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From Pressure to Potential: How SMEs Leverage Blockchain for Sustainability under Institutional, Paradoxical, and Resource Constraints

Albert Amanollahnejad[1*], Javad Izadi[2], Bahareh Hosseinnezhad Nedaei[3]
[1]York Business School, York St John University, London, United Kingdom
[2]The Claude Littner Business School, University of West London, London, United Kingdom
[3] School of Business, University of Lancashire, Preston, United Kingdom
[1]a.amanollahnejad@yorksj.ac.uk; [2]javad.izadi@uwl.ac.uk; [3]BHosseinnezhadNedaei@uclan.ac.uk
*Corresponding Author: a.amanollahnejad@yorksj.ac.uk

Abstract *Blockchain technology (BCT) has garnered significant attention as a catalyst for advancing sustainability in small and medium-sized enterprises (SMEs). However, extant research has often relied on single-theory perspectives or has emphasized either technological potential or compliance imperatives, thereby overlooking the complex and context-dependent nature of BCT adoption. This study develops an integrative conceptual framework that synthesizes institutional theory, paradox theory, and the resource-based(RBV) view to elucidate the dynamics underpinning BCT adoption for sustainability in SMEs. The framework posits that adoption is not solely driven by external institutional pressures such as regulatory, normative, and mimetic forces but is fundamentally facilitated by the internal paradoxical tensions SMEs face and their distinctive organizational resources and capabilities. By highlighting the coexistence of opportunity and risk including enhanced transparency, traceability, technical complexity, and environmental impacts this study reveals that SME blockchain adoption is best understood as a dynamic, non-linear, and context-sensitive process. The framework advances the literature by demonstrating how the ability to navigate institutional and paradoxical pressures is contingent upon firm-level learning orientation, adaptive capacity, and resource endowments.*
Keywords *Blockchain adoption; Sustainability; Small and medium-sized enterprises (SMEs); Institutional theory; Paradox theory; Resource-based view; Digital transformation*

INTRODUCTION

Sustainability has become a cornerstone of modern business strategy, reflecting a shift in how organisations perceive their responsibilities toward the environment, society, and long-term economic health [29, 24, 2, 8]. As global awareness of environmental degradation and climate change intensifies, businesses are increasingly expected to minimize their ecological footprint, use resources efficiently, and contribute to the broader goals of sustainable development [17, 28, 27, 21]. Adopting sustainable practices is no longer seen as a voluntary or peripheral activity; rather, it is regarded as essential for maintaining competitiveness, building stakeholder trust, and ensuring compliance with emerging regulations [9, 20, 18, 25]. For companies of all sizes, integrating sustainability into core operations not only addresses environmental and social risks but also opens opportunities for innovation, cost savings, and access to new markets [25, 31, 18]. In parallel with the growing emphasis on sustainability, blockchain technology (BCT) has rapidly gained prominence as a transformative tool across various industries [22, 27, 5]. Originally developed as the backbone of cryptocurrencies, blockchain's core attributes decentralisation, transparency, and immutability are now being harnessed for a wide array of business applications [20, 29, 4]. For small and medium-sized enterprises (SMEs), blockchain offers the potential to overcome traditional barriers such as limited access to trustworthy data, high transaction costs, and complex regulatory requirements [10, 15, 12]. By enabling secure and verifiable record-keeping, blockchain can facilitate transparent supply chains, streamline compliance processes, and improve trust among business partners [25, 16, 11]. These capabilities are particularly valuable for SMEs seeking to demonstrate their sustainability credentials, participate in green markets, or collaborate with larger organisations that require robust environmental reporting and traceability [24, 28, 10].The intersection of sustainability and BCT represents a promising frontier for addressing some of the most pressing challenges facing businesses today [24, 11, 17]. By embedding transparency, traceability, and accountability into business processes, BCT has the potential to strengthen sustainable practices across supply chains, resource management,

