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A taxonomy of blockchain technology application and adoption by small and medium-sized enterprises

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ABSTRACT

Objective: The objective of the article is to comprehensively examine the application and adoption of blockchain technology in SMEs. Recently, blockchain technology has garnered substantial attention owing to its transformative potential across diverse industries. Blockchain represents a decentralized and distributed ledger system that ensures data transparency, security, and immutability. This unique set of attributes has garnered attention from various sectors, ranging from finance and healthcare to supply chain and beyond. While predominant attention has been directed towards its impact on large corporations and financial institutions, the application and adoption of blockchain technology in small and medium-sized enterprises (SMEs) remains a relatively unexplored area.

Research Design & Methods: This research utilized a narrative and critical literature review of the existing literature on blockchain technology and SMEs.

Findings: We identified the key areas of application and drivers and barriers to SMEs' adoption of blockchain technology. Supply chain and finance have emerged as primary domains witnessing heightened blockchain implementation. The intricate nature of supply chain operations involving a multitude of stakeholders and the centralized nature of financing with inherent information asymmetry have propelled blockchain adoption within these sectors. However, the complex nature of technology, regulatory uncertainty, and lack of technological capabilities of SMEs have been the barriers inhibiting the widespread adoption of blockchain technology in SMEs.

Implications & Recommendations: The insights derived from this study can facilitate the successful design and implementation of blockchain-based solutions for SMEs. Blockchain solution providers must understand and tailor the solutions to SMEs. Blockchain-as-a-service (BaaS) can accelerate flexible application development, expediting blockchain integration in SMEs. Government, regulatory bodies, and SME groups are urged to collaborate in enhancing technological literacy among SMEs, facilitating their capacity to harness the advantages offered by blockchain technology.

Contribution & Value Added: This research contributes to the field by shedding light on the underexplored realm of blockchain technology in SMEs. The created taxonomy, examination of adoption drivers and barriers, and the formulated opportunities-challenges framework provide valuable tools for understanding and navigating blockchain technology's application and adoption-related challenges in SMEs. The identified gaps and proposed areas for future research further contribute to the ongoing discourse in this evolving field.

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INTRODUCTION

The global landscape of business operations and financial transactions has evolved in recent years. The catalyst driving this transformation is the integration of cutting-edge technologies with blockchain

technology being a prominent example. With its decentralized, transparent, and secure ledger, blockchain has emerged as a potential game-changer in various industries. Small and medium-sized enterprises (SMEs) can benefit significantly from blockchain technology, because it promises to revolutionize all domains of the SME business landscape. However, due to the newness of the technology and the inherent lack of technical expertise and resources in the SMEs, the application and adoption roadmap for Blockchain technology for SMEs is unclear.

Often called the lifeblood of most economies, SMEs occupy a pivotal position in the intricate chain of global business landscapes. They are engines of economic growth, innovation hotbeds, and employment generation stalwarts (Segers, 2016). SMEs exhibit a remarkable ability to adapt, innovate, and drive economic vitality, making them indispensable contributors to the prosperity of nations. The agility and resilience that characterize these enterprises underscore their importance as economic entities and social and technological change agents. In this era of rapid digital transformation, the adoption of cutting-edge technologies has become a distinguishing factor in the competitiveness and sustainability of SMEs (Pfister & Lehmann, 2023; Dana *et al.*, 2022). Among these transformative technologies, blockchain has emerged as a groundbreaking innovation with the potential to revolutionize the very foundations of business operations.

Blockchain's unique structure and functionalities characterized by its decentralized and tamper-resistant nature hold the potential to reshape the financial landscape for SMEs. By minimizing intermediaries, reducing transactional friction, and enhancing trust through transparent and auditable records, blockchain presents a compelling case for addressing some of the long-standing challenges SMEs face across their operations (Akpan *et al.,* 2022). Moreover, the technology's programmable smart contracts offer opportunities for automation and the creation of new financial instruments, potentially enabling innovative lending and investment models tailored to SMEs' needs.

This article embarks on an exploratory journey into the blockchain technology application and adoption in SMEs. Our primary objective was to create a taxonomy of application and adoption and provide an in-depth review of the associated drivers, barriers, opportunities, and challenges. We explored how to leverage blockchain technology to aid SMEs in enhancing financial inclusivity, operational efficiency, and access to new funding mechanisms. The identification of opportunities can lead to the development of SME-focused blockchain solutions. Analyzing associated risks accompanying blockchain integration, ranging from regulatory uncertainties and technical complexities, can help fix them and design clear roadmaps. Identifying drivers and barriers to blockchain adoption can help expedite the diffusion of the technology amongst SMEs.

In the following part, we will establish foundational definitions and key concepts pertinent to blockchain technology. Subsequently, we will provide a detailed overview of the materials and methodologies employed in the study. The ensuing discussion section presents the findings, focusing on the taxonomy of blockchain technology application and adoption in SMEs and presenting the opportunities and risks framework. Concluding, we will summarize its contributions, discuss implications derived from the study, and outline potential paths for future research.

LITERATURE REVIEW

Blockchain technology is a decentralized and distributed ledger system that records and verifies transactions securely across multiple nodes or computers (Casino *et al.,* 2019). Each transaction is encapsulated within a block and then added to a sequence of prior blocks, constituting a tamper-resistant and chronological record of all transactions (Crosby *et al.*, 2016). Blockchain operates within a peer-to-peer network, eliminating the need for a central authority. In this decentralized system, multiple participants, often called nodes, access and validate the same data. This collaborative approach fosters a distributed structure, ensuring no single entity controls the entire network. Figure 1 illustrates the transaction process in blockchain technology.

Blockchain relies on consensus mechanisms to validate and agree upon the ledger's state. These mechanisms play a crucial role in ensuring blockchain's integrity and security. Notable examples of consensus mechanisms include proof of work (PoW), proof of stake (PoS), and delegated proof of

stake (DPoS). Each mechanism has its unique approach to validating transactions and maintaining the blockchain, contributing to the system's robustness and efficiency. Smart contracts, a central innovation in blockchain technology, are self-executing agreements with predetermined rules encoded directly onto the blockchain (Philipp *et al.,* 2019). These contracts automatically enforce terms and execute actions once specific conditions are met. Smart contracts have diverse applications, from facilitating automated payments to managing complex business processes. They create a trustless multi-party business ecosystem involving tamper-proof transactions.

