows that relational network is forming but continues to evolve in the blockchain + life sciences ecosystem. A few central organizations have emerged, such as ConsenSys, which has footsteps in life sciences, the IBM blockchain team that covers life sciences projects, Microsoft Azure, and BurstIQ. These organizations actively participate in public speaking, research, business development, and education. As such, these organizations are given higher status by other participants in the ecosystem. However, the rest of the network seems in flux.

> I know most of the start-ups. But I think most of them have gone out of business except a few. (Interview, start-up founder)

Notably, the relational network is thin in content because the resources exchanged through the ties are limited. Although start-ups, universities, and pharmaceutical companies have organized seven major consortiums, the consortiums have yet to deliver substantial outcomes.

4.1.4 Proto-Practices Being Explored

Practices in the context of ecosystems are defined as "behaviors, strategies, ideas, technologies, or structures that have obtained a social fact quality [that] renders them as the only conceivable, 'obvious,' or 'natural' way to conduct an organizational activity" ([36], p. 229). Based on this definition, practices have certainly not taken form in the blockchain + life sciences ecosystem. Nevertheless, proto-practices are being explored by various organizations. For example, the MELLODDY project is exploring federated learning (combining blockchain and machine learning) for molecule data sharing. Even though federated learning is still a developing technology, EncrypGen, and Nebula Genomics are exploring decentralized, blockchain-enabled genomics data marketplaces. Regardless of the stage of these experimentations, experts understand that the experimentations have not given rise to conclusions as to what kind of blockchain applications in life sciences are the most feasible, how to implement them, and what structures could secure implementation.

> I don't think we know the ultimate use case. In fact, I don't know [that] many people understand what blockchain can do and what it cannot do. This year, there has been so much confusion… (Interview, blockchain expert)

Having described the key characteristics of the blockchain + life sciences ecosystem, the socio-organizational barriers that early adopters have experienced will be described.

4.2 Socio-organizational Barriers for Blockchain Adoption in Life Sciences

The interviews and documents show that three types of blockchain use cases can be distinguished based on primary goals: use cases that aim to improve compliance, facilitate research data sharing and transactions, and enable individuals to monetize personal data. These different types of use cases are associated with the increased necessity to engage multiple stakeholders and build permissioned blockchain solutions. Specifically, the use cases that aim to improve compliance with regulations can be realized on private blockchains inside a particular organization. Those aiming to facilitate data sharing may require establishing "consortiums" among different organizations and creating blockchain solutions that only consortium participants can access. Last, the use cases aiming to enable personal data monetization may need permissioned blockchains that contain delicate smart contracts. Regardless of use cases, early blockchain adoption has commonly experienced the following socio-organizational barriers.

4.2.1 Barrier 1: The Negative Stereotype About Blockchain Technology

Participants shared that the negative stereotype about blockchain technology has become a significant roadblock when they attempt to create "buy-in." Many participants experienced indifference or dismissal from regulators, patients, and executives, due to the widespread perception that blockchain is a "troublesome" technology linked to cryptocurrency scams, opportunistic investing, money laundering, or financial schemes. Besides, since early blockchain promoters often used evangelical language such as "blockchain will change the world," "blockchain will give power to normal people." Since blockchain's first use case—Bitcoin-was created by a mythical figure (Satoshi Nakamoto) and embodies the ideology of decentralization and anarchism, blockchain is often perceived as supporting a "cult" or alike. As one participant depicted: "There is much skepticism about blockchain. When you talk about blockchain, people think about Bitcoin. They think you are a hippy and want to take them into the scheme" (Participant 18). The stereotype that blockchain is associated with schemes or special agendas has made it increasingly difficult for early adopters to promulgate adoption. Study participants reported that when they engage colleagues or stakeholders for support or resources, they are often met with the attitude that "I don't want to hear blockchain anymore." In response, they had to mention the word "blockchain" as little as possible when they attempted to create buy-in. Some participants opted for "distributed trust technology" as a substitute for blockchain, and others emphasized that blockchain advocators must make a strong case that blockchain can add practical value to life sciences, as shown by the following quotes:

