



Distributed ledger technology as a catalyst for open innovation adoption among small and medium-sized enterprises

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ABSTRACT

Open innovation and distributed ledger technology (DLT) are both based on the underlying principles of distribution and sharing. While open innovation is about sharing knowledge to improve innovation processes and performance, DLT is a distributed data ledger that is utilized to enhance efficiency, reduce costs, and ensure immutability, traceability, security, and transparency. In this paper, we investigate the barriers to open innovation currently faced by small and medium-sized companies (SMEs) that DLT can solve. To achieve this goal, we conducted semi-structured interviews with 11 experts in open innovation and DLTs from Spain, Germany, Australia, and India. The results of our exploratory study show that DLTs can help to solve several problems, including external barriers, such as problems with contracts, financing, lack of trust, raw materials, lack of information, domestic and international market limitations, IP rights, and governmental regulations as well as bureaucracy. Internal challenges include insufficient funding, organizational systems that are out of date, and lack of trust. When it comes to difficulties associated with the management of open innovation, external barriers are frequently caused by customers' demands, while internal barriers are frequently caused by organizational culture or human nature, which cannot be improved by DLTs. Finally, SMEs might face new obstacles when integrating DLTs, such as integration problems, complex transition phases, and high setup costs as well as problems with attracting and retaining qualified employees.

1. Introduction

Open innovation, which is defined as “a distributed innovation process based on purposely managed knowledge flows across organizational boundaries, using pecuniary and nonpecuniary mechanisms in line with the organization's business model” (Chesbrough & Bogers, 2014, p. 1), has been studied extensively in recent years. In contrast, distributed ledger technology (DLT), “a novel and fast-evolving approach to recording and sharing data across multiple data stores (ledgers)” (Natarajan, Krause, & Gradstein, 2017, p. 13), has only recently caught the attention of researchers. Both open innovation and DLTs share common goals in that they promote the concept of sharing and distribution or, in other words, decentralization of authority and control.

Previous studies have confirmed the importance and potential benefits of open innovation for SMEs (Parida, Westerberg, & Frishammar, 2012; Spithoven, Vanhaverbeke, & Roijakkers, 2013; Taghizadeh, Nikbin, Alam, Rahman, & Nadarajah, 2020; van de

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Vrande, de Jong, Vanhaverbeke, & de Rochemont, 2009) and have identified several limitations and barriers that prevent the adoption of open innovation. These include lack of trust in partners, intellectual property issues, and limited financial resources (Bigliardi & Galati, 2016; Lee, Park, Yoon, & Park, 2010; Rahman & Ramos, 2010). However, a thorough investigation of the potential of DLT to remove SMEs' barriers to open innovation is largely missing to date. This constitutes an important research gap since DLT allows for the recording, sharing, and synchronization of transactions and data in an immutable, secure, transparent, and traceable manner across a distributed network of different participants (Treiblmaier, 2019). It eliminates the need for third party intermediaries to ensure trust, validation of transactions, and transfer of value. Since open innovation relies heavily on knowledge sharing, it can benefit substantially from a technology that facilitates information sharing and potentially also secures information transfer using cryptography. DLT also automates the auditing of contracts, which can be used to validate accounts and financial information issued by an economic entity. This can potentially reduce or even eliminate the need for litigation and courts. Furthermore, the transfer of value can be facilitated with smart contracts, and network members can be incentivized through a peer-to-peer remuneration system. Based on a narrative literature review, in this paper we initially classify open innovation barriers to SMEs into two categories, namely, search barriers (split into internal and external) and management barriers. Using semi-structured expert interviews, we identify open innovation obstacles to SMEs that can potentially be solved or improved by DLTs.

To the best of our knowledge, this is the first paper that systematically investigates the potential of DLT to solve SMEs' problems that pertain to the adoption of open innovation. It is structured as follows: in section two, the findings of our literature review are presented. Section three outlines the research methodology, including a brief description of the data. In the fourth section, the results are presented and, finally, in the fifth section, we conclude our study and highlight some limitations as well as avenues for future research.

2. Literature review

2.1. Open innovation barriers to SMEs

Spithoven et al. (2013) investigated how SMEs' use of open innovation differs from that of large corporations as well as the advantages they reap from it. Their result shows that SMEs, unlike large companies, are more successful at using multiple OI practices at the same time. Also, they found that SMEs are more dependent on open innovation than big companies, though both positively benefit from open innovation in relation to the introduction of new products and services to the market. Studies by (Lichtenthaler & Ernst, 2006; Sag, Sezen, & Güzel, 2016; van de Vrande et al., 2009) show that SMEs face substantial barriers when adopting open innovation in comparison to big companies. Piatier (1984) divides the barriers to innovation into two categories of internal (e.g., resource availability and employee resistance) and external (e.g., supply, demand, and environment). Later, Rahman (2013) adopted the same categories and added barriers, which occur either before or during the open innovation adoption phase. In this paper, we have combined Rahman's findings with results from other researchers to create a broader picture. More specifically, we divide the adoption barriers to open innovation into two phases, namely, the search phase and the management phase.