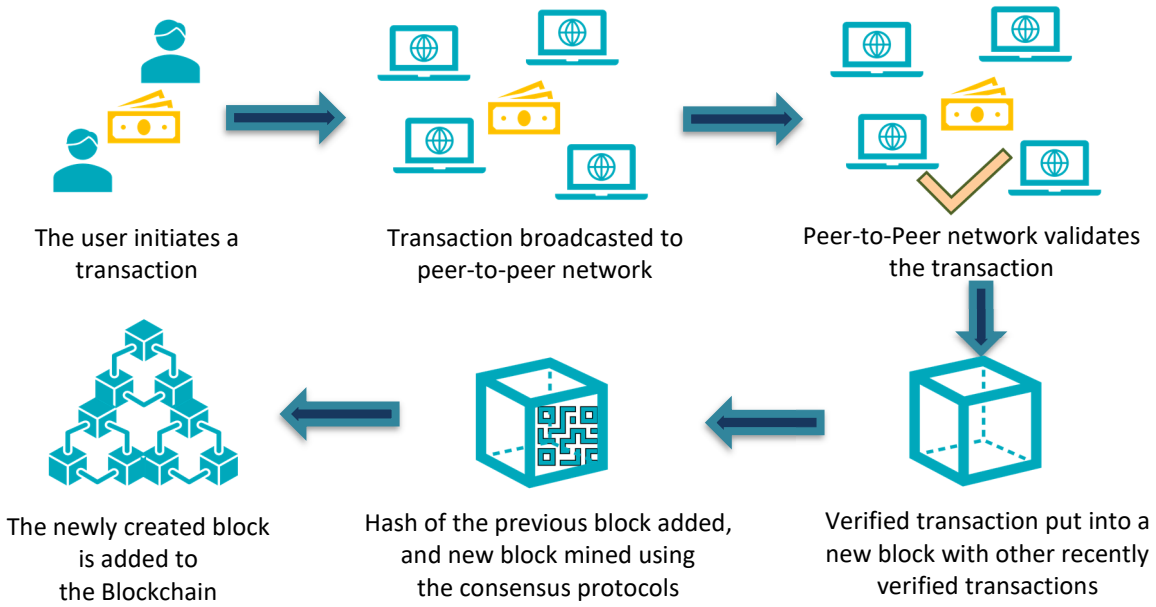

Figure 1. Blockchain transaction process
Source: own elaboration.

Another innovative feature is blockchain tokens, digital assets, or units of value created and managed on a blockchain. These tokens can represent various forms of value, including cryptocurrencies, utility tokens, or security tokens (Ante, 2020). They have become integral to blockchain ecosystems, enabling various use cases such as facilitating transactions, accessing specific services, or participating in decentralized applications (DApps). Tokens can be traded, exchanged, and utilized within the blockchain network and even beyond, incentivizing and governing participation within the blockchain community.

Blockchain technology encompasses various types, primarily classified into public, private, and Hybrid blockchains, each tailored to distinct requirements within the blockchain landscape (Crosby *et al.*, 2016). Public blockchains represent an open, permissionless paradigm, permitting widespread participation and fostering transparency. Prominent exemplars of public blockchains encompass the likes of Bitcoin and Ethereum, which excel in applications necessitating trust among potentially anonymous participants. In contrast, private blockchains manifest as exclusive and permissioned networks expressly designed for deployment within regulated and controlled environments. These networks impose limitations on participation, typically granted through invitations or established processes. Their utilization predominantly revolves around internal record-keeping, supply chain management, or collaborations among select entities.

Hybrid blockchains represent a dynamic fusion of public and private blockchain attributes, striking an equilibrium between transparency and privacy (Dutta & Saini, 2021). Within this framework, select components of the blockchain infrastructure are publicly accessible, while others remain private, confined to specific participants. Hybrid blockchains are especially well-suited for scenarios that demand varying degrees of data transparency, affording the flexibility to leverage the benefits of public blockchains while concurrently preserving the confidentiality and control of sensitive information. The selection among these diverse blockchain typologies is contingent upon the specific requirements, objectives, and gov-

ernance considerations intrinsic to the entities and applications under consideration. Such a discerning choice proves indispensable in facilitating the judicious implementation of blockchain technology.

Blockchain's core feature lies in its capacity to establish transparent and auditable transaction records. By creating tamper-proof ledgers that capture every transaction, blockchain fosters trust and accountability among its users. This transparency is particularly beneficial in scenarios requiring multiple parties to access and verify shared data, such as supply chain management and financial transactions. It is a shared source of truth, reducing conflicts and enhancing collaboration (Philipp *et al.*, 2019). The cryptographic foundation of blockchain forms a robust defence against data tampering and fraud. It ensures the integrity and immutability of data, rendering it resistant to unauthorized modifications. Employing security measures like digital signatures and encryption, blockchain engenders high trust in data authenticity. This attribute is especially vital in sensitive sectors like healthcare and finance, where data privacy and integrity are paramount.

One of blockchain's primary advantages is its potential to enhance operational efficiency significantly. Blockchain streamlines transactions by eliminating intermediaries and manual reconciliation processes, reducing time, costs, and error rates associated with traditional systems (Genta *et al.*, 2021). This newfound efficiency translates into faster, cost-effective operations, ultimately bolstering productivity and competitiveness across various industries, from cross-border payments to supply chain logistics. A central hallmark of blockchain is its decentralization, with no central authority in control. This empowers participants and diminishes the risk associated with single points of failure. Decentralized networks exhibit greater resilience with no singular entity capable of causing widespread disruption if compromised. This feature is especially pertinent in critical applications like voting systems and digital identities, where trust is paramount even without central control. Figure 2 provides an overview of Blockchain technology features and its resultant benefits.

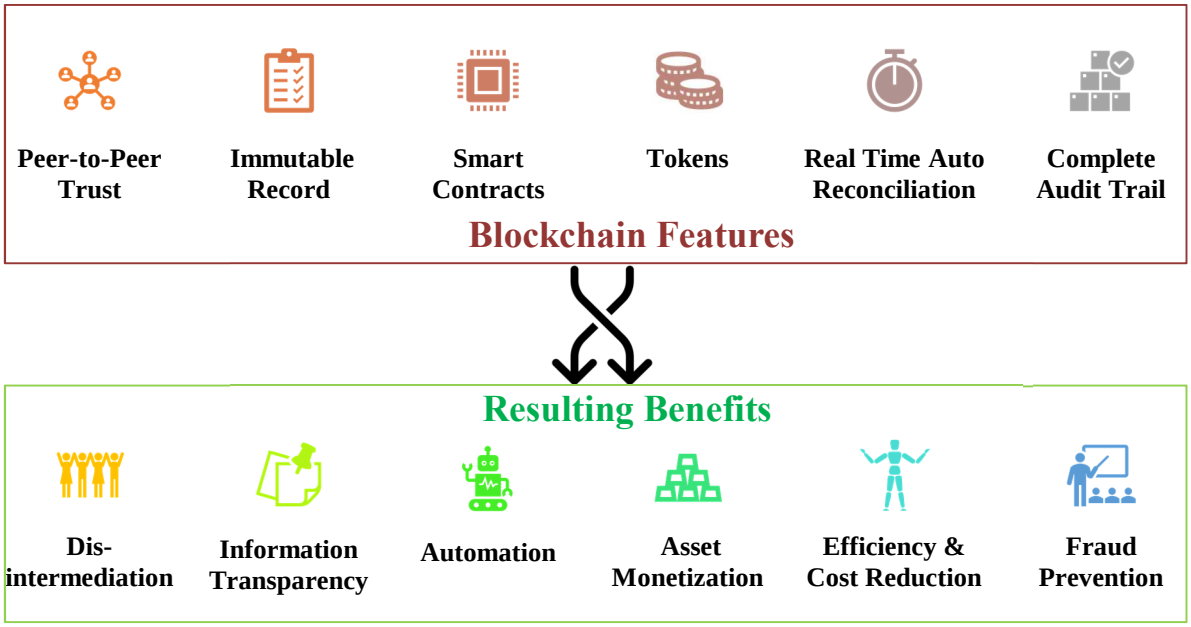

Figure 2. Blockchain features and resulting benefits
Source: own elaboration.