> We have done many presentations [about blockchain], but many times, people look at us sideways. It feels like they just don't want to hear about blockchain anymore. So, we have to do all sorts of analysis, cost–benefit analysis, risk analysis, competitive analysis just to make sure they understand where we come from and what is the business value [of blockchain]. (Participant 10)

4.2.2 Barrier 2: Perceived Technological Complexity of Blockchain

The second barrier study participants pointed out is the perceived technological complexity of blockchain, which somewhat contributes to the difficulty overcoming the first barrier. Study participants report that the complexity of blockchain technology has created the dilemma of whether they should explain the technical foundations of blockchain to decision-makers. If they show blockchain's highly developed computational methods and network infrastructure, not only are most of the decision-makers unable to follow and understand how blockchain is technically sound but also the study participants themselves may have technical "blind spots." "Sometimes it gets too technical that I, myself, find it hard to explain" (Participant 2). The display can discredit the blockchain technology and reinforce the impression that the blockchain community is "religious" or backed by some schemes. On the other hand, if they do not explain blockchain in technical terms, decision-makers would not have the opportunity to develop trust for blockchain and the early adopters who promulgate further adoption. This dilemma makes it challenging to educate decision-makers (as well as laypeople) about blockchain, slowing down the purging of the negative stereotypes of blockchain.

4.2.3 Barrier 3: The Highly Institutionalized Nature of Life Sciences Systems

Blockchain is in its infancy, facing substantial technological and economic uncertainties. However, life sciences are highly institutionalized [37, 38], meaning that there are rule systems practices, role identities, and shared understandings of rewarded behaviors. In specific terms, life sciences professionals understand who the authorities are, what regulations or protocols to follow, how to reserve and analyze data, the responsibilities of different roles, and the risks of deviating from those rules. Study participants describe that the highly institutionalized nature of life sciences has made blockchain adoption very challenging. First, as the field of life sciences is heavily regulated by government and professional authorities, using blockchain to alter the structure and process of life sciences (e.g., enable individuals to monetize their genomics data by selling the data on a blockchain-based exchange) runs the risk of deviating from established rules. As participants described, the field of life sciences is highly regulated by authorities. While regulations are intended to be technology-agnostic, life sciences organizations may be hesitant to pursue substantial adoption of blockchain without authority clarification.

> In clinical trials, I think that the authorities are a main actor where you need to convince them and explain why they can trust what you're building. But they are very conservative. The bottom line is patient safety. (Participant 11)

The reliance on organizational decision-makers also creates a "chicken-and-egg" problem; life sciences organizations would not pressure top-down adoption unless they see substantial benefits of blockchain. However, the benefits of blockchain (determined by its distributed nature) can only be realized when there is large-scale adoption. As such, the blockchain projects that study participants worked on are commonly incremental; the change they bring is significantly less than that promised in the blockchain discourse.

> Haha, yes, exactly. We have a chicken and egg problem. As a start-up, the only thing we can do is build relationships as much as possible…. We are only taking small steps. (Participant 28)

Second, despite continuous adjustment, the institutionalized practices of life sciences have been largely stable, and the same set of structures and processes have become taken for granted [37, 38]. Study participants describe that this "taken-for-grantedness" of life sciences practices tends to perpetuate itself, supported by shared beliefs such as "this is how we do clinical trials" and "this is how insurance transactions are handled" (Participant 24). As a result, even though advocators of blockchain proposed many blockchain applications, their colleagues and stakeholders often put those proposals aside because they could not conceive of doing life sciences differently with blockchain.

