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Blockchain on the rise: A global overview of adoption, trends, and market applications

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Abstract: This study analyzes the role of blockchain technology in the digital transformation of businesses, focusing on its adoption, sectoral applications, challenges, investment trends, and integration with emerging technologies such as artificial intelligence (AI). The research employs a technology surveillance methodology in its analytical phase, supported by a documentary review of 69 sources published between 2017 and 2025. The findings reveal that blockchain has evolved beyond its original use in cryptocurrencies and is increasingly applied in finance, healthcare, logistics, education, and public administration. Key benefits identified include enhanced traceability, operational efficiency, and transparency. However, several barriers persist, such as technological infrastructure limitations, high implementation costs, regulatory uncertainty, and a shortage of specialized talent. The study also highlights a growing convergence of blockchain and AI, as well as accelerated adoption among small and medium-sized enterprises (SMEs) and in emerging markets. The conclusions position blockchain as a strategic enabler of business transformation, with strong potential to reshape business models and increase competitiveness. As a practical implication, the study recommends implementing adoption strategies that address investment, talent development, and legal frameworks to fully leverage blockchain's long-term impact in digital markets.

Keywords: *Blockchain, Business innovation, Digital transformation, Emerging markets, Technology watch.*

1. Introduction

This study focuses on carrying out technological surveillance on blockchain technology to identify trends, emerging applications, key players, and innovation opportunities that can guide the development of technological solutions in specific contexts. In recent years, blockchain technology has become increasingly relevant in the business environment. Although it was originally developed as the technical base for cryptocurrencies, especially Bitcoin, its potential has grown in the financial system to become a high-value strategic tool in many economic sectors.

This expansion is due to its fundamental features: a decentralized, transparent, secure, and unchangeable structure that allows transactions to be recorded in a reliable way without the need for intermediaries [1]. These properties have opened a wide range of possibilities for their implementation in sectors such as health, logistics, commerce, manufacturing, public administration, and, of course, accounting and finance. It has become an innovation in these sectors, mainly driven by investments in technology. Although investment in research and development (R&D) is important, it does not guarantee innovation success by itself; therefore, collaboration, the combination of knowledge, and the exchange of information both within and between different sectors are key to business innovation performance [2]. Success in innovation can bring value to both the company and its customers [3]. In

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this sense, blockchain is not just a separate technological innovation; its proper adoption depends on the integration of multidisciplinary knowledge and cooperation among diverse actors.

This technology allows the elimination of intermediaries, reduction of waiting times, and prevention of possible manipulation, which creates efficient, secure, and reliable processes [4, 5]. This not only reduces costs but also lowers uncertainty in business operations, especially in environments with high levels of institutional mistrust or economic informality.

In the business field, its use is creating significant impacts by strengthening integrity, fairness, and transparency, values that are essential for the proper functioning of any modern company [6]. Besides being a technological innovation, blockchain is becoming a driver of organizational transformation, pushing companies to rethink traditional business models and move towards more collaborative and data-driven structures.

One of the most important aspects is the role blockchain plays in supporting small and medium-sized enterprises (SMEs), which have traditionally had limited access to advanced technology. This tool helps them move towards transparent and efficient management models, promoting digitalization and boosting their competitiveness in digital markets [7]. The so-called "smart SMEs" are emerging as a new type of organization, adapted to today's environment, where trust, traceability, and information security are essential requirements.

However, implementing blockchain is not without challenges. It requires significant investments in technological infrastructure, as well as technical training for staff. Also, many companies still do not understand how blockchain works, which creates substantial entry barriers. These technical, economic, and human challenges must be addressed through a strategy that combines innovation, training, and regulatory adaptation [8]. This approach can help maximize the potential of this tool and prevent it from becoming merely another technological promise instead of a practical solution.

For all these reasons, blockchain is no longer an emerging technology only for the financial sector as it was initially thought, but a digital infrastructure that is changing the rules of the game in the global economy. This study focuses on understanding its practical application in the business environment, its real benefits, the barriers to its adoption, and the implications it has for organizational competitiveness and sustainability.

1.1. Conceptual Framework

This study builds on several key ideas that view blockchain not just as a new technology but as a widespread phenomenon capable of transforming various sectors of the economy. In the following sections, we explore the main concepts that support this research.