A study on the influence of the determinants that affect the use of open innovation among SMEs in Poland done by Stanislawski (2020) shows that among the external determinants of using open innovation, market factors such as the need to improve competitiveness and the image of the company in the environment play a crucial role for SMEs. More specifically, the results show that the larger a company's market, the more likely it is to use open innovation; thus, they concluded that the market is the main determinant in using open innovation by firms. Asad, Basheer, Irfan, Jiang, and Naveed (2020) conducted a quantitative study in Pakistan to examine the effect of external knowledge, internal innovation, and knowledge management on firms' open innovation performance. Their study shows an advancement of open innovation in SMEs through external knowledge incorporation and maximization of internal innovation, which also promotes knowledge management practices. Knowledge management, which is a key indicator of SMEs' performance, can in turn promote open innovation through the positive role of external knowledge incorporation and maximization of internal innovation (van de Vrande et al., 2009). The authors illustrate that the main managerial challenges that SMEs face when practicing open innovation are related to organizational and culture-related issues. Administrative issues, financing, and knowledge transfer are some other managerial problems.

Based on previous literature, we divide SME barriers to open innovation into a search stage, which itself is divided into an external

Table 1

Search stage: External barriers for SMEs to open innovation (Hadjimanolis, 1999; Janesvski, Davitkovska, & Petkovski, 2015; Nerone, Canciglieri Junior, Steiner, & Young, 2014; Odoro, 2019; Rahman, 2013; Rahman & Ramos, 2010; van de Vrande et al., 2009).

External		
Supply	Demand	Environment/culture
Lack of information	Customer needs	Government regulation/ bureaucracy
Problems with the raw materials	Customers' perception of risk of innovation	IP rights
Lack of technical knowledge	Domestic and international market limitations	Free-riding behavior
Lack of administrative knowledge	Customer demands that are too specific	Policy actions
Lack of legal knowledge		
Insufficient financing		
Problems with contracts		
Lack of trust		

and internal search and management stage. Tables 1 and 2 categorize the literature regarding search stage barriers and list numerous problems that SMEs encounter during their internal and external search for knowledge, ideas, and innovation. As Rahman (2013) points out, external problems relate to supply, demand, and environment/culture, while internal barriers refer to resources, culture/human nature, and the organizational system. Table 3 summarizes the literature on challenges at the management stage that SMEs face after the adoption of open innovation. These problems can be further divided into network and collaboration barriers as well as administration and control barriers.

2.2. DLT and open innovation

Blockchain is a type of DLT in which transactions are stored as timestamped blocks that are linked in a chain by cryptographic hashes to achieve security, transparency, privacy, robustness, integrity, and authentication of data (Fernandez-Carames & Fraga-Lamas, 2020; Hashimy & Sandner, 2020; Treiblmaier, 2019). Open innovation is all about sharing and distributing knowledge, which fosters cooperation and leverages distributed innovation processes. By its very nature, innovation is about creating new ideas, and, similar to DLT, it is rooted in the principles of decentralization and distribution of data. Distributing data in a secure and immutable manner means eliminating numerous problems that open innovation faces nowadays. In this paper, we use the term DLT and blockchain interchangeably while acknowledging that the former also includes data structures that do not necessarily follow a chain-like structure (e.g., directed acyclic graphs).

Consequently, Narayan and Tidström (2019) propose that blockchain technology can harness the open innovation market through decentralization. Companies in transition can use blockchain-powered open innovation to test new ideas and allow technology to shape the development process (Treiblmaier & Sillaber, 2020; Seulliet, 2016). The distributed nature of DLTs enables it to connect multiple stakeholders in a trusted and reliable way, allowing more robust intellectual property protection, smart contract deployment, privacy and data protection, and regulatory compliance Treiblmaier and Clohessy (2020). Seulliet (2016) points out that collaboration or competition between large and small firms might lead to trust issues, resulting in demotivation and further leading to ineffectiveness in open innovation. In this regard, DLTs provide “a technical solution (cryptographic consensus) to the problem of cooperation in joint or group production at scale” (Davidson, De Filippi, & Potts, 2016, p. 14) through the embedment of a trustless system that is determined by computer coding. Thus, the technology’s deterministic algorithms enable firms to transfer value without the need to trust specific intermediaries.