and product lifecycle tracking [29, 4, 12]. For SMEs in particular, blockchain can provide practical tools to verify environmental claims, combat greenwashing, and ensure compliance with evolving sustainability standards and regulations [10, 31, 15]. This alignment not only helps SMEs meet stakeholder expectations for responsible business conduct but also unlocks new opportunities in markets where sustainability credentials are increasingly demanded [9, 21, 18]. As businesses and societies strive for more sustainable futures, the integration of BCT and sustainability initiatives holds the potential to drive innovation, reduce environmental risks, and foster long-term value creation [17, 28, 2]. However, despite its promise, the adoption of blockchain for sustainability in SMEs is fraught with both opportunities and paradoxes. While blockchain technology can act as a catalyst for credible sustainability practices and improved accountability, it also introduces new layers of complexity, including high implementation costs, technical immaturity, skill shortages, and significant concerns over its own environmental impact particularly energy-intensive consensus mechanisms [13, 4, 2]. This duality exemplifies the sustainability–blockchain paradox: the very technology designed to enhance environmental performance can itself generate unintended environmental consequences [22, 20, 11]. Understanding how SMEs navigate this tension is crucial, given their resource constraints and heightened sensitivity to both reputational and operational risks.To provide a comprehensive understanding of how SMEs approach blockchain adoption for sustainability, this paper draws primarily on Institutional Theory [6, 7, 23], which posits that organizational decisions are strongly shaped by external institutional pressures namely, coercive (regulatory), normative (stakeholder and industry), and mimetic (peer) forces. These pressures influence how SMEs interpret and respond to sustainability challenges and opportunities, as they seek legitimacy and continued competitiveness in rapidly evolving business environments [24, 12, 29]. In addition, Paradox Theory [32] is applied to frame the inherent tensions and dualities faced by SMEs as they weigh the potential benefits of blockchain against its costs and environmental footprint. Finally, insights from the Resource-Based View (RBV) [1, 33] further enrich the analysis by considering how internal resources and capabilities facilitate SMEs' responses to institutional demands and technological innovation. Against this backdrop, the purpose of this conceptual paper is to develop an integrative theoretical framework that explains how environmental institutional pressures, paradoxical tensions, and organizational resources collectively shape blockchain adoption for sustainability in SMEs. In doing so, the paper offers new avenues for theory development and provides practical guidance for managers and policymakers seeking to foster more responsible, effective, and sustainable digital transformation.Our paper begins by discussing BCT and sustainability, emphasising their significance for SMEs. We then present the theoretical background that underpins our study. This is followed by a detailed explanation of our methodological approach to data collection and analysis. After presenting and discussing our findings, we introduce a comprehensive model of blockchain adoption. The paper concludes by outlining our contributions, evaluating the practical implications, and identifying avenues for further research.

Theoretical Background

BCT has emerged as a disruptive innovation with the potential to reshape a range of business operations, including supply chain management, financial transactions, and sustainability reporting [22, 28, 5]. Its core features decentralisation, immutability, and transparency enable secure, real-time record-keeping accessible to multiple stakeholders, thereby offering practical solutions to persistent issues of trust, traceability, and compliance [20, 29, 4]. For SMEs, which frequently contend with information asymmetry, limited resources, and stringent regulatory demands, blockchain presents significant opportunities [12, 10]. Empirical studies indicate that BCT adoption can help SMEs overcome barriers to sustainable supply chain management, improve environmental reporting, and facilitate access to new, sustainability-oriented markets [24, 28, 25]. The technology has proven especially valuable for enhancing product traceability, verifying environmental claims, and automating compliance procedures [11, 10, 15]. Nevertheless, the diffusion of blockchain within the SME sector faces considerable obstacles. The literature consistently identifies high initial costs, technical complexity, limited skills, and regulatory ambiguity as persistent challenges to widespread adoption [2, 4, 13]. Moreover, concerns regarding blockchain's environmental impact particularly the energy intensity of proof-of-work (PoW) consensus mechanisms have raised questions about its net sustainability benefits [22, 20, 4]. Some scholars argue that while blockchain can enhance transparency and traceability, its overall contribution to

environmental sustainability must be critically evaluated, particularly in light of its carbon footprint and energy consumption [22, 4, 11]. This has given rise to a paradox within both academic and practitioner discourse: can a technology designed to foster sustainability also create new environmental risks? Table 1 summarises key peer-reviewed studies that address the intersection of blockchain, sustainability, and SME contexts. The table highlights the diverse theoretical frameworks adopted, main findings, and the evolution of thinking in this field.