1.2. Technology Watch

Technology Watch (TW) is a strategic approach that helps organizations stay ahead by systematically gathering, analyzing, and sharing important information. This information can relate to technology, economics, politics, or social factors, and by examining it, organizations can identify opportunities and risks that may impact their decisions and long-term success [9]. Thus, TW serves as a critical tool for maintaining competitiveness, fostering innovation, and mitigating risks in dynamic business environments.

1.3. Blockchain

Blockchain technology has become a key tool for maintaining data integrity and security in digital environments. It functions as a distributed ledger, recording every transaction in a manner that is permanent and tamper-proof. This structure not only safeguards data but also enables traceability and verification without third-party intermediaries, significantly enhancing process transparency [10]. As Hiwale et al. [11] note, blockchain offers an ideal solution for delivering trust, transparency, and decentralization in systems such as healthcare, thereby improving privacy and security.

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Given this, it is evident that this technology is no longer exclusive to the financial sector. In fact, its capacity to facilitate secure operations without the intervention of a central authority has enabled its expansion into sectors such as healthcare, logistics, education, and public administration [12].

In the case of Colombia, the study by Narváez et al. [13] concludes that blockchain technology is still in a development phase. However, it is evident that coordinated actions by the Ministry of Information Technologies and Communications are driving its adoption and advancement. Moreover, it is relevant to note that all initiatives analyzed in the country aim to mitigate risks of corruption or tampering with data and documents, reinforcing its potential as a strategic tool. This diversification of use demonstrates that blockchain not only represents a technological innovation but also a strategic tool for transforming the way data is managed and digital trust is built in various contexts.

1.4. Digital Markets

Digital markets represent a significant evolution in the way commercial relationships are developed in the contemporary era. They are configured as virtual spaces in which companies can interact, establish connections, and exchange goods, services, and information through the tools provided by the internet [14]. This digitalization of commerce has profoundly transformed business dynamics, enabling greater accessibility and global reach. From an economic standpoint, these markets are primarily structured around digital platforms that act as intermediaries among multiple users and agents. These platforms not only facilitate transactions but also generate value by reducing the costs associated with information search, improving logistics processes, and creating user communities that benefit from network effects [15]. Altogether, these features make digital markets highly efficient and dynamic environments, capable of adapting to the new demands of globalized trade and fostering innovation in business models.

1.5. Emerging Markets

Emerging markets constitute a group of economies that are in a transition phase toward development, characterized by sustained growth in their productive capacity, although they still face challenges related to institutional and financial stability [16]. These countries, which have not yet reached the levels of fully developed economies, show clear signs of modernization in key sectors such as industry, services, and infrastructure. This progressive transformation makes them relevant players within the global economic scene. Despite the uncertainties they may present, factors such as a young population, increased purchasing power, and the expansion of middle classes create attractive conditions for foreign investment [17]. Consequently, emerging markets are generating increasing interest among international investors seeking new opportunities for profitability in regions with high growth potential. Moreover, their dynamism contributes to the reconfiguration of global economic relations, positioning them as key players in the economy of the future.

1.6. Smart Contracts

Smart contracts have emerged as a key innovation in the digital realm, allowing for the automation and streamlining of agreements between parties through the programming of predefined conditions. According to Valencia Ramírez [18], these contracts are computer programs that, by relying on the automatic execution of the established conditions, eliminate the need for intermediaries, thereby reducing costs and increasing efficiency in the execution of agreements. On the other hand, Ballabriga Solanas [19] emphasizes that smart contracts are structured as code-based writings, enabling not only the automation of contractual relationships but also their integration with systems that interpret and respond to specific situations, assigning appropriate legal consequences autonomously.

Moreover, procedural smart contracts manage the security and accessibility of data flows and can also administer voting and execute the fulfillment of a selected proposal [20]. This multifunctional capacity is complemented by the guarantee that data are stored securely and accessible only to

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authorized parties [21]. Together, these features position smart contracts as a revolutionary tool across industries, transforming contractual obligation management into a transparent and efficient process.

1.7. Technology Adoption

Technology adoption is a multifaceted process influenced by perceived usefulness, ease of use, and user intent [22]. These user-centric factors determine whether technology is successfully integrated or rejected. In organizational contexts, technology adoption must balance economic efficiency with workplace well-being. Frameworks like the Technology Impact Model (TIM) evaluate how innovations affect productivity, labor dynamics, and job design [23]. Such holistic approaches ensure that technological integration enhances both economic performance and employee welfare.