Third, as the life sciences field is highly institutionalized, individuals and organizations have entrenched material and political interests into existing practices. However, blockchain is claimed to transform existing practices by eliminating some manual tasks (e.g., calibrating trial data or cross-validating research output) and re-arranging workflows. Therefore, adopting blockchain would mean a shock to entrenched interests. Study participants report that they worry that blockchain may break down the connection between material, political interests, and existing practices have made some individuals resistant to blockchain.

> From a business standpoint too, you have to remember, there's hundreds of thousands of people who have jobs in creating risk profiles for patients in insurance companies, and they [inaudible 00:22:26]. And to tell them that overnight, we're going to completely change the nature of your job, there's going to be a lot of pushback. (Participant 15)

Unfortunately, study participants report that they do not anticipate the highly institutionalized nature of life sciences will change any time soon because the field must be highly institutionalized for pragmatic and ethical reasons. Taking that as a given, blockchain advocators may promulgate adoption through small-scale innovations over a long period.

4.3 *Barrier 4: The Lack of an "Ecosystem" Mindset*

Another barrier that study participants commonly experienced is the lack of an "ecosystem" mindset among those considering adopting blockchain. An "ecosystem" mindset means that different businesses consider each other as complementors, prioritize the building of system infrastructure, and adopt business strategies that would make the "pie" bigger for all participants to grow [30]. Study participants report that the ecosystem mindset is crucial for blockchain adoption, given that blockchain is a distributed ledger technology. However, participants describe that those at the demand side of blockchain solutions have yet to consider each other as complementors and forge ecosystem-building at the level that blockchain developers would prescribe. Despite the other efforts to build industry-level infrastructure for blockchain adoption, for example, by forging consortiums consisting of research institutions and pharmaceutical companies, participants report that life sciences organizations have not demonstrated the "ecosystem" mindset. In executive meetings, the conversations about using blockchain to facilitate trial data sharing often have yet to yield substantial outcomes; some report that those conversations seemed to be symbolic gestures due to the perpetuating, siloed way of thinking.

> I think interoperability is a technical priority. The Ethereum community knows that there is not going to be a single blockchain… But I think the top priority for many companies is building business value on top of Ethereum [for themselves]. (Participant 6)

On the supply side, established IT firms and blockchain start-ups have yet to do businesses in an ecosystem fashion, continuing to show the "competition" mindset and consider each other as competitors despite some initial conversations about collaboration. Study participants describe that this lack of ecosystem mindset slows down blockchain adoption. Blockchain start-ups who face tremendous, immediate financial pressure cannot explore the most cutting-edge applications by leveraging established IT firms' capabilities. As a result, they go out of business quickly. In the meantime, established IT firms may not develop easily adaptable applications by leveraging the creativity and flexibility of start-ups. Consequently, it becomes challenging to create a supply market for blockchain applications in life sciences. (Note that some participants suggest that academic institutions must be engaged to infuse the ecosystem mindset to blockchain consumers and suppliers.)

> We [as a blockchain-life sciences start-up] can't wait for years because we have a responsibility to our investors to create value for them… We'd like to partner with those big companies, but we haven't seen much interest. I don't think we have reached the point where everyone understands the ecosystem. (Participant 3)

4.4 Adoption Strategies

Despite that the blockchain + life sciences ecosystem is at the early stage of development and that early adopters have experienced the barriers above, interview participants who gained initial success in pilot projects suggested that specific strategies may facilitate adoption. These strategies are described in the following section.

4.4.1 Holistic Evaluation of Blockchain Life Sciences Use Cases

Interview participants suggested that the first step for successful adoption is to perform a holistic evaluation of the proposed use case. Throughout the interview and document data, four factors were described as crucial in determining the adoptability of a blockchain + life sciences use case, and the factors need to be considered holistically.