Another problem is the fair sharing of added value (Seulliet, 2016). When it comes to cooperation at the individual level, the problem frequently lies in individuals’ competitive nature. Lack of a system that allows for the recognition, traceability, and capitalization of ideas and knowledge can demotivate individuals’ drive to innovate. Using DLTs during the open innovation process will therefore not only enable a secure way to record ideas from their inception, but will also enable the introduction of a decentralized incentive system that can encourage innovators to further develop their ideas and be appreciated, acknowledged, and remunerated for their work (Rivière, 2018). With the use of distributed ledgers and smart contracts, the cost of transactions can be decreased while simultaneously achieving improvements in security, verifiability, and transparency. Thus, DLTs can create favorable conditions for open innovation (Pazaitis, 2020) and can be used for traceability, sourcing, negotiation, trade, and the transfer of innovation.

2.3. DLT and SMEs

The adoption of DLTs by SMEs mainly affects two key operational costs types, namely, the cost of verification and the cost of networking (Catalini & Gans, 2016). Using a distributed technology, transactions can be verified by all parties involved in the network without the need for intermediaries or trusted third parties. From an economic point of view, lower transaction costs, a higher level of trust, and more efficient economic coordination increase the marginal efficiency of investment and exchange (Lott & North, 1992). From a neoclassical perspective, the adoption of DLT provides marginal productivity gains by either increasing efficiencies or decreasing production process inefficiencies. Walport (2015) and Böhme, Christin, Edelman, and Moore (2015) follow this approach and posit that DLTs will improve firms’ and governments’ productivity. More specifically, DLT can decrease the financial industry’s economic costs by reducing back-office costs that result from the manual reconciliation of conflicting trade data (Priem, 2020). Wang, Lin, and Luo (2019) illustrate the application of blockchain technology and smart contracts in reshaping the traditional credit system. They suggest a blockchain-based credit system without collateral in which SMEs with low risk and high quality can easily display their credibility and risk category. The study shows that integrating DLT into hometown investment trust funds (HIT) can lead to more transparency and a reduction in associate risk, which subsequently results in a higher share of investments.

Table 2

Search stage: Internal barriers for SMEs to open innovation (Hadjimanolis, 1999; Janesvski et al., 2015; Nerone et al., 2014; Oduro, 2019; Rahman, 2013; Rahman & Ramos, 2010; van de Vrande et al., 2009).

Internal		
Resource	Culture/human nature	System
Lack of funds/capital	Attitude of top management toward risk	Outdated organizational system
Technical expertise (scientific/legal/ technological)	Not-Invented-Here syndrome	Outdated technological system
Lack of human resources	Employee resistance to innovation	Undefined business model
	High turnover/ lack of commitment	

Table 3

Management Stage: Barriers for SMEs to open innovation (Christensen, Olesen, & Kjær, 2005; Termeer & Nooteboom, 2014).

Management Stage	
Network and collaboration	Administration and control
Management of networks	Management of employees' ideas
Partners do not meet expectations	Time management
Insufficient trust	Adoption problems
Limited contact network	Unstructured innovation process
Cognitive, organizational, cultural, and institutional differences	Managers' perceptions of open innovation
Limited ability and resources to maintain the network	Suboptimal use of talents, knowledge, and qualities of employees

According to Rivière (2018), DLTs can also solve some of open innovation's limitations, such as trust issues and lack of coordination. This solves the free-rider problem and the tragedy of the commons that are frequently associated with open innovation. Concerning the adoption of DLTs by SMEs, cost reduction incentives and increased total factor productivity will eventually encourage SMEs to adopt DLTs. But the question remains: which DLT can specifically solve open innovation barriers to SMEs? Although some research has been done on the open innovation barriers that SMEs currently face (Spithoven et al., 2013), and some solutions have been proposed (Sağ et al., 2016), previous research has not investigated the consequences of a DLT uptake by SMEs and how it can facilitate the adoption of open innovation in detail.

3. Methodology

In the current study, the expert opinion method has been used to explore the potential role of DLTs in helping SMEs tackle some of the problems they face when adopting open innovation. In case quantitative methods and statistical techniques are not applicable due to lack of historical data, the expert opinion method can help researchers to build a conceptual framework and better understand the underlying technologies. Since experts' judgments play a vital role in planning, resource allocation, and decision making, we conducted online interviews (Aengenheyster & Masoliver, 2017) that involved active members of DLTs and open innovation communities in the current study. All interviews were recorded as audio files, and the transcripts of all of these files were thoroughly analyzed.