1.8. Smart SMEs

"Smart SMEs" (Small and Medium-sized Enterprises) are defined as those enterprises that effectively adapt to constant economic and technological changes through efficient knowledge management and the implementation of innovative processes [24]. These enterprises are characterized by their adaptability and focus on continuous learning, enabling them to remain competitive in an ever-evolving market.

In this context, artificial intelligence (AI) plays a crucial role by providing solutions that optimize daily tasks and operational processes without requiring substantial capital investments. According to Bravo [25], the adoption of technologies such as AI can serve as a strategic tool for SMEs, allowing them to enhance efficiency and productivity while gaining a significant competitive advantage without major financial investments. Thus, AI not only drives innovation in these enterprises but also enables them to address challenges that previously may have seemed unattainable.

New technologies like blockchain continue to change how businesses operate online. This study examines blockchain from various perspectives, including the economy, market, and business sectors, to identify where it is applied and the challenges that arise when companies attempt to implement it. Using technology watch methods, it highlights key areas of blockchain usage and the primary issues faced by businesses.

At the same time, the research examines how blockchain can change how companies operate and create new opportunities for various business ideas. This study demonstrates how blockchain, like other new technologies, can alter traditional methods of trading and collaboration among companies, providing businesses with a simpler and clearer way to manage digital tasks.

2. Methodology

This study employed the technology watch method proposed by Rodríguez [26], which follows a structured three-stage approach: formulation and observation, analysis, and utilization. This method has been previously applied in creative and cultural industries' contexts, demonstrating its effectiveness for finding technological opportunities and supporting informed strategic decision-making. For the present research, the method will be applied through the analysis stage.

2.1. Formulation and Observation

2.1.1. Need Identification

This study focuses on analyzing the impact of blockchain investment as a driver of corporate digital transformation. The primary objective is to understand how this technology is reshaping organizational paradigms, creating new business models, and optimizing operational processes. Specifically, it seeks to identify adoption patterns, relevant success cases, and persistent challenges that could inform effective implementation strategies across various industrial contexts. To guide the research, the following key questions were established:

- How has the international landscape of blockchain technology evolved in recent years?

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- What are the main application areas for blockchain technology today?
- How is blockchain technology being integrated with artificial intelligence across different applications?
- In which economic sectors is blockchain technology most frequently adopted?
- What is the current level of blockchain adoption in the business sector?
- How does blockchain adoption vary across different industries and global regions?
- What are the main barriers limiting wider adoption of blockchain technology?
- How have investment patterns in blockchain-based projects evolved?
- What impact is blockchain technology having on smart SMEs?
- In what ways is blockchain transforming current digital markets?
- How has the global growth and adoption of blockchain technology progressed in recent years?

2.1.2. Identification of Restrictions

The research was conducted within clearly defined parameters to ensure feasibility and focus. Temporally, the analysis was limited to documents published between 2017 and 2025, a period that captures technology's recent evolution. Geographically, the study prioritized experiences from four strategic regions: Latin America, North America, Asia, and Europe, selected for their diversity in adoption levels. Linguistically, only Spanish and English sources were considered to ensure a comprehensive understanding of the content. Additionally, accessibility criteria were established, favoring open-access documents or those available through institutional subscriptions.

2.1.3. Selection of Information Sources

The data collection process employed a multi-layered strategy combining primary and secondary sources. Indexed scientific databases such as Scopus and Web of Science were prioritized for their academic rigor, supplemented by Google Scholar to capture emerging research. The documentary corpus was enriched with technical reports from specialized consulting firms (Deloitte, Gartner), corporate white papers, and case studies published by industry leaders in blockchain implementations. For the analysis of the business ecosystem, specialized press reports and recognized technology portals were included, with consistent verification of their alignment with the research objectives.

2.1.4. Formulation of Search Equations

The search strategy was implemented through a carefully designed Boolean equation system to ensure precise and relevant results. Basic combinations of AND, OR, and NOT operators were employed to connect the research's key concepts. For instance, equations such as ("blockchain" OR "distributed ledger") AND ("digital business" OR "emerging markets") were used to capture the study's central focus. For specific sectoral approaches, additional terms like "supply chain," "financial services," or "healthcare applications" were incorporated.

The initial search yielded over 550 potential results across various academic databases and specialized sources. This volume was systematically reduced through a four-phase selection process: first, duplicates were removed; then titles and abstracts were evaluated; subsequently, thematic relevance was verified; and finally, methodological quality was examined. This rigorous filtering process identified the 69 most pertinent references for the research, selected based on their timeliness, academic rigor, practical applicability, and geographic representativeness. Each step of the search and selection process was meticulously documented to ensure methodological transparency.