- **Economic value of the use case**: As many interviewees pointed out, the economic value is the bottom-line factor to consider when adopting blockchain in life sciences, in other words, "what business problems can blockchain solve?" or "how much value can blockchain add to existing business models?" In particular, interviewees cautioned that potential adopters should not adopt blockchain for the sake of blockchain (e.g., adopting blockchain for religious reasons) but for the practical benefits.
- **Readiness for adoption**: Readiness for adoption includes two aspects: technological readiness and behavioral readiness. Technological readiness means the extent to which technological infrastructure is developed for the mass adoption of blockchain, consisting of indicators such as the electrocyclization of data, the availability of blockchain technical knowledge, and the interoperability of blockchains. Behavioral readiness refers to the extent to which those who need to participate in the adoption are willing and conditioned to incorporate blockchain into their current pattern of technology use. Indicators may include perceived benefits of blockchain, perceived ease of adoption, and perceived necessity [5]. As interviewees described, the lack of either technological or behavioral readiness dramatically reduces the likelihood of mass adoption.

  In labs, a lot of work is still done on paper. How can you create a blockchain solution when everything has to be on paper? (Interview, start-up founder)

- **Compliance with existing rules**: The field of life sciences is highly regulated by regulations and organizational rules. There exist taken-for-granted rule systems practices and role identities, as well as shared understandings of rewarded behaviors. Although the multilayer rule system may cause managerial inefficiencies, some interview participants also maintain that the rules are necessary as they help people behave in a way that produces good science.

Adopting blockchain may ultimately lead to the transformation of the rules in life sciences. However, this study suggests that blockchain use cases should comply with existing rules in the foreseeable future. If the use cases are at odds with existing rules, life sciences professionals who must be on board to implement the case may not be inclined to do so as they may fear personal penalty. As mentioned in the previous section, the decision-makers who create and sustain the rules in life sciences are often the same ones who make vital decisions during blockchain adoption. If a blockchain use case violates the rules they created, they are unlikely to endorse it. As such, compliance with existing rules is another factor that determines the adoptability of a blockchain use case.

- **The preservation of data assets, intellectual property, and privacy**: As blockchain is a distributed ledger, the benefits of blockchain rely much on data sharing, and synchronization via blockchain. However, organizations are dispositioned to protect their commercial interests in a business ecosystem, which means protecting the intellectual property crucial for their competitive advantage. Indeed, a vital issue that blockchain experts are concerned about is how to protect data privacy when blockchain is meant to improve data transparency. Smart contracts represent one way to address this issue.

In life sciences, privacy is of paramount importance. Whether protecting clinical research data or genomic data, unrestricted access to the data has severe commercial, ethical, and legal consequences. Thus, blockchain use cases that utilize these data must protect the privacy of each data contributor (node) to the maximum.

> I think there also are some ethical considerations around blockchain that policy could potentially also help with. And, you know, things like anonymity and, you know, the double-edged sword there, right? Anonymity is good to mitigate the risk or preserve privacy. But, you know, anonymity can be abused, right? It's used with ransomware, it's used with extortion, all kinds of things, you know, fraud, and so forth. So, I think policies can help maximize the pros and minimize the cons as well. (Interview, blockchain start-up founder)

One way to consider all these factors holistically is to follow the formula below, where the adoptability of a use case involves multiplying all the factors.

Adoptability = economic value of the use case * readiness for adoption * compliance with existing rules * the preservation of data assets, intellectual property, and privacy

If a use case is rated very low in any of these factors, the adoptability of the use case will be low due to the multiply effect. In contrast, a use case that strikes a balance among these factors will have higher adoptability. By using the proposed formula, decision-makers can gain a deep understanding of the use case and preclude cases with low adoptability.

4.4.2 Framing Blockchain Adoption as Aligned with Both the Innovative and Safety-Driven Culture in Life Sciences Organizations

Interview participants described that it was challenging to legitimize blockchain adoption in life science, in other words, to create buy-in among leaders and key staff. Although some were enthusiastic about blockchain adoption, others focused on traditional role activities and did not demonstrate a strong motivation to understand and incorporate blockchain into their core businesses. Interviewees also reported that the values and beliefs, as part of the culture in life sciences organizations, seem not to support the adoption of blockchain.