All study participants were given a semi-structured questionnaire that contained multiple open-ended and closed-ended questions. The questionnaire further contained demographic questions, filter questions, and multiple-choice questions. We gave the experts a list of barriers that SMEs potentially face when adopting open innovation, and they had to choose among the answers "Yes", "No," or "To some extent" to assess whether a specific problem could be improved by DLTs; in this study, the latter of these options was evaluated as being slightly positive. Next, they had to elaborate on their initial assessment with a short explanation. All problems were grouped into either management barriers or search barriers.

The semi-structured expert interviews were conducted in July 2020 with both experts on open innovation and DLTs. A total of 53 experts who were identified in professional society databases, citations in books and papers, and academic department lists were contacted through e-mail and LinkedIn. A total of 19 experts responded. Among the 19 respondents, five declined to participate in the study since they were not familiar enough with the technology, while three turned out to be unavailable for an interview. In summary, 11 experts from universities, private companies, associations, and organizations in Spain, Germany, Australia, and India, all of whom had sufficient previous experience with open innovation and DLTs, participated in the interviews. The interviews were conducted online face-to-face and were recorded. The anonymity of the respondents was guaranteed. A lot of effort was made to avoid bias due to the expert's background, the communication between experts, and the communication between the interviewer and the experts. Additionally, each interview candidate was selected based on their relevant professional experience and comprehensive understanding to evaluate the open innovation and DLT. To select the interview partner, a detailed structure of selection criteria was followed that included four significant steps: firstly, the interview partner was selected based on their interest in the potential outcome of the study; next, the respondent demonstrated a knowledge of the subject; thirdly, the respondent was directly involved in the main component of the study; and finally, the interview partner had experience in the blockchain industry. Due to the unavailability of published literature on this topic, this paper has outlined the possible themes and sub-themes to evaluate open innovation and DLT. Furthermore, the respondent was given the complete freedom to respond during the interview session. The collected data was analyzed by using a content analysis on the verbatim statements of the respondents. In the following sections, we present the resulting clusters and include some verbatim statements for illustration purposes. Apart from collecting the responses from the respondents, this study conducted the interview to synthesize the comments and has broken these comments down into themes and sub-themes. Subsequently, all of the responses were analyzed to develop a framework based on the expert comments and to condense information about open innovation and DLT (Saunders, Lewis, & Thornhill, 2019).

4. Results

All respondents (R) agree that DLT has the potential to boost open innovation in SMEs. In general, they believe that trust plays an important role when it comes to sharing information, ideas, and new technologies. As R10 pointed out: "SMEs primarily engage in open innovation for market-related motives, such as meeting customer demands, keeping up with increased global competition, or to share financial resources for developing new technologies, and trust is the key issue." R11 argues that "DLT basically changes the rules of engagement in

complex scenarios.” DLTs not only facilitate securing and certifying information, but also alter the role of connections. They change the functions of intermediaries and the way in which information is provided, received, and verified. So, anything that includes “multiple parties, especially if those parties are working in multi-disciplinary projects or different areas of expertise, can benefit from having a trustless ledger that does not depend on a central authority” (R4). Features of DLT, such as traceability, enable “identifying where information comes from” (R3) and ensures “tracking and rewarding contributions” (R2), which in turn will “make firms less reluctant when it comes to collaboration and entering relationships with other firms or individuals” (R1). R5 provided the example of blockchain projects on the open-source platform GitHub as evidence that DLTs enhance open innovation.

Based on the experts’ responses and our content analysis, we developed a structural thematic network that is shown in Fig. 1. As suggested in the literature, we divided SMEs’ barriers to open innovation into the two stages of search and management. The two main themes within the search stage are external and internal barriers, and the two themes identified in the management stage include (a) network and collaboration and (b) administration and control. Seven sub-themes (supply, demand, regulations and rights, resources, culture/human nature, environment/culture, and system/infrastructure) emerged under external and internal themes.

4.1. Search stage

4.1.1. Theme 1: external barriers

An effective way for SMEs to benefit from open innovation in their search stage is to integrate external innovation into the internal innovation process. Companies are constantly involved in numerous relationships with suppliers, customers, governments, individuals, and other organizations, and they can use these partners to enrich their own innovation portfolio. At the same time, SMEs may face problems with supply (i.e., companies with whom they collaborate), demand (i.e., consumers for whom they want to innovate), and existing regulations.