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2.2. Analysis

2.2.1. Information Validation

The validation process considered both the relevance and reliability of information sources. The selected sources were categorized by type: scientific articles, corporate reports, technical documents from specialized consulting firms, official announcements, expert news articles, and academic studies, including undergraduate and postgraduate theses.

For scientific articles, preference was given to those published in recognized journals indexed in major databases such as Scopus and Web of Science, as well as reputable academic platforms including RedALyC, SciELO, Latindex, Dialnet, DOAJ, EBSCO, ProQuest, and Google Scholar. This ensured the selected studies possessed robust methodological foundations and verifiable data.

Corporate and consultancy reports (e.g., Deloitte, Gartner) were included for their practical orientation and analysis of real-world technology implementation cases. News articles and official statements were likewise considered, provided they originated from credible sources in technological, institutional, or economic domains and offered current, verifiable information.

Academic works underwent a thorough review to confirm their provenance and methodological quality. Priority was given to studies with clearly defined objectives, well-grounded methods, appropriate samples, and properly substantiated conclusions, while excluding those failing to meet these fundamental requirements.

A cross-verification process was systematically applied, contrasting key data points across multiple independent sources. This implemented the principle of triangulation to enhance findings' reliability and minimize interpretive biases. Furthermore, the temporal inclusion criterion restricted sources to the 2017-2025 period, capturing the most recent trends, technological advancements, and emerging blockchain applications across economic sectors.

This methodological approach facilitated the construction of a balanced documentary corpus integrating scientific, technical, institutional, and applied evidence. Consequently, the analysis results reflect both the state of the art and real-world technology implementation practices.

Table 1.
Inclusion and Exclusion Criteria for Source Selection in the Sectoral Analysis of Blockchain Applications.

Category	Inclusion Criteria	Exclusion Criteria
Relevance	Focus on specific sectoral applications (finance, logistics, healthcare)	Generic content on blockchain without concrete applications
Timeliness	Publications 2017-2025 (prioritizing 2022-2024)	Documents published before 2017
Source type	Indexed articles (Scopus/WoS)	Personal blogs
	Consultant reports (Deloitte, WEF)	Unattributed content
	Corporate case studies (IBM, Maersk)	Non-peer-reviewed platforms
Methodology	Studies with sample data	Conceptual papers without empirical data
	Quantitative analyses	
	Validated case studies	
Objectivity	Sources with verifiable data (metrics, ROI, KPIs)	Promotional material
		Startup white papers without substantiation
Accessibility	Open access	Paywalled content without institutional access
	Institutional subscriptions	
Coverage	Balanced representation:	Exclusively local case studies without a comparative perspective
	Global studies (40%)	
	Regional analyses (60%)	

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2.2.2. Information Analysis

Table 2.
Distribution of Documentary Sources by Type and Platform Used in the Blockchain Analysis

Source type	Google Scholar	Scopus	Web of Science	Corporate Websites	Media/Press	Others	Total
Scientific articles	18	9	3	0	0	0	30
Business reports	2	0	0	5	3	0	10
Official announcements	0	0	0	12	0	0	12
Specialized news	0	0	0	4	7	0	11
Academic works	4	1	0	0	0	1	6
TOTAL	24	10	3	21	10	1	69

The examination of the 69 selected sources enabled the structuring of results into eleven principal categories, which will be thoroughly developed in the study's results section. These thematic axes, derived from the systematic document review process, are:

1. Blockchain in the international context
2. Primary implementation areas of blockchain
3. Integration of blockchain technology with artificial intelligence
4. Economic sectors with the highest utilization
5. Current level of corporate adoption
6. Industry-specific and regional adoption patterns
7. Barriers to adoption
8. Investment trends and dynamics
9. Impact on Smart SMEs
10. Transformation of digital markets
11. The growth and adoption of blockchain technology

Each of these themes will subsequently be examined in depth, presenting concrete evidence drawn from the analyzed sources, supported by relevant quantitative data, and illustrated through specific case studies that demonstrate the identified trends. This structured categorization not only facilitates an organized analysis of technological advancements but also enables a comprehensive evaluation of persisting challenges in blockchain adoption worldwide. Furthermore, by systematically addressing these eleven thematic areas, the study provides a holistic perspective on both current implementations and future potential, while maintaining methodological consistency throughout the comparative assessment of different sectors and regions. The framework thereby offers valuable insights into the multifaceted nature of blockchain integration across global business environments.