> So, I'm very confident in these arguments I'm bringing forward [about the blockchain project]. But because the ideas are too big—maybe too big is the wrong way to describe them—because they're just too hard to comprehend. It's more of a try to get their head around this horizontal type of innovation that's going against their belief system. (Interview, manager)

In response, those who gained initial success in pilot projects carefully framed the adoption as aligned with both the innovative and safety-driven cultures in life sciences. Every organization or sector has a culture, which refers to a system of shared assumptions, values, and beliefs about appropriate and inappropriate behavior

[39, 40]. An organization's or sector's culture is supported by its structure, working processes, and everyday behaviors of the participants. Researchers have consistently found that culture plays a crucial role in successfully adopting new technologies or practices [8]. Specifically, culture can affect what is considered legitimate innovation and whether adoption would receive all levels of endorsement. Researchers also recommend that managers customize innovations to organizational or sector culture to achieve adoption [8, 41].

Although scholars have traditionally considered culture as singular, that is, an organization or field only has one dominant culture, recent work has pointed to the existence of competing cultures within an organization or field [41, 42]. From the perspective of cultural pluralism, the author finds that qualitative data revealed two cultures prevalent in life sciences: innovation-driven and safety-driven. The innovation-driven culture manifests through the ongoing medical experiments and the resources dedicated to innovation, in contrast, the safety-driven culture manifests via the strong focus on compliance to behavioral protocols, hierarchical structures, and the value orientation that treatment should cause no harm.

While two cultures might seem contradictory, some interviewees stated that they had combined them to frame blockchain to legitimize adoption. For instance, they highlighted that the spirit of blockchain adoption is to foster decentralized innovations. Further, the innovations can reduce the risk of non-compliance to data-retention regulations thanks to the near-immutability advantages of blockchain. Also, such innovation can protect life sciences organizations from privacy breaches and reduce the risks of sensitive information being exploited by malicious people. These framings appeal to both the innovation and safety-driven culture in the life sciences field, helping gain traction for blockchain adoption among important stakeholders.

> Well again, it comes down to having a crystal clear business case that could appeal to many different decision-makers meet. Like the "better, faster, cheaper." We're going to save money on this and reduce costs, or you know the risk-averse person. We can reduce non-compliances, and therefore patient risk, and therefore to risk in general. (Interview, manager)

4.4.3 Unobtrusive Implementation

Interview participants also suggest that it is essential to keep the implementation process unobtrusive, meaning that blockchain adoption should be managed so that it does not overtly clash with the existing power structure or the material interests of incumbents. Blockchain project managers need to navigate through the structures and ensure that all the individuals and organizations in the structure—especially those who maintain the structures—are thoroughly engaged. Specifically, health executives, physicians, and researchers that hold high status should be approached early as their endorsement is crucial for the success of blockchain implementation. Also, existing IT departments should have a say about the implementation and should be engaged during the selection process of use cases and the selection of vendors. In addition, compliance officers need to be engaged such that the adoption of blockchain does not challenge any information regulations or science ethics.

4.4.4 Acting Swiftly When the Innovative Culture Gains Strength

Research has suggested that multiple cultures can co-exist in an organization or field. The strength of the cultures (i.e., that extend to the people who enact the culture and the prevalence of the enactment) can wax and wane [42]. In life sciences, safety-driven and innovation-driven cultures often simultaneously guide a particular organization and change in their strength due to resource flows or policy changes. Interview participants suggest that when the innovation-driven culture gains strength, blockchain advocates should take the opportunity and act swiftly to advance adoption.

For example, participants who gained initial success in a corporate blockchain project described that when senior executives who embraced innovations were in charge, they moved quickly to secure financial support from those executives. They also organized themselves quickly around the executives such that the executives were given leadership in the project, which further helped them gain endorsement both within and outside the organization. Participants believed that they successfully identified and exploited the political window of opportunity, which was crucial to the initial success of adoption.