Supply. Barriers related to supply that SMEs face in the search stage are listed in Table 4. The majority of the experts believe that problems with contracts, financing, lack of trust, provision of raw materials, and lack of information can be improved through DLTs, which create a shared understanding regarding the underlying data and processes. Contrariwise, a supplier’s lack of administrative, legal, or technological knowledge is less likely to be resolved with DLTs.

In general, SMEs are reluctant to do business with actors who have no transparent and trustworthy trading record. One of the pitfalls they experience in their relationships with externals include contractual problems. However, two respondents also pointed out that managing contracts and transactional protocol is much easier with DLTs (R4; R11). Furthermore, smart contracts help in “operations, risk management, transaction block clearance, and automatic feedback” (R10). Additionally, they “offer SMEs the chance to do business with untrusted parties” (R8). Using smart contracts, SMEs can establish conditions for the execution of business operations, and

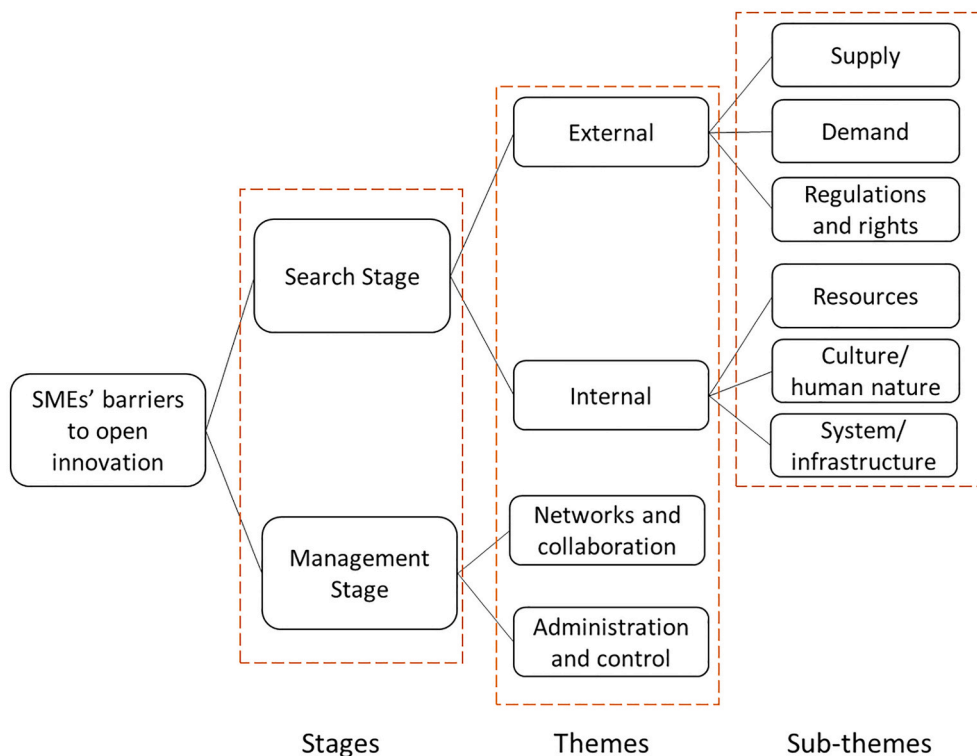


Fig. 1. Thematic Network Model.

Table 4
Supply barriers.

Barrier	Yes	No	To some extent
Problems with contracts	10	1	0
Financing	8	1	2
Lack of trust	8	1	2
Problems with raw materials/inputs	8	2	1
Lack of information	7	5	0
Lack of administrative knowledge	4	6	1
Limited legal knowledge	2	8	1
Lack of technological knowledge	1	10	0

the contracts can autonomously execute value transactions if the specified requirements are met. A total of eight respondents believe that with the application of DLTs, managing finances with suppliers will be facilitated for SMEs as pending transactional issues can be solved rapidly through “*smart contracts and cryptocurrencies*” (R1) without any “*interventions of a middlemen*” (R2). As payment can be initiated at a certain point of time that “*strictly follows the transactional protocol, DLT also safeguards the trust issue*” (R11).

Eight respondents point out that DLTs can help companies to track the raw materials they receive from suppliers. In this regard, the distributed ledgers’ transparency in the supply chain enable “*getting back to the supplier for information about the raw materials or inputs*” (R6), which will subsequently “*improve trust issues with suppliers*” (R8). A “*distributed and immutable network*” (R11) thus ensures the “*traceability and authenticity*” (R3) of data from suppliers. Additionally, identifying the source of the materials will be easy, and “*cheating is traced*” (R11). Seven respondents believe that DLT can help in sharing information about their suppliers. By using DLTs, companies can build a “*transparent network*” (R1) in which they can share information among one another. DLTs will also allow the supply partners to “*access the same source of information*” (R7).