Blockchain relies on consensus mechanisms and cryptographic techniques for verifying and validating transactions, reducing the reliance on intermediaries for trust. This holds particular significance in industries where intermediaries traditionally play a pivotal role, such as the real estate and legal sectors. The blockchain simplifies complex processes, reduces dependency on third parties, and expedites transactions (Genta *et al.*, 2021). For SMEs, the potential for cost savings is particularly compelling. Blockchain optimization minimizes redundancy and overhead costs, leading to efficient resource allocation, reduced administrative expenditures, and an enhanced competitive edge for SMEs.

By streamlining operations and reducing the need for intermediaries, blockchain technology offers cost-effective solutions to help SMEs flourish in today's fiercely competitive business landscape. Combining these features and advantages underscores blockchain's transformative potential across diverse industries, redefining how businesses operate, collaborate, and manage their data. Understanding and harnessing these attributes can lead to more efficient and secure processes, benefiting organizations of all sizes.

RESEARCH METHODOLOGY

In this research article, we undertook a comprehensive examination of the application and adoption of blockchain technology in SMEs through a narrative and critical literature review following the approach outlined by Ratten (2023). Employing a methodology that builds upon existing research and prior literature, we explored the academic landscape of blockchain technology in SMEs. We used 'SME' and 'Blockchain' as keywords for the initial literature search and successively screened the result by title and abstract analysis followed by full-text screening. We classify the collected literature into different themes of blockchain technology application in SMEs to create the taxonomy and then analyze each of these themes to present and reflect on the trends therein.

The study also draws some methodological lessons from Korzynski *et al.* (2023). Through analyzing pertinent academic literature in the area, we crafted a taxonomy encompassing key themes related to the application and adoption of blockchain technology. The taxonomy developed through our analysis is an organizational tool to distil key themes, fostering a deeper understanding of the subject. We acknowledge and address inherent limitations through continuous reflexivity, ensuring transparency and credibility. The synthesis of findings contributes to the evolving knowledge base, offering valuable insights into the nuances, challenges, and future trajectories of blockchain technology adoption in the SME sector.

Through this article, we created a pivotal conceptual contribution, wherein an exhaustive literature review has led to formulating a detailed taxonomy of blockchain technology application and adoption in SMEs. Our exploration extended across diverse dimensions of blockchain technology applications in SMEs, culminating in developing a nuanced thematic taxonomy. The investigation further delved into various adoption theories and frameworks employed to analyze the adoption of blockchain technology in SMEs, resulting in conceptual frameworks delineating the enablers and barriers to adoption. Moreover, this comprehensive analysis unveiled the associated opportunities and challenges of blockchain adoption in SMEs. The conceptual framework presented herein is an invaluable guide for SMEs, blockchain solution providers, and researchers, offering direction for exploring and designing blockchain-based solutions tailored for SMEs.

RESULTS AND DISCUSSION

Blockchain Technology Applications in SMEs

Blockchain technology offers a wide array of applications for SMEs spanning various sectors, including finance, supply chain finance (SCF), supply chain management (SCM), manufacturing, IT infrastructure, collaboration, energy, human resource management (HRM), and marketing. This technology has the potential to play a pivotal role in addressing inefficiencies arising from the involvement of numerous intermediaries and conventional methods. In SCM, Blockchain fosters transparency, enhances traceability, and improves product quality (Casino *et al.*, 2019). It can also streamline manufacturing, promote collaboration, enhance energy trading, and improve HRM processes.

Blockchain is a transformative force within the supply chain finance sector, bolstering participant coordination and trust while reducing credit risk and providing transparency and traceability (Yang, 2021). These changes are particularly advantageous in sectors like the food industry, leading to improvements in product quality. Figure 3 provides a taxonomy of blockchain technology applications in SMEs based on analyzing available literature on SMEs and blockchain technology. Within the financial sector, blockchain's transformative influence extends to creating a financing paradigm characterized by enhanced transparency, security, and trust through its distributed ledger and cryptographic features. In

turn, this reduces information asymmetry and gives rise to a blockchain-based credit system capable of better distinguishing between varying risk profiles (Anwar, 2019).

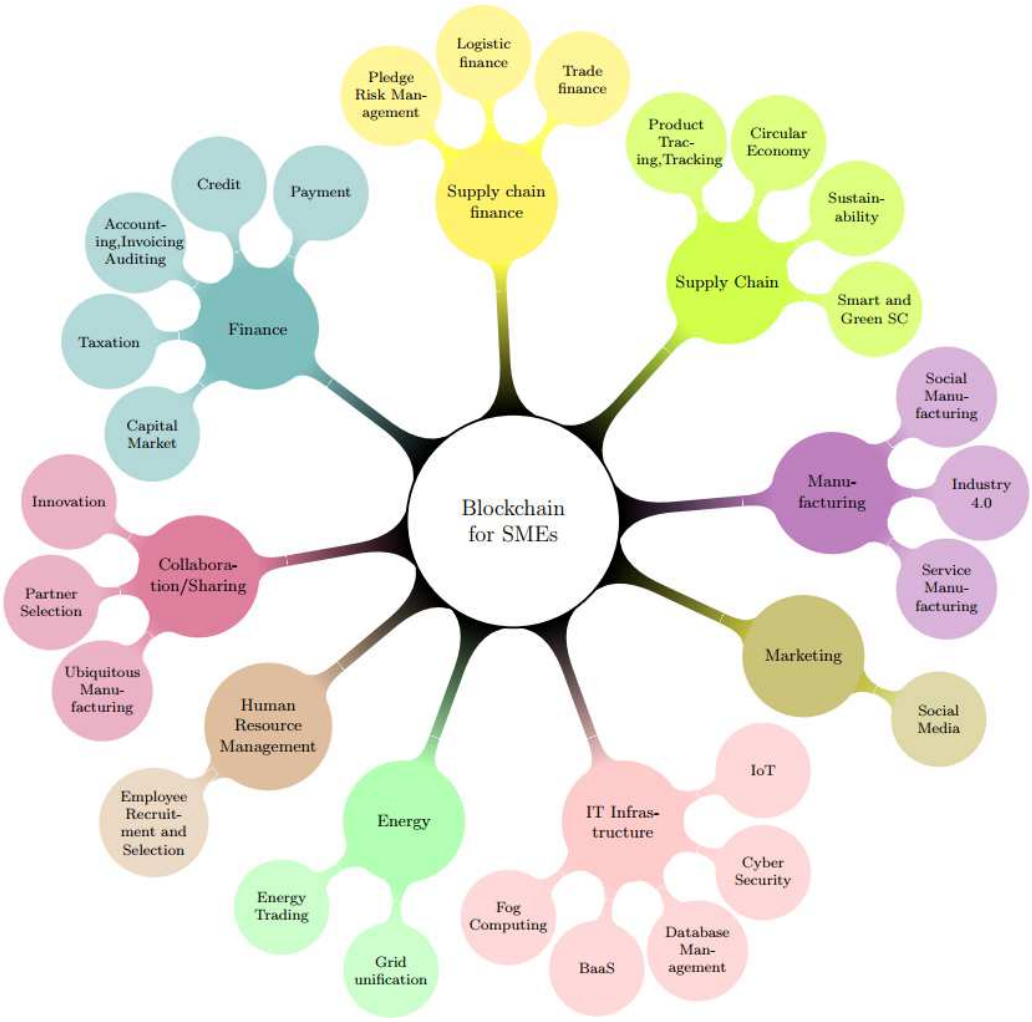

Figure 3. Taxonomy blockchain applications for small firms
Source: own elaboration.