3. Results

Following the application of the previously described method, the results demonstrate how blockchain technology has been incorporated across various business sectors, extending beyond its initial exclusive use in the financial domain. The findings reveal significant benefits, including enhanced traceability, improved operational efficiency, and reduced reliance on intermediaries. Concurrently, the study identifies critical barriers related to technological infrastructure, implementation costs, and the absence of clear regulatory frameworks. Furthermore, the findings underscore the impact of blockchain on small and medium-sized enterprises (SMEs), as well as its transformative role in digital markets, both in developed economies and emerging markets.

3.1. Blockchain in the International Context

Blockchain technology has emerged as a disruptive innovation with a global impact, transforming key sectors including finance, logistics, governance, and data protection. Its inherent capacity to ensure

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transparency, security, and decentralization has garnered significant attention from governments, corporations, and international organizations alike. From cryptocurrencies to smart contracts and supply chain traceability, blockchain is fundamentally redefining global paradigms for transaction processing and record management.

3.1.1. Latin America

Table 3.
Blockchain application cases in Latin America.

Country	Sector	Application
Brazil	Politics and transparency	Brazil has yet to establish specific cryptocurrency regulations but is progressing with a bill to classify them as payment instruments. Notably, blockchain technology has been employed in political campaigns to enhance transparency and combat financial corruption [27].
Chile	Government	Chile has not enacted cryptocurrency legislation but is developing a flexible regulatory framework. The country actively promotes blockchain applications in healthcare and finance, while its Ministry of Energy utilizes Ethereum to securely record energy sector data [27].
Colombia	Healthcare	In Colombia, blockchain is being implemented in public contracting and finance, though adoption remains limited. Early adopters, such as Clínica Las Américas and the Port of Buenaventura, leverage the technology to streamline operations and improve transparency [28].

3.1.2. North America

Table 4.
Blockchain application cases in North America.

Country	Sector	Application
Mexico	Financial	Mexico enacted the Fintech Law in 2018 to regulate cryptocurrencies and crowdfunding, strengthening financial stability. As Latin America's second-largest fintech startup hub, Mexico has developed a robust market, exemplified by Bitso, a cryptocurrency exchange with over 500,000 users [27].
USA	Government	Blockchain technology holds transformative potential for U.S. government systems by enhancing transparency, efficiency, and public trust. While challenges like scalability and regulation persist, responsible adoption promises more secure, participatory, and efficient governance [29].
		Blockchain is revolutionizing U.S. governance through improved security, efficiency, and transparency in identity management, voting systems, and public finance. Despite persistent challenges regarding scalability and regulation, public-private partnerships are driving adoption. Maintaining an optimal balance between transparency and privacy remains crucial for developing reliable governance frameworks.
Canada	Logistics	Blockchain implementation in supply chains enhances efficiency by reducing delays, optimizing inventory management, and automating processes. Industry leaders like Walmart Canada have adopted this technology for real-time logistics data management, achieving significant cost reductions and improved traceability [30].

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3.1.3. Asia

Table 5.
Blockchain application cases in Asia.

Country	Sector	Application
China	Logistics	China leads the adoption of blockchain in the food industry, ensuring product traceability and origin. Since 2016, its regulations have restricted foreign access, strengthening digital sovereignty and optimizing logistics through smart port technology [31].
	Food industry	Blockchain technology enhances supply chain traceability, preventing counterfeiting and ensuring transparency. However, it faces challenges in scalability, performance, and data governance. Its adoption requires accessible IoT solutions and efficient design to maximize impact [32].
Japan	Energy	In Japan, economic challenges in blockchain adoption for the energy sector include reliance on subsidies, market competition, and contractual interoperability. While peer-to-peer (P2P) electricity trading via blockchain offers efficiency and decentralization, its scalability depends on integrating these models with traditional wholesale markets and promoting investment in renewable energy [33].
	Financial	Japan was the first country to recognize Bitcoin as a legal payment method and established a national system to regulate cryptocurrency exchanges. The Financial Services Agency oversees operators, promoting security and the development of blockchain projects [34].
South Korea	Government	South Korea leads in blockchain adoption within government services, voting, and administration. Seoul is developing the ICON project, while the Korea Internet & Security Agency (KISA) is testing KISA Coin for identification and rewards. Additionally, the National Tax Service is assessing cryptocurrency taxation [35].
	Financial	Blockchain technology enhances reliability in banking services, including deposits, loans, and currency exchange. It also optimizes international remittances and trade management, reducing costs and processing times. Ripple (XRP) exemplifies its impact by enabling real-time settlements and efficient cross-border transactions [36].
Singapore	Technology and financial	Singapore promotes blockchain through Project Ubin for payments and securities. The Monetary Authority of Singapore (MAS) and IBM established the Blockchain Innovation Centre, while the Infocomm Media Development Authority (IMDA) developed TradeTrust and organizes hackathons. Ngee Ann Polytechnic uses blockchain for diploma verification, and the Customs Authority modernizes trade with the Networked Trade Platform (NTP), improving efficiency [35].
	Energy	Blockchain technology optimizes energy management in residential and industrial sectors. Studies in Singapore and Brooklyn confirm its effectiveness in P2P transactions and renewable energy. Projects like Blockzoom and Ethereum-based testbeds enhance communication between virtual power plants, ensuring decentralized, secure, and efficient energy transactions [37].