TABLEI
Summary of Key Studies on Blockchain, Sustainability, and SMEs

Authors (NEW Number)	Topic/Focus	Key Findings	Implications
Qadri, Ali, Mustafa [19]	Blockchain and sustainability in companies	Environmental performance indices and regulations shape blockchain adoption for sustainability.	Regulatory frameworks are key to supporting sustainable blockchain use.
Friedman, Ormiston [11]	Blockchain for sustainability in food supply chains	Drives traceability and fair trade; faces resistance due to complexity and status quo.	Institutional change is required for greater adoption and impact.
Abdollahi et al. [2]	Blockchain adoption challenges for sustainability	Technical, cost, and expertise challenges hinder adoption; still early in most firms.	More education, support, and resources are needed for wider adoption.
Biswas et al. [4]	Blockchain's impact on supply chain traceability/sustainability	Increases traceability, but energy use may offset environmental benefits.	Need to weigh traceability benefits against environmental costs.
Upadhyay et al. [25]	Blockchain and the circular economy	Lowers transaction costs and increases transparency; faces trust and high cost barriers.	Blockchain can support the circular economy, but practical barriers exist.
Schinckus [22]	Sustainability of blockchain technology (PoW systems)	Transparency/energy trading benefits; high PoW energy use; sustainability is debated.	Addressing PoW energy use is necessary for sustainability.
Popkova et al. [17]	Blockchain for climate action and clean energy	Aids climate action via compliance; regional impact varies; potential not fully reached.	More regional adaptation and development are needed for impact.
Shah et al. [24]	Blockchain in sustainable garment supply chains	Enhances link between sustainable practices and performance; tech/organizational barriers exist.	Blockchain adoption improves performance, but support is needed.
Nayak, Dhaigude [15]	Blockchain in SME supply chain management	Culture, competition, and finance drive adoption; management capability critical.	Sector/culture-specific support for SMEs is important.
Savelyeva, Park [21]	Blockchain for sustainable education	Commons-based approach supports inclusion and SDGs; tech focus can exclude stakeholders.	Expand stakeholder access in educational applications.

Varma et al. [27]	Blockchain in supply chain sustainability	Improves sustainability; main barriers are technical immaturity, cost, and resistance.	Overcoming barriers is key for effective adoption.
Fang et al. [10]	Blockchain adoption in Malaysian SME supply chains	Usefulness and compatibility are main drivers of SME adoption.	Focus on practical integration to encourage SME adoption.
Al Mamun et al. [3]	Blockchain in Bangladeshi banks for sustainability	Usefulness and compatibility drive adoption; positive effect on sustainability.	Training can foster sustainable blockchain in banking.
Khan et al. [13]	Blockchain and green supply chain analytics in SMEs	Boosts sustainability and performance; cost and tech maturity are barriers.	Financial and technical support needed for SME adoption.
Mukherjee et al. [14]	Blockchain in agri-supply chains for sustainability	Blockchain-enabled agri-supply chains outperform traditional ones.	Supports blockchain integration in agriculture.
Ezzi, Jarboui, Mouakhar [9]	Blockchain and CSR in European firms	Improves CSR, especially in larger and mature firms.	Large firms should lead; SMEs need more access/support.
Rudd et al. [20]	Bitcoin's environmental, social, and economic impacts	Environmental cost lower than gold, but mass adoption may not be sustainable.	Manage environmental impacts as blockchain adoption grows.
Wu, Tran [28]	Blockchain in sustainable energy systems	Compatible with energy internet; challenges include energy use, security, and standards.	Energy sector projects need efficiency and standards.
Nuryyev et al. [16]	Blockchain adoption in tourism/hospitality SMEs	Social influence and orientation drive adoption for payments.	Use social networks/market trends to support adoption.
Yan et al. [29]	Blockchain and ESG disclosure in supply chains	Boosts sustainability on ESG pillars; more empirical research is needed.	Calls for more empirical, ESG-focused implementation.