Blockchain's positive impact extends to payment systems, taxation, and auditing. Automating financial processes and incorporating smart contracts alleviates administrative burdens for SMEs in obtaining timely capital. This technological innovation has the potential to substantially aid cost savings and increase access to essential financial tools, equipping SMEs to compete globally. The section below discusses the application of blockchain technology in SMEs across the domains depicted in Figure 3.

Finance

The financial system's inefficiencies, rooted in outdated practices, centralization, and exclusivity, can be transformed by blockchain technology, streamlining financial operations and making them more efficient and accessible (Kumar *et al.*, 2023). This transformation can be especially beneficial for SMEs as they often struggle to obtain timely and affordable capital during cash shortages (Dimitropoulos *et al.*, 2020). Prevalent information asymmetry and a lack of sufficient collateral block SMEs' access to finance, hindering their growth and expansion (Kumar & Rao, 2016). Blockchain technology addresses these issues by enhancing information availability and sharing among stakeholders. Distributed ledgers on the blockchain record and share data, mitigating original information asymmetry (Utkarsh *et al.*, 2022). This allows SMEs with a low-risk profile and strong performance metrics to demonstrate their creditworthiness and access loans without collateral.

Furthermore, blockchain can significantly improve the credit system by enhancing transparency, equalizing access to transaction and default records, and using smart contracts to automate loan processes. It enables users to instantly share default information with all lenders and corporations, which increases the cost of default for companies, acting as a screening method. This enables blockchain-based credit systems to distinguish between different risk classes, thus mitigating credit rationing issues (Wang *et al.*, 2019). For example, in a blockchain-based e-commerce platform for SMEs, the authenticity, transparency, and unforgeability of trading and logistical data serve as sources for data financing, with banks evaluating loan firms based on historical transaction and logistics data (Jiang & Chen, 2021). Moreover, blockchain can address the agency problem by reducing information asymmetry between matching agencies and network users, increasing transparency, and reducing transaction costs (Chang & He, 2018).

Blockchain technology can improve credit reporting systems for SMEs by utilizing big data and blockchain to create a comprehensive credit evaluation system (Sun *et al.*, 2021). Blockchain-based distributed credit evaluation architecture can offer a more accurate and complete evaluation of enterprise credit status. Smart contracts integrated with current systems can enhance the efficiency and transparency of microfinance institutions. Anwar (2019) notes that each entrepreneur or organization approaching the bank for microfinance can sign a unique smart contract, serving as an identity for loan issuance and transparency in loan records. This system reduces defaults and strengthens the role of central banks as regulatory bodies.

Besides credit, blockchain technology has applications in various financial areas, including banking, payments, taxation, and auditing. For example, it can improve transparency in the deposit market and streamline payment processes in industries with transaction delays (Giuda *et al.*, 2020). It also has the potential to revolutionize tax settlement, reducing administrative burdens on SMEs (Søgaard, 2021). Blockchain technology enhances trust in financial transactions, leading to lower financing costs for SMEs. The technology is poised to reinvent the financial ecosystem by reducing transaction costs and processing times and improving transaction security. This can benefit SMEs by making timely and affordable financing available.

Supply Chain Finance

Supply chain finance (SCF) is a banking service designed to streamline the flow of capital within supply chains. Conventional SCF models, including accounts receivable, prepayment, and inventory financing, often fail to meet SMEs' specific requirements due to their inherent inefficiencies. Blockchain technology presents a promising solution to address these challenges by providing a decentralized, transparent, and secure ledger of transactions. This innovative approach not only enhances the efficiency of supply chain finance but also significantly reduces transaction costs associated with information asymmetry (Feng & Wang, 2022). Moreover, the intricate nature of collaboration and coordination within supply chains involving financial institutions, core firms, and various supply chain entities mirrors the capabilities of blockchain technology. By fostering mutual trust among all supply chain entities, blockchain enhances coordination efficiency within SCF, allowing multiple institutions to cooperate while eliminating the risk of private collusion seen in traditional SCF models (Zhang *et al.*, 2021).

A blockchain-based architecture streamlines SCF using smart contracts to coordinate with different agents autonomously. The dynamic pledge management process, characterized by transparency, reliability, and cost-efficiency, reduces the need for third-party intermediaries, expediting transactions and minimizing errors in supply chain processes (Xu *et al.*, 2021). Blockchain also addresses information gaps in supply chains, particularly at the chain's margins, where companies face difficulties accessing financial support. By enhancing traceability, transparency, and authenticity, blockchain reduces attenuation in credit transmission, facilitating credit access for SMEs in SCF (Xu *et al.*, 2021). Furthermore, blockchain overcomes the information island challenge, where information concentration at core companies limits access for other supply chain participants. Blockchain bills ensure that information is certified by all participating nodes, allowing SMEs at the end of the supply chain to access low-cost finance and financing services (Zhang *et al.*, 2021).

Blockchain technology has revolutionized SCF in several ways, including platform development, innovative SCF models, and in-depth mechanism design. These blockchain-powered SCF platforms bring together stakeholders from different layers, introducing self-guarantee mechanisms that boost SMEs' credit access and overall SCF sustainability (Liu *et al.*, 2023). For instance, in the Kenyan retail trade industry, blockchain has simplified SMEs' access to financial products by implementing a three-party transaction model involving buyers, sellers, and intermediaries, supported by a hyperledger fabric blockchain backend (Kinai *et al.*, 2017). In trade financing, blockchain streamlines processes by reducing stages and verifications, improving information sharing, and increasing accessibility for SMEs. This transparent and interconnected approach benefits all parties, including buyers, sellers, banks, and shippers, leading to more favourable trade financing terms for SMEs.

Blockchain technology contributes to SCF risk management by improving supply chain information transparency and reducing credit, operational, and collateral risks while enabling real-time monitoring. Combining the internet of things (IoT) and blockchain further enhances risk management in SCF (Li *et al.*, 2019). Blockchain is also instrumental in developing sustainable SCF models by addressing legal and regulatory challenges, thereby improving the overall supply chain finance ecosystem (Nayak & Dhaigude, 2019). Notable platforms like we.trade and Linklogis harness blockchain to enhance supply chain visibility and credibility, facilitating bank financing for SMEs.