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3.1.4. Europe

Table 6.
Blockchain application cases in Europe.

Continent	Sector	Application
Europe	Government	Electronic voting, supported by technologies such as blockchain, offers a secure and transparent pathway to strengthen participatory democracy. It would enable voting from anywhere while ensuring the uniqueness and confidentiality of ballots through reliable algorithms [38].
	Government	Public procurement can benefit from blockchain by guaranteeing full transparency in expenditures and ensuring the integrity of documents submitted in tenders, preventing unauthorized modifications [38].
	Government	Blockchain-based solutions have been implemented for managing the digital identities of migrants. A notable example is the use of iris scanners in refugee camps in Jordan to facilitate aid payments and distribution [39].
	Real estate	The implementation of smart property in real estate requires the use of blockchain and transferable smart contracts, necessitating significant legal reforms. These include adapting the Land Registry and automating legal processes [40].
	Financial	In 2020, the IDB (Inter-American Development Bank) developed a blockchain-based pilot for cross-border payments, demonstrating greater transparency, traceability, and efficiency compared to SWIFT. This solution facilitates remittances, conditional transfers, financial inclusion, and international trade [41].

3.2. Principal Areas of Blockchain Implementation

Although initially associated with cryptocurrencies, blockchain technology has found significantly broader applications. Today, companies across various sectors are implementing it to enhance processes such as quality control, data management, and product tracking. As noted by Morocho et al. [42], this technology has enabled organizations to automate key tasks, optimize resources, and gain competitive advantages.

A prominent case is Walmart, which integrated a blockchain to ensure food traceability. In collaboration with IBM, the company developed a Hyperledger Fabric-based solution that tracks fresh produce such as mangoes and lettuce from farm to supermarket shelves. This system reduced the time required to trace product origins from seven days to just 2.2 seconds, significantly improving food safety [43, 44].

In the shipping industry, Maersk partnered with IBM to launch TradeLens, a platform that digitized maritime shipping documents and processes. Although the project was discontinued in 2022 due to limited industry participation, it demonstrated how blockchain could streamline procedures, reduce errors, and facilitate information exchange among logistics chain participants [45, 46].

Another noteworthy implementation is De Beers' Tracr platform, a blockchain solution for diamond provenance verification. This system tracks each stone from extraction to sale, helping combat illegal trade while providing consumers with greater transparency [47].

These cases demonstrate that blockchain applications in business extend beyond theoretical discourse, with concrete implementations transforming processes across diverse industries. Technology's ability to enhance traceability, efficiency, and transparency continues to drive its adoption in various sectors.

3.3. Integration of Blockchain Technology with Artificial Intelligence

The convergence between blockchain and artificial intelligence (AI) is revolutionizing multiple sectors by enhancing security, operational efficiency, and decision-making processes. This evolving technological integration represents a field with significant potential to transform various industries.

The intersection of blockchain and AI demonstrates a promising synergy. Blockchain provides a secure, transparent, and decentralized environment for managing large datasets, while AI optimizes processes such as fraud detection, transaction management, and decision-making through pattern recognition in data analysis [48]. AI significantly contributes to improving blockchain network

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performance by enhancing consensus mechanisms, smart contract execution, and data privacy protection [49]. In healthcare, this synergy enables more precise and effective clinical data management, with notable applications in cardiovascular medicine [50].