To understand the factors shaping blockchain adoption for sustainability, scholars have increasingly drawn on Institutional Theory. This framework posits that organizations are embedded within a web of formal and informal rules, expectations, and cultural norms that exert significant influence on their behaviour [8, 9, 23]. Institutional pressures are typically categorized as coercive (regulatory/legal requirements), normative (industry standards and stakeholder expectations), and mimetic (imitation of peers or industry leaders) [8, 9, 23]. Coercive pressures include governmental regulations and environmental mandates that require organizations to adopt sustainable practices and robust reporting mechanisms [25, 18, 12]. For SMEs, these pressures are often linked to supply chain access, public procurement, and compliance with green standards [31, 30]. Normative pressures arise from the expectations of customers, industry groups, and professional associations, all of which can drive SMEs to embrace BCT as a means to demonstrate environmental responsibility and meet market demands for credible sustainability claims [29, 30, 13]. Mimetic pressures reflect the tendency of organizations to imitate successful peers, particularly in conditions of uncertainty or when best practices are not well established [15, 17]. In the blockchain context, the visible adoption of BCT by sector leaders or competitors can trigger a bandwagon effect, motivating other SMEs to follow suit to maintain legitimacy

and competitiveness [15, 17, 27].Existing studies have primarily focused on the technological or organizational drivers of blockchain adoption [2, 22, 1, 13], but recent research has highlighted the need to systematically analyse how institutional pressures especially environmental ones influence SMEs' technology decisions [12, 21, 26]. As Table 1 in this paper shows, while the literature affirms blockchain's transformative potential, there remains a lack of comprehensive exploration of how multiple, often conflicting, institutional forces interact to shape adoption processes in resource-constrained SME environments [13, 21].The adoption of blockchain for sustainability is characterized by inherent tensions most notably, the so-called "sustainability–blockchain paradox." On the one hand, BCT offers SMEs new avenues for environmental accountability, transparency, and efficiency; on the other, it presents challenges such as high energy consumption, increased complexity, and operational uncertainty [28, 20, 15]. Paradox Theory provides a valuable lens for theorizing these competing demands and for exploring how organizations experience and navigate contradictory yet interrelated objectives [32]. According to this perspective, managers are often required to balance opposing logics for example, advancing sustainability through technology versus managing the negative impacts of that same technology and to develop dynamic capabilities that enable adaptation and innovation amidst persistent tensions [32]. In the SME context, this paradox is particularly acute, given resource limitations and heightened sensitivity to reputational risks. Addressing such paradoxes demands both strategic clarity and organizational agility, making Paradox Theory an important conceptual addition to the study of blockchain adoption for sustainability.While institutional and paradox theories explain the external and paradoxical forces shaping blockchain adoption, it is equally important to consider the internal resources and capabilities that enable or constrain SME responses. The RBV posits that firms with superior resources and capabilities are better equipped to leverage technological innovations and to respond effectively to institutional pressures [1]. In the context of BCT, SMEs with greater financial, technological, and human capital are more likely to successfully implement blockchain for sustainability and to navigate the complexities and uncertainties inherent in such initiatives. RBV also highlights the importance of dynamic capabilities that is, the ability to integrate, build, and reconfigure internal competencies to address rapidly changing environments [33]. This perspective explains the observed variation in how SMEs respond to similar institutional pressures and paradoxical challenges. Thus, RBV serves as a useful complement to institutional and paradox theories, offering a more complete understanding of blockchain adoption processes in SMEs.

Proposed Conceptual Model

The integrative conceptual framework (Fig 1) elucidates the complex dynamics underlying blockchain adoption for sustainability among SMEs. Drawing from institutional theory [6, 23, 34], paradox theory [12, 32], and the resource-based view [1, 33], this model provides a nuanced understanding of how external pressures, internal tensions, and organizational characteristics converge to shape adoption decisions. Within this framework, environmental institutional pressures exert a foundational influence on SMEs' consideration of blockchain technology. Regulatory, or coercive, forces such as environmental legislation, reporting mandates, and sustainability-linked procurement requirements often serve as the initial catalyst for exploring blockchain adoption [6, 23, 19]. The imperative to comply with these requirements, particularly when access to key markets or participation in public procurement processes is at stake, prompts SMEs to seek technological solutions that enhance their ability to demonstrate transparency and accountability [13, 10, 4].Beyond regulatory forces, normative pressures emanating from value chain partners, industry associations, and professional communities intensify the perceived necessity of adopting blockchain for sustainability [23, 27, 15]. As expectations for transparent and traceable business practices become embedded within industry norms and stakeholder demands, SMEs experience heightened pressure to conform [21, 17, 4]. These normative influences reinforce the legitimacy of blockchain adoption, especially when environmental credentials become a prerequisite for participating in certain markets or supply chains [16, 14]. Mimetic pressures also play a pivotal role in the diffusion of blockchain technology within the SME sector. In contexts characterized by uncertainty and rapid technological change, SMEs often look to the visible actions of peers, sector leaders, and early adopters as reference points [6, 23, 15]. When competitors or influential actors within an industry successfully implement blockchain solutions, other SMEs are motivated to imitate these strategies to