> Yeah, I think when the medical director left, when that happens to you, you lose a key source of support, right? And you have to review the support from the top executive team and that would take a lot of time. After all, there are a lot of background politics going on. (Interview, manager)
>
> So, it was surprising that we made it, in hindsight—especially in the timelines that we're working in. I think there was a whole lot of strategic politics in the background. Our story was very resonating, so we had a lot of leeway to work in the fail fast, fail forward type of mentality and do different things. (Interview, senior manager)

5 Discussion

Understanding the experience of early adopters of blockchain in life sciences is crucial to utilizing the technology's potential to transform the field. This study explored the experiences of the early adopters and identified four primary socio-organizational barriers that they have encountered. Some findings are consistent with previous studies on adopting IT in life sciences; in particular, the barrier "life sciences is highly institutionalized" somewhat resonates with prior research on the barriers for adopting ELN [17, 18, 20]. However, this study highlights three barriers that are unique to the adoption of blockchain: "negative stereotype of blockchain technology," "perceived technological complexity of blockchain," and "the lack of ecosystem mindset." The negative stereotype of blockchain can be attributed to the unique trajectory of how the technology was utilized and became widely known. That blockchain has been negatively stereotyped might be suggestive of its transformational potential. As previous research suggested, genuinely novel, transformational technology often originates from the margins of established institutions [6, 43], the association between the margins and the technology is likely to bring negative stereotypes to the technology.

The "perceived technological complexity of blockchain" barrier is tied to the drastically innovative nature of blockchain. As blockchain represents a decentralized computation system instead of traditional centralized platforms, it requires decision-makers to comprehend the fundamentally technical departure of blockchain. As explained in the previous section, this has created a dilemma for early adopters when they attempt to create "buy-in." The barrier "lack of ecosystem mindset" may also be observed when adopting other technologies that emphasize connectivity and scale of economy, such as the Internet of Things. Even though the barrier "the highly institutionalized nature of life sciences organizations" resonates with previous studies that examine the barriers for ELN adoption, the difficulty that this barrier creates is unique in the case of blockchain. As noted, it creates the "chicken and egg" problem. Namely, decision-makers would only allow mass adoption before they see substantial benefits of blockchain, but such benefits can only be shown after mass adoption has occurred. This problem is peculiar to blockchain adoption because of its distributed nature. The difficulties that the four organization behavioral barriers have created reinforce the perspective that blockchain adoption is not merely a technical issue and focusing on perfecting the technology does not necessitate mass adoption. Furthermore, the barriers identified in this study created difficulties for study participants through "trade-offs" or "dilemmas," highlighting that blockchain adoption involves the delicate balancing of seemingly paradoxical demands and responses, echoing the general discussions about the trade-offs prevalent in blockchain design and implementation [44].

The adoption strategies uncovered in this study relate and contrast the existing literature in the following ways. The first strategy—holistically evaluating blockchain + life sciences use cases—emphasizes that economic value is a crucial parameter for determining a use case's adoptability. This finding echoes the proposition of experts that blockchain adoption in life sciences should not be for "religious" reasons [5]; instead, the adoption must bring practical benefits to various stakeholders. However, the contribution of this finding is that it articulates other factors that need to be accounted for and points out how to do so holistically by introducing the multiplier formula. The multiplier formula contains the economic value of a use case, readiness for adoption, compliance with existing rules, and the preservation of data assets, intellectual property, and privacy. This formula also determines that the overall adoptability would approach zero when any of these parameters approaches zero. It not only accommodates some of the most critical aspects when adopting blockchain in life sciences but also alerts experts and practitioners to consider all those aspects concurrently when evaluating a blockchain + life sciences use case.