4.1.1.1. Demand. The market structure and pull-technology derived from demand are explained by demand barriers, which are also known as market barriers (Segarra-Blasco, Garcia-Quevedo, & Teruel-Carrizosa, 2008). Some demand barriers that SMEs face include domestic and international market limitations, customers’ perception of risk, customers’ needs, and a demand that is too specific and challenges SMEs to find a solution that matches the problem (see Table 5). Most respondents believe that using DLTs cannot be of much help. Only a few respondents believe that domestic and international market limitations (the barriers SMEs face while engaging in open innovation in the local or international market) can be improved using DLTs. The respondents mentioned that the advantage of a peer-to-peer network is that it is not limited to the regional and local markets. They noted that “*It is possible to break the regional barriers*” (R10) as “*jurisdiction plays a vital role in limiting the transactions*” (R10). They further note that DLTs can open up new opportunities for SMEs in a “*global market without limitations*”(R7).

4.1.1.2. Regulation and rights. In the search stage for open innovation, SMEs occasionally face barriers related to IP rights, governmental regulations (e.g., bureaucracy), free-riding behavior from the partners’ side, and policy actions (see Table 6). One of the biggest fears that SMEs have when engaging in open innovation is losing ownership of their technologies, know-how, and inventions. The costs and inefficiencies of the existing patent system discourage SMEs and academia from protecting their ideas, consequently limiting collaboration and open innovation. In this respect, DLT is believed to “*lower IP costs by eliminating intermediaries*” (R8), “*mak[ing] it much simpler to record the evidence of the ownership in a time-stamped manner*” (R1), “*track and monetize IP*” (R10), and “*generate contracts*” (R5). SMEs can protect their IP rights in the open innovation process by storing data on distributed ledgers. In the words of R1: “*If someone else brings up the same idea, the original creator can use the evidence on the blockchain to sue against them.*”

Additionally, DLTs provide an “*alternative approach to the existing regulatory system where the technology can promote openness and increase transparency between states, citizens, and businesses*” (R10). Using DLTs, it will be easier for governments to “*share information*” (R3), “*audit the activities of companies*” (R1), “*verify transactions*” (R4), and “*detect fraud and crime*” (R2). Ultimately, the technology can help to build trust, “*enhance transparency and participation*” (R6), “*reduce strict regulations*” (R9), and “*cut down business bureaucracy*” (R2).

4.1.2. Theme 2: internal barriers

In comparison to large firms, SMEs face more internal barriers to the adoption of open innovation due to insufficient internal resources and expertise. Additional bottlenecks might be the perceptions of managers regarding open innovation, absence of skilled employees, and the resistance of employees to innovation. We have classified these barriers into three groups of resources, culture/

Table 5
Demand barriers.

Barrier	Yes	No	To some extent
Domestic and international market limitations	5	3	3
Customers’ perception of risk	1	9	1
Customers’ needs	0	9	2
Customer demands too specific	0	10	1

Table 6
Regulation and rights barriers.

Barrier	Yes	No	To some extent
IP rights	9	1	1
Government regulation/ bureaucracy	7	1	3
Free-riding behavior	2	2	7
Policy actions	1	5	5

human nature, and system/infrastructure (see Table 7).

4.1.2.1. Resources. SMEs need resources to dedicate to open innovation. Some internal resource-related challenges that most SMEs face include lack of funding, lack of human resources, including time, and limited technical expertise, namely, scientific, legal, or technological knowledge. Access to financing is a common problem for SMEs. Therefore, most experts believe that DLTs offer new opportunities for SMEs to raise funding both for internal and external activities. *“Initial Coin Offering (ICO) using DLTs has offered many entrepreneurs and SMEs the chance to raise the capital needed to fund their projects”* (R11). They provide SMEs with a *“quick and less regulated financing mechanism”* (R3). Several experts also believe that open innovation can be a solution for lack of funding: *“Collaboration with other companies can help SMEs to save costs and have more resources to dedicate to open innovation [...] DLTs can be used as the technology base for collaboration”* (R8). However, on average, the experts are skeptical about the potential of DLTs to eliminate barriers related to limited technical knowledge.