Supply Chain Management

There are two primary directions of blockchain applications in SCM: streamlining operations and ensuring the authenticity and provenance of materials and products. Blockchain has been deployed in supply chain management for various purposes, such as automation, improved integration across supply chain streams, enhanced traceability, tracking, restructuring agricultural commodity trading, and creating smart rural supply chains (Gerasimova *et al.*, 2021). It reduces administrative complexities and costs by facilitating secure data sharing among geographically dispersed parties, lowering transaction times and overheads.

Blockchain supports transparent, real-time tracking, enhancing product lifecycle management, and optimizing various supply chain functions through smart contracts. The technology also enhances product quality, customer relationships, and visibility for SMEs. By boosting transparency and trust through a distributed ledger, blockchain can help small firms establish good reputations. Innovative blockchain-based platforms that support fair trade, authenticity in documentation, and cost reduction can benefit SMEs (Nowiński & Kozma, 2017). Blockchain helps secure geographical indication (GI) tags for regional food products by ensuring traceability throughout the supply chain. The technology prevents identity fraud, ensures food safety, and provides origin information (Katsikouli *et al.*, 2021).

In the supply chain industry, blockchain can usher into smart agriculture and smart logistics (Gerasimova *et al.*, 2021). Digitization, IoT, big data, and blockchain enhance supply chain traceability and transparency, driving sustainability and efficiency (Desai *et al.*, 2019). They enable more accurate consumer reactions, demand forecasts, and reduced inventory. Blockchain's decentralization and tamper-proof records enhance security and transparency in the supply chain, particularly in geographically dispersed, small producer-heavy food chains (Adams *et al.*, 2021). Major players like Walmart, Maersk, and Nestle have adopted blockchain in the supply chain to improve efficiency, reduce costs, ensure product freshness, and verify product authenticity and origin.

Manufacturing

Blockchain technology can assist SMEs in improving demand and supply planning, reducing production costs, and fostering manufacturing collaboration. It can usher into Industry 4.0, empowering SMEs to digitalize and optimize their production processes (Rymarczyk, 2020; Karamchandani *et al.*, 2021). It can enable secure data sharing, access management, and remote maintenance among the SMEs. In the context of Industry 4.0, smart contracts bring self-enforcing capabilities, enabling cloud and ubiquitous manufacturing, enhancing demand and supply planning, reducing overproduction, and lowering costs (Barenji *et al.*, 2019). Blockchain is a pivotal enabler of the shared economy, especially for SMEs in social manufacturing (Liu & Jiang, 2020). Blockchain enhances cooperation and trust among geo-

graphically dispersed MSMEs, creating more efficient manufacturing communities. Service manufacturing, a shift from traditional product-centric models, leverages digitalization and customer-centric strategies. Blockchain digitizes manufacturing resources through a multi-layer secure digital twin platform, accelerating the transition to service-oriented manufacturing (Liu *et al.*, 2021).

Collaboration and Sharing

Small and medium-sized enterprises are adopting cloud and ubiquitous manufacturing to foster trustworthy collaboration and information sharing in a dynamic market (Barenji *et al.*, 2019). By automating data exchange and promoting connection among participants, blockchain technology aids decentralized business communities (Petek & Zajec, 2018). However, concerns arise about public data sharing, as some players, like SMEs in the food supply chain, are cautious about revealing proprietary knowledge (Ali *et al.*, 2021). Blockchain and smart contracts enhance cross-organizational collaboration, benefiting entrepreneurs and SMEs by reducing entry barriers and corporate dominance (Sciarelli *et al.*, 2021).

Decentralized autonomous organizations (DAOs) allow for the creation of distributed organizations driven by organizational entrepreneurship, many of which are based on blockchain technology (Poeschl, 2023). The DAO members' self-organization and entrepreneurial behaviour are crucial to the organization's development. Distributed ledger technology provides secure intellectual property protection, smart contract execution, and data privacy, fostering cooperation and regulatory compliance in manufacturing networks. Industry-University cooperation offers a path for SMEs to improve technological capabilities with partner selection being critical for success (Ran *et al.*, 2020).

IT Infrastructure

Blockchain ensures secure and decentralized data storage, reducing IT infrastructure costs and improving data security. It also supports decentralized applications (DApps), enhancing scalability and flexibility while lowering costs. In the digital transformation era, SMEs grapple with data dispersion that hinders effective utilization. Liu *et al.* (2020) proposed a blockchain-based platform that integrates decentralized identification to ensure data source authenticity and secure user data storage, aided by smart contracts and federated learning models to extract value from data. To combat the rising tide of cyber-attacks, particularly impacting small firms, Lopez *et al.* (2020) introduced an intelligent cybersecurity platform, combining machine learning and blockchain, which covers all phases of attacks, including prevention and recovery. Sadeq *et al.* (2021) advocate for blockchain to enhance data security, utilizing its intrinsic hash replication and mining algorithm to detect unauthorized data alterations.

Energy

Blockchain has found prominent applications for SMEs in the energy sector, from energy transmission to trading. Markakis *et al.* (2021) presented a groundbreaking solution that empowers small energy producers, like solar panel grids, to sell surplus energy via a blockchain-based energy brokerage, promoting peer-to-peer energy transactions. Leelasantitham (2020) offers a decentralized model for peer-to-peer electricity trading among Thai consumers and SME prosumers, aimed at saving on electricity costs. Extending this model to the mobility sector, Li *et al.* (2021) developed a blockchain network with smart contracts to bypass network congestion and enable electric vehicle peer-to-peer energy trading, incorporating a superconducting energy storage unit to enhance transaction reliability and user matching. This innovative approach enhances the success rate and demand consumption in electric vehicle peer-to-peer energy trading.

Human Resource Management (HRM)

Small and medium-sized enterprises encounter diverse challenges in attracting and retaining human resources (Koronios *et al.*, 2020). Blockchain provides a secure means to verify the authenticity of candidates' educational and employment history, aiding SMEs in more efficient recruitment. It enhances productivity by matching skills and performance with job requirements. Rhemananda *et al.* (2021) introduced a blockchain-based framework for human resource management in small firms, enhancing hiring by providing secure proof of candidates' educational and employment history, thus increasing productivity.

Marketing

Blockchain fosters trust and transparency in marketing by offering secure product tagging and verification, protecting brands from counterfeiting, and improving user experience. Small firms face marketing challenges due to limited resources, and the growing non-face-to-face e-commerce transactions pose moral hazard risks. Jiang and Chen (2021) developed an intelligent matching module to aid SMEs in connecting with relevant trading partners. Rotondi and Saltarella (2019) proposed a product tagging solution to protect SME brands, improve user experience, and combat counterfeit products.

Blockchain Technology Adoption in SMEs

The landscape of investment in blockchain-based business solutions is experiencing exponential growth. However, the broader adoption of blockchain technology by businesses, particularly small enterprises, remains notably subdued (Molati *et al.*, 2021). We may attribute this apparent restraint to several factors. Primarily, the novel nature of blockchain and its inherent complexity pose challenges, particularly for smaller firms with comparatively limited technical understanding. The transition from proof of concept to widespread applications has proven to be a formidable hurdle for numerous projects, resulting in fragmented utilization. Moreover, the financial constraints commonly faced by SMEs act as a barrier to embracing cutting-edge technology. In the above context, we explored the existing literature on blockchain adoption by SMEs to conceptualize the inherent drivers, barriers, opportunities, and challenges of blockchain adoption in SMEs.