In the energy sector, the combination of both technologies facilitates cryptocurrency-based automated payments, decentralized data exchange, and the adoption of smarter decision-making systems [51]. Within business environments, these tools are transforming supply chains, financial services, healthcare, and secure transactions, enabling the emergence of innovative digital business models [52].

Despite this integration's considerable potential, challenges persist regarding scalability, interoperability, and regulatory frameworks. Nevertheless, the joint advancement of these technologies fosters innovation and the development of more secure and efficient digital ecosystems. Blockchain's decentralized and immutable ledger ensures data integrity, while advanced AI algorithms enable in-depth analysis and enhanced predictive capabilities [53]. This combination is already being applied in cybersecurity, healthcare, finance, supply chain management, and social network analysis [54].

For autonomous vehicles, blockchain enables secure data exchange among connected vehicles, facilitating collective and accelerated learning [55]. Similarly, blockchain can strengthen AI by improving data quality, increasing algorithm transparency, and optimizing computational resource allocation [56]. However, this integration faces technical challenges, regulatory obstacles, and privacy concerns [53].

Examples such as Constitutional AI and ChainLink demonstrate how combining AI and blockchain facilitates model auditing and ensures traceability through immutable records [57]. Furthermore, this fusion enables decentralized cooperation among AI models and secure access to external data, thereby improving system scalability, trust, and efficiency.

Within Industry 4.0, this technological alliance promotes more agile and reliable decentralized decision-making, minimizing dependence on central authorities through smart contracts and autonomous algorithms [58]. While AI processes data to generate decisions, blockchain ensures system integrity and transparency, thereby enhancing trust and efficiency in decentralized environments [58].

Although blockchain technology facilitates business process digitization, automation, and transparency through features such as persistence, validity, and disintermediation, its adoption remains in the early stages [48].

3.4. Economic Sectors with the Highest Adoption Rates

Blockchain technology represents a transformative innovation that enables digital value transmission without intermediaries through a decentralized network, revolutionizing transaction methods [59]. In the financial sector, a report by Partz [60] reveals that 81% of executives consider this technology to have reached widespread adoption and scalability within their respective industries.

A concrete example of this application is found in the Italian banking sector, where the Interbank Spunta project has demonstrated improvements in data visibility and interbank transaction speed through blockchain implementation [61]. Similarly, Maestre's [62] study shows how IEBS Business School gained a competitive advantage by utilizing blockchain combined with an Initial Coin Offering (ICO) funding strategy.

In accounting and taxation, Uno and Sánchez [63] argue that this technology not only enhances transparency in tax allocation and promotes more reliable payment practices but also automates accounting and auditing tasks, thereby challenging traditional methodologies.

The healthcare sector has also experienced a significant transformation. Govindarajan et al. [64] highlight how blockchain has improved the protection, privacy, and integrity of medical information, enabling patients to share their data securely and selectively. In Estonia, over one million health records have been secured through blockchain, establishing this technology as an innovative and disruptive tool in public health management [65]. Despite these advancements, challenges remain; as Velmovitsky et al. [66] note, while promising, the technology still faces limitations that should not be underestimated.

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The logistics sector has similarly witnessed a substantial impact. Park's [67] study indicates that blockchain has enhanced efficiency, competitiveness, and traceability in supply chains, providing companies with improved real-time process control and reduced operational errors. Complementarily, Campos et al. [68] explain that this technology enables product tracking from origin to end consumer through integration with IoT and smart contracts. A noteworthy case is that of the company Trapex, which, facing challenges in its supply chain, opted to implement blockchain-based solutions to improve transparency, traceability, and efficiency [69].

Collectively, these findings demonstrate blockchain's significant transformative potential in strategic sectors, including finance, healthcare, and logistics. Its application has strengthened key aspects such as transparency, data management, traceability, and operational efficiency. While technical, regulatory, and cultural challenges persist, evidence suggests growing adoption is driving more resilient, collaborative, and innovative business models. This process represents not merely technological evolution but a fundamental transformation in how organizations interact with their environment and manage resources.

3.5. Enterprise Adoption Levels

In the last decade, blockchain has evolved from a buzzword to a tangible tool that many companies are beginning to use seriously. Although not all have fully integrated it, data indicate that adoption is growing at a steady pace.

Recent research by asperLabs [70] reveals that approximately 90% of businesses in the United States, the United Kingdom, and China have already initiated blockchain-based solutions. This demonstrates that beyond initial enthusiasm, organizations are identifying practical applications for this technology, despite ongoing challenges such as system interoperability issues and internal technical knowledge gaps.