preserve their competitive standing and legitimacy [10, 4]. Thus, the diffusion of blockchain adoption is frequently accelerated by a bandwagon effect, in which imitation becomes a rational response to environmental ambiguity and evolving best practices [12, 32]. However, the relationships between institutional pressures and adoption decisions are not linear or straightforward. Paradox theory provides critical insight into the moderating influence of what might be termed the "blockchain-sustainability paradox" [12, 32]. SMEs must continuously weigh the promised benefits of blockchain such as enhanced transparency, improved traceability, and increased trust [5, 30, 4] against associated costs and risks, including technical complexity, substantial resource demands, and the environmental impact of blockchain implementation [22, 20, 2]. The simultaneous presence of these contradictory forces requires SME leaders to develop a capacity for strategic sensemaking, enabling them to navigate and manage tensions rather than seeking simple resolution [12, 32]. The extent to which the blockchain-sustainability paradox is perceived as manageable or overwhelming fundamentally shapes the willingness of SMEs to pursue, delay, or reject adoption.Central to this framework is the role of organizational resources and capabilities, as articulated by the resource-based view [1, 33]. Not all SMEs are equally positioned to respond to institutional pressures or to engage productively with paradoxical tensions [14, 25]. Firms endowed with robust financial, technological, and human resources possess a greater capacity to absorb the costs of blockchain adoption, experiment with new business models, and develop the dynamic capabilities required for adaptation in uncertain environments [33, 1]. Such organizations are better equipped to translate external pressures into proactive strategies and to mitigate the risks associated with technological innovation [2, 10]. Conversely, resource-constrained SMEs may experience institutional and paradoxical pressures as insurmountable barriers, thereby limiting their engagement with blockchain technologies [14, 19]. As illustrated in Fig. 1, the proposed model conceptualizes blockchain adoption as a process shaped by institutional pressures, organizational resources, and the paradoxes SMEs perceive in weighing the benefits and challenges of blockchain for sustainability.

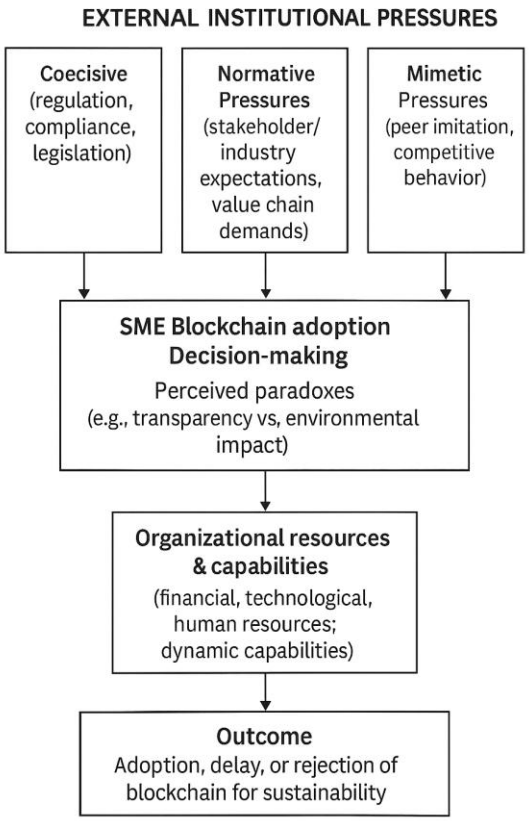

Fig 1. Integrative Conceptual Model of Blockchain Adoption for Sustainability in SMEs.