A Brief Overview of Technology Adoption Frameworks and Perspectives

To comprehend the intricate process of technology adoption, researchers and practitioners have developed a range of frameworks and perspectives that offer insights into the factors influencing the acceptance, diffusion, and integration of innovative technologies. These frameworks encapsulate the multidimensional nature of technology adoption, accounting for individual beliefs, social dynamics, organizational structures, and contextual factors. Table 1 presents a concise overview of prominent technology adoption frameworks and perspectives contributing to our understanding of blockchain adoption in SMEs.

Frameworks Used to Study Blockchain Adoption in SMEs

The decision-making process for technology adoption within firms is inherently complex, influenced by an intricate interplay of factors spanning technical, social, environmental, cultural, and behavioural domains. This decision becomes even more arduous for small businesses due to their limited resources and technical capabilities. Researchers conducted an academic exploration of blockchain adoption using diverse frameworks and theories as depicted in Figure 4. These frameworks illuminate the multidimensional considerations that influence SMEs' choices when it comes to the integration of blockchain technology. By examining these varied lenses, we can understand the challenges and opportunities underpinning the adoption journey for SMEs in the blockchain landscape.

Factors Influencing Blockchain Technology Adoption in SMEs

Despite the promising potential of blockchain technology, widespread adoption remains in its early stages. Based on the studies listed in Figure 4, we compiled the factors that affect blockchain technology adoption in SMEs into enablers, barriers, moderators, and insignificant ones. Enablers serve as catalysts, expediting the acceptance and utilization of new technology, while barriers represent the impediments that slow down or obstruct the adoption process. On the other hand, moderators influence the strength and direction of the effect of enablers and barriers. They can either amplify or mitigate the impact of these enablers and barriers based on the unique context and characteristics of the adopters. Insignificant factors denote elements that have minimal influence on the overall technology adoption process. Figure 5 provides a concise synthesis of the determinants governing the adoption of blockchain technology in SMEs. As these factors intersect and evolve, they shape the trajectory of blockchain integration among small businesses, guiding their decisions and highlighting the strategic considerations that pave the way forward.

Table 1. Technology adoption frameworks and perspectives summary

Technology acceptance model (TAM)	Proposed by Davis (1986), TAM focuses on individual attitudes and behaviours toward technology adoption. It posits that perceived usefulness and perceived ease of use are pivotal determinants that influence an individual's acceptance and eventual use of technology.
Unified theory of acceptance and use of technology (UTAUT)	Developed by Venkatesh *et al.* (2003), UTAUT integrates several preceding models to identify four core determinants of technology adoption: performance expectancy, effort expectancy, social influence, and facilitating conditions.
Technology-organization-environment (TOE) framework	TOE Framework recognizes the interaction between technological factors, organizational dynamics, and environmental influences in shaping technology adoption. This framework emphasizes variables like organizational size, top management support, external pressures, and technological complexity.
Post-acceptance model (PAM)	Extending TAM, PAM delves into post-adoption behaviour, encompassing variables like user satisfaction, continued usage, and word-of-mouth communication.
Diffusion of innovations (DOI) theory	Introduced by Rogers (1962), DOI offers a comprehensive framework for understanding how new technologies spread across social systems. This theory classifies adopters into distinct categories and emphasizes the role of communication channels, social networks, and the perceived attributes of innovations in the adoption process.
Innovation diffusion in networks (IDN) model	The IDN model focuses on the network's social structure and its role in driving innovation diffusion. It considers factors such as network node characteristics and the nature of ties between nodes to elucidate how innovations spread through interconnected relationships.
Social cognitive theory (SCT)	Developed by Bandura, SCT suggests that personal cognition, environmental factors, and behaviour influence individual behaviour. It underscores the significance of self-efficacy, observational learning, and outcome expectations in technology adoption.
Innovation theory perspective (ITP)	The innovation theory perspective focuses on the attributes of innovations, such as novelty, complexity, and compatibility, and their impact on adoption and diffusion. It underscores innovation management strategies and their role in fostering adoption.
Socio-technical perspective (STP)	The socio-technical perspective underscores the interplay between social and technical components in technology adoption. It emphasizes aligning technical and social systems for successful adoption and effective utilization.
Knowledge management perspective (KMP)	The knowledge management perspective focuses on how organizations create, share, and apply knowledge while adopting technology. It highlights the importance of knowledge sharing, learning processes, and transfer mechanisms in facilitating adoption.
Extended complexity theory (ECT)	The extended complexity theory applies complexity theory principles to technology adoption. It acknowledges adoption's intricate, nonlinear nature influenced by interconnected factors, feedback loops, and emergent behaviour.

Source: own study.

Among the myriad factors that impact blockchain adoption in SMEs, several stand out as pivotal for small firms. Notably, the steadfast support of top management, the comparative advantage offered by the new technology over its predecessors, technological compatibility, and competitive pressures have emerged as the most pronounced catalysts driving blockchain integration in SMEs (Molati *et al.*, 2021; Bhardwaj *et al.*, 2021). Conversely, the formidable hurdles that inhibit such adoption primarily encompass the cost implications and the intricate nature of the technology itself. The lack of management vision and cultural disparities among supply chain partners are other key inhibitors (Bag *et al.*, 2021; Kaur *et al.*, 2022). These formidable barriers obstruct initial progress and can cascade into other obstacles within the system, further impeding the integration of blockchain technology.

The adoption of blockchain technology is still in its early stages, as researchers continue to explore its complexities and potential applications. A striking observation is the role of regulatory support, which, thus far, has shown to be an insubstantial determinant of blockchain adoption across small firms (Bhardwaj *et al.*, 2021; Molati *et al.*, 2021). The crux of this assertion is that despite its promise, the technology has yet to materialize in extensive real-world implementations. The advent of supportive standards and laws to bolster SME engagement with blockchain technology is still in progress, creating uncertainty among SMEs regarding the technology's regulatory landscape. Therefore, the pressing need to establish norms and regulations becomes more apparent.