4.1.2.2. Cultural/human nature. The extent to which the dominant culture is open to change determines the organization’s ability to participate in open innovation successfully. In an environment characterized by fluctuating demand, flexibility and openness are essential. The experts’ assessments regarding the attitude of top management toward risk, high turnover/lack of commitment, employee resistance to innovation, and the Not-Invented-Here Syndrome are listed in Table 8. Some respondents believe that the use of DLTs in open innovation processes will alter the attitude of top management toward risk as the technology will help to better manage some aspects of innovation as *“recording ideas in an immutable ledger which ensures the authenticity”* (R11) and *“data security”* (R2). Others believe that these are internal problems to adopting open innovation that DLTs are unlikely to solve: *“Managerial, social and psychological techniques need to be used to handle these issues within companies”* (R9).

4.1.2.3. System/infrastructure. Occasionally, internal infrastructure also create challenges pertaining to the adoption of open innovation by SMEs. Several important barriers related to internal systems are outdated organizational systems, outdated technological systems, and undefined business models (see Table 9). The majority of the respondents believe that decentralized systems can change existing organizational structures and the way organizations work today. Companies have always been centralized entities, where power is concentrated in the hands of few, but this does not necessarily have to remain so: *“Using DLTs, organizations can move from traditional centralized or hierarchical systems to a more decentralized system”* (R10). Given their overall flexibility, SMEs might be among the first to shift toward this transition. Some experts also believe that other operational activities within organizations can be improved using DLTs, such as *“accounting and financial systems”* (R1), the *“human resources selection process”* (R11), and *“data storage and security”* (R3). All of these transformations might change the way organizations approach open innovation: *“Open-source software is becoming more and more common”* (R5). Some SMEs already benefit from this openness, but *“to further grow, they need to become even more open”* (R6). This shift in mindset necessitates *“transparent leaders who believe in empowering others within the organization”* (R3).

4.2. Management stage

4.2.1. Theme 3: networks and collaboration

Managing networks and establishing collaborations are among the most demanding tasks that SMEs currently face, and they include numerous barriers as shown in Table 10. All experts believe that trust issues can be solved or alleviated using DLTs: *“Using smart contracts, DLT can run without any human interaction. Thus, making a transaction trust-free”* (R5). DLTs have the potential to strengthen trust by removing intermediaries, reducing running costs, and enhancing the efficacy of open innovation. However, this does not equally hold for other management activities. On average, the experts believe that DLTs cannot help much in cases where limited ability and resources are available to maintain the network, partners do not meet expectations, cognitive, organizational, cultural, and institutional differences exist, and limited contact networks are available. To summarize, the management of networks does not benefit much from DLTs. Therefore, partners should care about the *“terms and conditions that need to be executed”* (R2) prior to

Table 7
Resource barriers.

Barrier	Yes	No	To some extent
Lack of funds/capital	7	2	2
Lack of human resources	4	4	3
Limited technical expertise (scientific/ legal/ technological)/knowledge	1	8	2

Table 8

Culture and human nature barriers.

Barrier	Yes	No	To some extent
Attitude of top management to risk	3	7	1
High turnover/ lack of commitment	3	8	0
Employee resistance to innovation	2	7	2
Not-Invented-Here syndrome	0	10	1

Table 9

System and infrastructure barriers.

Barrier	Yes	No	To some extent
Outdated organizational systems	7	1	3
Outdated technological systems	3	4	4
Undefined business models	0	9	2

Table 10

Networks and collaboration barriers.

Barrier	Yes	No	To some extent
Trust	9	0	2
Limited ability and resources to maintain the network	4	4	3
Partner does not meet expectations	3	4	4
Cognitive, organizational, cultural, and institutional differences	3	5	3
Limited contact network	3	6	2
Management of networks	0	8	3

engaging in open innovation.

4.2.2. Theme 4: administration and control

Our literature review identified several barriers that SMEs may face in managing open innovation processes (see Table 11). Most experts are fairly skeptical about whether these can be solved using blockchain or DLTs: “*Management of open innovation needs managerial skills rather than a technology*” (R2). DLTs can help to “*digitize processes and improve the efficiency of companies*” (R6), but are mainly a technology that by itself “*cannot change perception, skills, or knowledge*” (R10), nor “*abilities, qualities*” (R11) or the “*soft skills needed to manage open innovation*” (R6). Although it is believed that blockchain can make the management process more efficient, change an organization’s structure, and reduce friction in existing processes, it will not strongly affect managerial skills. Apart from technological tools, managers, need to have knowledge, experience, and specific qualities and soft skills. However, some respondents believe that DLTs can help to manage employees’ ideas. For example, “*managers can implement reward systems*” (R6) to incentivize employees to come up with new ideas and “*use DLTs to gather, store, and select ideas*” (R7) in a “*decentralized, transparent, immutable, and secure way*” (R8).