DISCUSSION

The integrative framework developed in this study offers novel insights into the multifaceted nature of blockchain adoption for sustainability within SMEs. By conceptualizing blockchain adoption at the intersection of institutional pressures, paradoxical tensions, and organizational capabilities, this perspective moves beyond the limitations of single-theory approaches and explains why SME digital transformation trajectories are often complex, iterative, and context-dependent [6, 1, 32]. A key contribution of this framework is the recognition that SMEs operate within a dense web of institutional influences, including regulatory expectations, normative standards, and mimetic behaviors shaped by sectoral leaders and peers [23, 6]. The convergence and sometimes conflict of these external pressures can simultaneously act as catalysts for innovation and sources of operational strain. This study reveals that SMEs' pursuit of legitimacy and compliance is not simply reactive, but is shaped by how organizations interpret, prioritize, and respond to overlapping institutional signals a finding that supports and extends prior research on institutional theory in technology adoption [34, 25].Furthermore, this study introduces and clarifies the paradoxical nature of blockchain adoption for sustainability. While blockchain is often promoted for its potential to enhance transparency, traceability, and accountability in supply chains [30], its adoption may also introduce significant challenges, including technical complexity, high energy consumption, and increased costs [31]. This duality, identified in the present framework as the "blockchain–sustainability paradox," demands that SME leaders engage in ongoing sensemaking, carefully weighing both anticipated benefits and unintended consequences [32]. Such a paradox perspective is critical, as it explains why some SMEs may hesitate or adopt only partially, highlighting the need for more nuanced, context-aware policy and managerial responses. Importantly, the framework highlights that the capacity of SMEs to navigate institutional and paradoxical pressures is facilitated by their internal resources and dynamic capabilities [1, 33]. SMEs with higher levels of financial, technological, and human capital, as well as adaptive learning and innovation capabilities, are more likely to convert external pressures into proactive strategies, realizing not only compliance but also competitive differentiation and business resilience [18, 25]. This study thus advances understanding by clarifying that successful blockchain adoption is not merely a function of environmental pressures, but is deeply contingent on the internal readiness and agility of the firm. Conversely, resource-constrained SMEs may struggle to keep pace, facing greater implementation challenges or even experiencing negative repercussions if they adopt technologies without sufficient preparation. This integrative understanding contributes new knowledge to the field by demonstrating that blockchain adoption in SMEs is best understood as a dynamic and context-sensitive process, requiring a simultaneous focus on institutional environment, paradox management, and capability building. In doing so, the framework provides practical guidance for policymakers and industry bodies, emphasizing the need for targeted support measures, such as capacity-building initiatives, demonstration projects, and regulatory guidance tailored to SME realities.

CONCLUSIONS

This study has advanced a fresh integrative framework to enlighten the dynamics of blockchain adoption for sustainability among SMEs. By synthesizing institutional theory, paradox theory, and the resource-based view, the research demonstrates that blockchain adoption is shaped by the interplay of external institutional pressures, internal paradoxical tensions, and organizational capabilities. This multidimensional approach provides a more nuanced and realistic account of SME decision-making processes, highlighting that adoption trajectories are rarely linear or uniform but are instead contingent upon a constellation of contextual and organizational factors. The framework moves the discourse beyond the technological or compliance-centric perspectives that have dominated much of the existing literature. It reveals that, while institutional pressures coercive, normative, and mimetic serve as significant drivers, they are facilitated by the paradoxical realities SMEs face as they attempt to balance the potential benefits of blockchain for transparency and traceability with its inherent risks, such as technical complexity and environmental concerns. Critically, the capacity to convert these pressures and tensions into positive organizational outcomes is determined by the quality of an SME's resources, adaptive capabilities, and learning orientation.The study's conceptual contributions yield important practical implications for both

policymakers and practitioners. Policy interventions must move beyond generic incentives and instead consider the distinct constraints and readiness levels of SMEs, fostering targeted capacity-building, peer learning, and practical demonstration projects. Managers, meanwhile, are encouraged to approach blockchain adoption with both strategic ambition and critical reflection, developing not only technical competencies but also paradox navigation skills and organizational agility. Future research is invited to empirically test the propositions and relationships outlined in the framework, to explore sectoral and regional variations, and to investigate the long-term sustainability outcomes of blockchain adoption in SMEs. Ultimately, this study highlights that realizing the sustainability potential of blockchain within the SME sector will require context-sensitive strategies, multi-level collaboration, and an ongoing commitment to balancing innovation with responsibility.

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