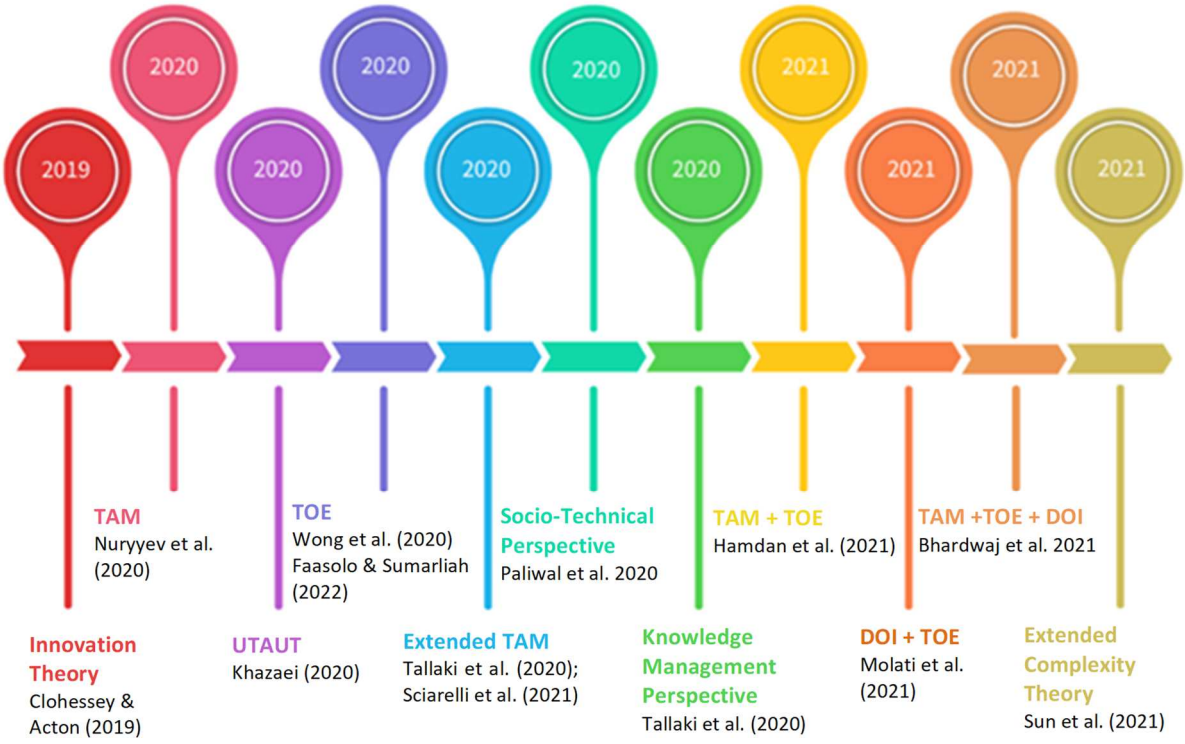

Figure 4. Adoption frameworks used in blockchain-SME literature
Source: own elaboration.

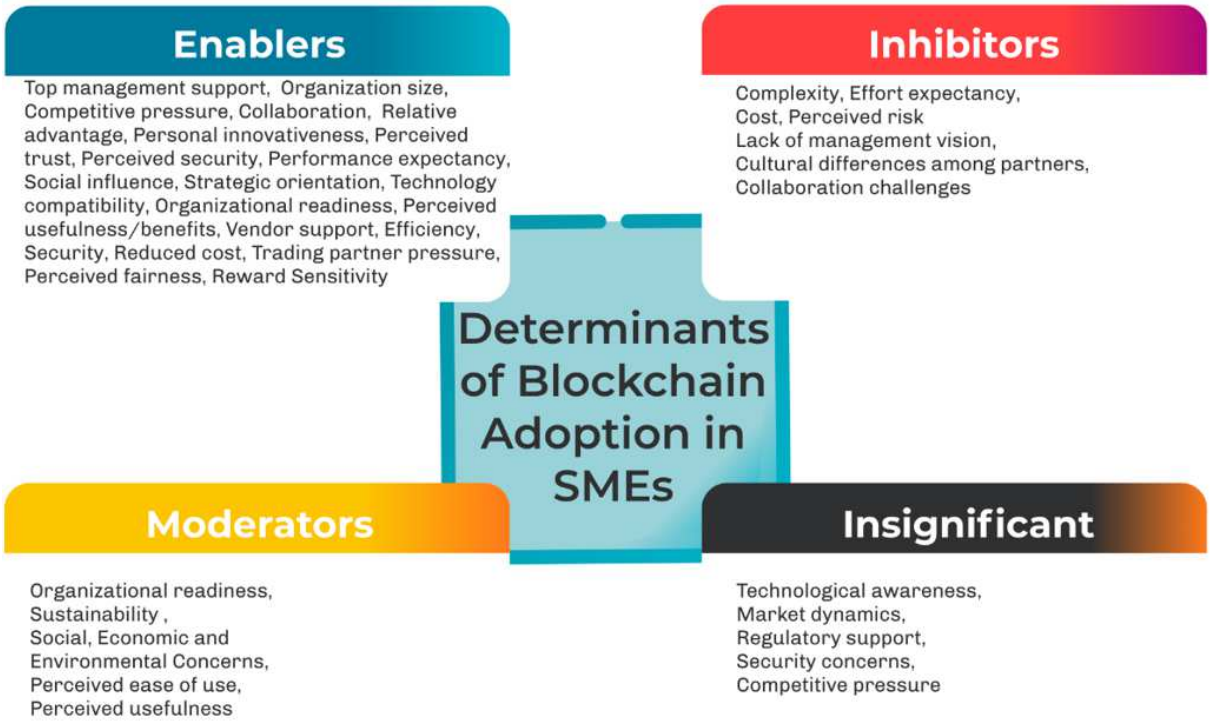

Figure 5. Determinants of SME blockchain adoption
Source: own elaboration.

Addressing the twin cost and complexity concerns is paramount to achieving widespread adoption. This concern has found potential relief through the emergence of Blockchain-as-a-Service (BaaS) solutions (Yu, 2021). This approach offers a managed blockchain platform, allowing businesses to construct applications on a distributed network while the vendor provides the necessary infrastructure and development tools. Analogous to the software-as-a-service model, BaaS accelerates application deployment, providing enhanced flexibility and expediting blockchain integration in SMEs. Chabani *et al.* (2021) proposed a flexible adoption approach that prioritizes upgradability, scalability, and interoperability to accommodate the evolving needs of SMEs and enhance the chances of a successful adoption.

Other primary concerns include a substantial knowledge gap and a lack of education about blockchain technology in SMEs. Furthermore, businesses hesitate to adopt the technology without a standardized collaborative effort backed by national or international norms and regulations. It becomes evident that education and establishing standardized frameworks are pivotal to propelling blockchain technology's widespread adoption in SMEs. Developing SME-focused applications and laying out a clear adoption roadmap backed by established standards and regulatory support is key to promoting SMEs' adoption of blockchain technology.

Opportunities and Challenges of Blockchain Technology Adoption in SMEs

Blockchain technology offers SMEs a multitude of opportunities across their business domain. It enhances transparency by providing a transparent and immutable ledger that reduces the risk of fraud and errors, thus fostering trust among stakeholders (Wang *et al.*, 2018). Moreover, SMEs can leverage blockchain for improved supply chain management, allowing real-time tracking and transparency in the supply chain's movement of goods and materials. This optimization leads to streamlined processes, ultimately reducing operational costs. Blockchain also opens doors to alternative funding sources, such as initial coin offerings (ICOs) and security token offerings (STOs), making it easier for SMEs to raise capital (Block *et al.*, 2021).