The second strategy—framing blockchain adoption as aligned with both the innovative and safety-driven culture in life sciences organizations—challenges how blockchain is framed in academic and industry discourse where blockchain tends to be overly described as "transformational," "innovative," or "disruptive." While blockchain does represent a decentralized way of information storage and transaction [4], and may indeed help legitimize adoption and acquire resources for blockchain ventures in market-driven sectors such as finance or gaming. However, this study found that overly emphasizing blockchain's disruptive property may backfire in life sciences due to the highly institutionalized nature of the field and its risk-averse culture. Rather than simply describing blockchain as disruptive, researchers and practitioners in life sciences may stress blockchain as an innovative tool. Using this tool can strengthen compliance and enhance patient safety without necessitating the dismantling of existing systems. This discursive strategy may facilitate adoption at the present since it reduces the threat perceived by powerful incumbents.

The third strategy, "acting swiftly when the innovative culture gains strength," brings forward the political aspect of blockchain adoption in life sciences, which prior research has not yet addressed. Despite that the literature on innovation adoption has long suggested the crucial role of politics in blocking or facilitating adoption [7, 8], the informatics literature seems not yet to pay plentiful attention to organizational politics when studying the adoption of ELN, not to mention blockchain. However, when blockchain adoption occurs, as described by this study, it would need a political window of opportunity where the advocators embrace the innovation-driven culture—as opposed to the safety-driven culture—attain powerful positions and exercise their power to support the adoption. Such political windows of opportunity may disappear as the advocators lose power, and therefore it is crucial to take swift actions to make adoption happen when the windows are present. This insight opens the research avenue for studying the appropriate speed of adoption, specifically for blockchain as well as other nascent technologies in life sciences.

5.1 Limitations and Future Directions

Despite that this study is one of the first to investigate the socio-organizational barriers for blockchain adoption in life sciences and delineate adoption strategies, it is not without limitations. Due to privacy concerns, it was not possible to sit in executive meetings to directly observe the decision-making process regarding blockchain adoption and document how these barriers manifest in micro-level social interactions. Also, due to the limited period of this study, the author was unable to base the findings on blockchain + life sciences projects that have achieved substantial success. Hence, the adoption strategies presented in this study might be limited in applicability.

Future research may observe in real-time the blockchain + life sciences projects that are widely adopted, achieving a high return on investment and penetration rate, and compare the adoption strategies with those found by this study. Moreover, although consumers are important stakeholders in many blockchain life sciences applications (e.g., blockchain-based genomics marketplaces), this study did not include consumers in the pool of interview participants. Future research should investigate what adoption barriers might stem from the consumer side and how adoption strategies may engage consumers. In addition, as blockchain becomes more widely accepted and understood, some of the socio-organizational barriers that adopters experience may change over time. For instance, the barrier—negative stereotypes of blockchain and perceived technical complexities—may weaken. Future research may investigate what new barriers might emerge and how they may differ from those discovered in this study.

6 Conclusion

Blockchain can transform how information is stored and shared and thus holds strong potential to improve the efficiency of life sciences research and the quality of scientific discoveries. However, early adopters have experienced significant socio-organizational barriers for adoption, which calls for balanced attention to the engineering problems and socio-organizational processes that blockchain adoption may incur. The adoption strategies uncovered in this study may serve as steppingstones for academics and practitioners to re-think blockchain adoption in life sciences.

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Dr. Chang Lu is a postdoc research fellow at Blockchain@UBC, the University of British Columbia. His theoretical research focuses on technology adoption, organization and institutional change, and the interplay between culture and power. Currently, he studies these topics in the context of adopting blockchain technology in life sciences, examining the adoption processes at both organizational and institutional levels. He has published several articles in leading management journals and taught senior undergraduate and MBA students Organizational Strategy and Organizational Behavior. He supervises master's and MBA students for their research projects and is currently creating education materials for executives about blockchain in life sciences. He earned his PhD in Strategic Management and Organization, School of Business from the University of Alberta. Prior to his academic career, he worked as an HR professional in China and Europe.