4.3. Additional challenges

Although DLTs might support SMEs in many ways, the experts also warn that they can also generate new problems as can any other new technology. Difficulties in systems integration, transition and setup costs, acquisition of talent, and legal concerns are common problems that SMEs might encounter.

4.3.1. Integration issues

In most cases, the introduction of a new system is a resource-intensive process. As R8 points out: “*The integration of data and information from an existing system to a new system is costly and complicated.*” It takes time and money to transfer a company’s previous transactions into a new system. Additionally, a distributed ledger is not a stand-alone system, but rather serves as an underlying information source on which applications are built that make use of shared data. Implementing a distributed system is only useful in cases where multiple players are involved, but it is exactly this coordination that frequently turns out to be an issue in and of itself. In this regard, the use of an open-source platform such as GitHub facilitates the introduction of DLTs for boosting open innovation processes, but this does not solve issues during the operation of such a system, which might be caused by conflicting interests of the involved parties.

4.3.2. Transition and setup costs

Developing a distributed and decentralized system regularly needs substantial investment. SMEs are usually restricted in their resources and therefore need to prioritize capital allocation. In this regard, it has to be pointed out that transition costs are usually not

Table 11
Administration and control barriers.

Barrier	Yes	No	To some extent
Management of employee's ideas	4	5	2
Suboptimal use of talents, knowledge, qualities, and initiatives of employees	3	5	3
Managers' perceptions of open innovation	3	7	1
Less structured or professionalized innovation processes	2	7	2
Time management	1	6	4
Adoption problems	1	6	4

only technology development costs, but also include the expenses needed for staff training. In this respect, DLTs also require a shift in an organization's mindset, which might include the reallocation of organizational roles and the redesign of functional responsibilities. The total costs of these efforts might vary significantly between companies and are currently poorly understood.

4.3.3. Attracting and retention of talent

In order to successfully implement DLTs, SMEs need qualified personnel that understand the nuts and bolts of this fast-moving technology. As there is a current shortage of talents in the market, it is especially difficult for SMEs to find qualified employees at a reasonable cost. Currently, the majority of the available labor force tends to join large cooperations that can afford a bigger IT infrastructure and are willing to pay higher salaries.

4.3.4. Legal issues

DLTs frequently operate across geographical locations and as jurisdictions differ across countries, it is difficult to come up with contract rules that can be applied to business partners around the globe. Moreover, there is a dearth of commonly agreed upon standards and regulations regarding the use of DLTs, especially when it comes to identity management, property management, IP rights, and payments. This slows down the current development of the technology, but progress in this area is crucial to facilitate trade among business partners operating in different jurisdictions.

5. Conclusions, limitations, and further research

Both open innovation and DLT are novel concepts that shape the way in which organizations work together and share information. Open innovation has been extensively investigated during the last ten years, while DLT has only attracted the attention of innovation researchers in recent years. Distributed technologies offer novel features, such as data immutability and shared access, which in turn enable increased information transparency and traceability of data. Furthermore, they allow the deployment of program code that is executed automatically given the occurrence of predetermined conditions.

In this study, we target researchers and practitioners that strive to better understand the importance of DLTs for the innovation process in SMEs, and we investigate the opportunities that DLTs offer for SMEs to resolve some of barriers they face in adopting open innovation. Our findings, which are based on interviews with 11 domain experts, show that several problems can be solved or alleviated by the use of DLTs in this context. These include external problems with contracts, financing, lack of trust, raw materials, lack of information, domestic and international market limitations, IP rights, and governmental regulations as well as bureaucracy. Internal challenges that can be solved include insufficient funding, organizational systems that are out of date, and lack of trust. However, the introduction of DLTs might also lead to additional problems, such as integration issues, high costs, lack of available talent, and unclear legislation.

This paper is one of the first research papers on the application of DLTs to foster open innovation within SMEs. It was our goal to create an exploratory framework that can serve as a basis for future research. Since our findings are based on qualitative interviews with 11 domain experts, the views might not be representative across industries or geographical locations. Therefore, further empirical research is needed to validate our results and to ensure their generalizability. Although our study captures numerous challenges that SMEs might face during the open innovation practices, it lacks a part dedicated to the post-implementation phase in which the companies have already adopted open innovation.

To summarize, the framework presented in this paper constitutes the basis for further research that delves deeper into how distributed ledgers can support SMEs in their open innovation processes. Given the current innovation landscape, which is characterized by rapid change and increasing importance of digitalization, this is a topic that is of relevance for both academia and the industry alike.

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Further reading

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