The cryptographic security of blockchain safeguards sensitive data and transactions, fortifying the system against malicious actors. Smart contracts are another game-changer, enabling SMEs to automate various business processes like payments and contract execution, significantly reducing manual intervention and operational costs (Giuda *et al.*, 2020). Blockchain facilitates global expansion by enabling trade and collaboration on an international scale. Its decentralized nature ensures no single points of failure, enhancing resilience in the face of system disruptions.

Moreover, blockchain is instrumental in sectors like food production, where it offers traceability to monitor and enhance product quality (Petek & Zajec, 2018). Finally, it gives SMEs more control over their data and digital assets, reducing their reliance on third parties. These opportunities collectively redefine how SMEs operate, collaborate, and manage data in a dynamic and competitive business environment. Figure 6 provides an overview of opportunities and challenges associated with SMEs' adoption of blockchain technology.

Alongside the opportunities, blockchain adoption by SMEs comes with its share of challenges. The lack of regulatory clarity within the blockchain landscape presents a notable challenge, as the technology and regulations are still evolving (Chang & He, 2018). Small and medium-sized enterprises may encounter difficulties in navigating compliance and legal issues. Furthermore, the initial costs associated with implementing blockchain technology can be substantial, encompassing investments in infrastructure and expertise. This financial barrier may prove challenging for smaller businesses. Integrating blockchain with existing systems and processes can be complex, potentially causing operational disruptions. Scalability concerns in some blockchain networks may limit their capacity to handle a growing volume of transactions, posing scalability concerns.

Despite its robust security features, blockchain is not entirely immune to all cyber threats, and privacy concerns can arise when sensitive data is stored on a public blockchain (Bhardwaj *et al.,* 2021). Moreover, if SMEs employ cryptocurrencies within their blockchain applications, they may become exposed to the inherent volatility of these digital assets. Finding and retaining talent with blockchain expertise can be challenging, especially for SMEs with limited resources, giving rise to a skills and ex-

pertise gap. Another formidable challenge is ensuring seamless interoperability among different blockchain networks and applications, particularly in a multi-blockchain environment (Casino *et al.,* 2019). Convincing all stakeholders, including customers and partners, to adopt blockchain technology can be met with resistance, resulting in adoption barriers (Zhang *et al.*, 2021). Small and medium-sized enterprises must know the technical complexities, scalability challenges, regulatory dynamics, cybersecurity risks, and market volatility associated with this disruptive technology. A balanced understanding of these opportunities and risks is crucial as SMEs embark on the journey to harness the power of blockchain and drive innovation in their financial operations.

Figure 6. Opportunity and risk framework for blockchain-based SME finance literature
Source: own elaboration.

CONCLUSIONS

Paving the Path for Future Exploration

Blockchain technology is considered the next tectonic shift in the world of the web. It has shown immense potential to reshape industries and revolutionize the business ecosystem. Small and medium-sized enterprises, which suffer due to their small size and lack of resources, can leverage this technological shift to propel their business to newer heights (Nowiński & Kozma, 2017). We explored the application and adoption of blockchain technology in SMEs, illuminating the application areas and adoption factors. Examining the opportunities and challenges of blockchain adoption for SMEs highlights its transformative potential while necessitating careful consideration from SMEs. Blockchain offers several advantages, from unlocking expanded access to capital and enhancing transparency to fostering trust and efficiency in financial operations (Anwar, 2019). However, the path forward is not devoid of challenges. Technical intricacies, scalability concerns, evolving regulatory landscapes, and awareness deficits are among the concerns that SMEs have as they venture into this evolving landscape (Chang & He, 2018).

This study significantly advances the discourse on blockchain technology by shedding light on its application within SMEs, a realm often overlooked in favour of discussions centred around larger corporations and financial institutions. In addressing this gap, our research contributes a vital perspective to the burgeoning field of blockchain. The thorough examination of the application and adoption of blockchain in SMEs, conducted through a narrative and critical literature review, extends the understanding of the transformative potential of this technology.

Establishing a comprehensive framework delineating opportunities and challenges for blockchain adoption in SMEs is a significant contribution. This framework not only enriches the theoretical underpinnings of blockchain technology, but also serves as a practical guide for designing and implementing tailored solutions to meet the unique needs of SMEs. The developed taxonomy and insights into adoption-related dynamics equip practitioners and researchers with valuable tools for comprehending and navigating challenges specific to SMEs in the blockchain landscape.

Moreover, by pinpointing existing gaps in the current literature and proposing future research avenues, this study contributes to the ongoing discourse, fostering continued exploration and innovation

in the field. The identified gaps signify opportunities for further scholarly inquiry and provide direction for practitioners seeking to address unmet needs and challenges in integrating blockchain within SMEs. This dual contribution, blending theoretical insights with practical applicability, underscores the broader implications of our research, encouraging sustained engagement and advancement in the dynamic intersection of blockchain technology and SMEs.

While this review encapsulates a diverse array of studies, frameworks, and perspectives, it is imperative to acknowledge the limitations inherent in such an exploration. The dynamic nature of technology and the rapidly evolving landscape of blockchain adoption necessitate continuous vigilance. Moreover, while we have endeavoured to comprehensively understand the opportunities and challenges, implementation specifics can vary greatly across industries, regions, and even individual SMEs (Chabani *et al.*, 2021). Therefore, readers should consider our insights as a foundation upon which further research can be built.

The path ahead requires a multifaceted approach characterized by collaboration, research, and strategic foresight. To address the challenges, partnerships between SMEs, technology providers, and policymakers become pivotal, enabling an ecosystem that nurtures blockchain-based solutions for SMEs. Robust educational initiatives will empower SMEs to navigate the complexities with confidence. Moreover, regulatory bodies must proactively dialogue to establish frameworks that foster innovation while ensuring security and compliance.

In terms of future research, the landscape remains ripe for exploration. In-depth case studies across diverse industries can illuminate the nuanced strategies and adaptations that SMEs undertake to leverage blockchain's potential. Comparative analyses across different countries and regions can provide insights into the impact of regulatory variations on adoption trends. Furthermore, longitudinal studies tracking the evolution of SMEs that embrace blockchain can offer a dynamic perspective on the long-term benefits and challenges.

Emphasizing a forward-looking approach, future research endeavours could delve deeper into the contextual factors influencing blockchain adoption in specific industries or geographical locations. Moreover, focusing on the socio-economic implications, ethical considerations, and the role of emerging technologies in shaping the trajectory of blockchain adoption by SMEs could further enrich the understanding of this dynamic phenomenon. Incorporating mixed-methods research designs could offer a more comprehensive view, combining qualitative insights from case studies with quantitative data to identify patterns and correlations. By embracing a multifaceted research agenda, scholars can contribute to a holistic understanding of the evolving role of blockchain in SMEs and foster a more informed and resilient business ecosystem.

This review serves as a stepping stone towards a future where blockchain technology intertwines seamlessly with the fabric of SME business operations. Furthermore, SMEs can navigate the challenges and harness blockchain's transformative potential by cultivating a holistic understanding of the opportunities, risks, and strategic considerations. With collective efforts, unyielding curiosity, and a strategic mindset, SMEs can position themselves at the forefront of a financial landscape redefined by blockchain innovation.

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