Similar findings emerge from Deloitte [71] global survey of over 1,000 business leaders regarding their perceptions of blockchain and digital assets. Key results indicate that 81% of respondents believe blockchain has achieved mainstream adoption, while 78% report their executive teams recognize its clear strategic value. Notably, these figures rise significantly among financial sector pioneers, reaching as high as 97% in some cases.

These trends are clearly illustrated in the following chart extracted from the report:

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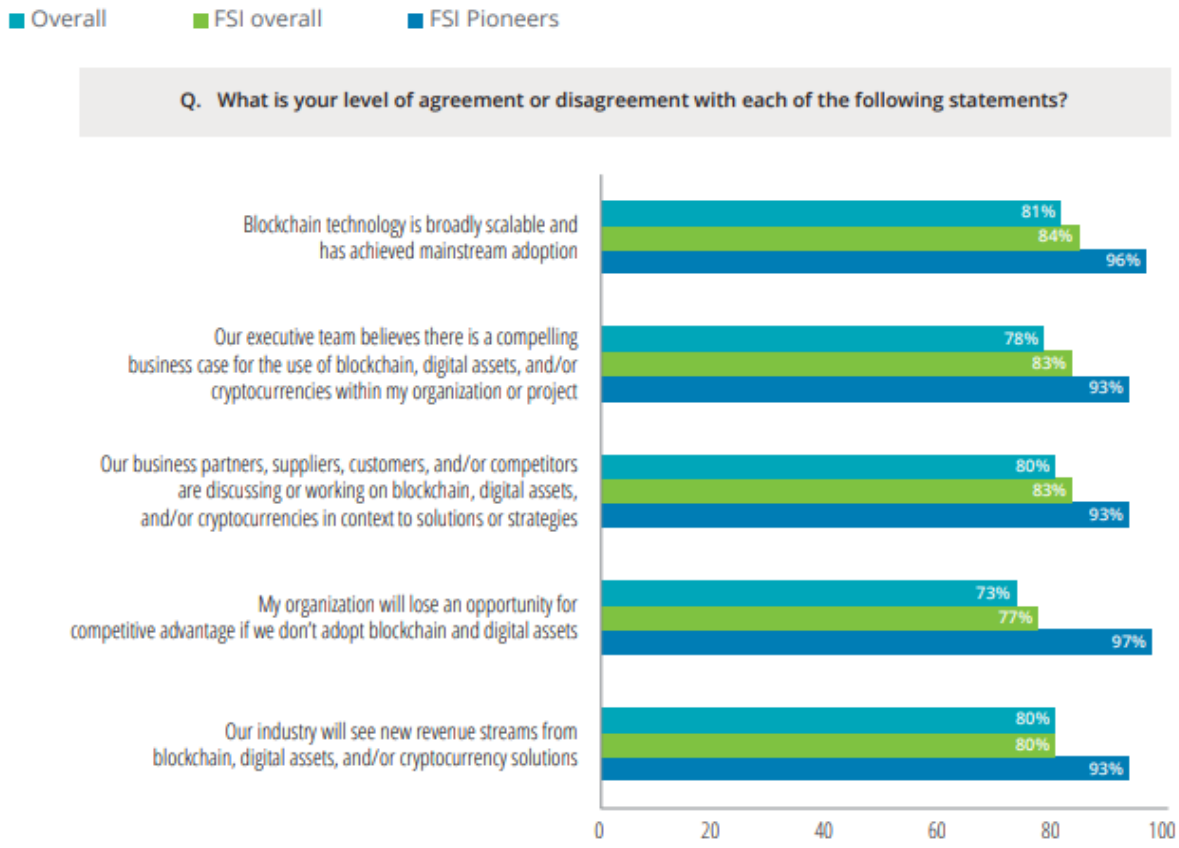

Figure 1.
Business insights on blockchain, digital assets, and cryptocurrency.
Note. Deloitte [71].

The World Economic Forum [72] offers a significant projection, estimating that by 2027 approximately 10% of global GDP could be stored and tokenized on blockchain networks, which would fundamentally transform how value is stored and transferred worldwide. This forecast underscores blockchain's growing importance in the global economy. When examining current adoption trends alongside these projections, it becomes clear that enterprise blockchain implementation is not merely a passing trend but rather an enduring technological shift. The sustained growth in adoption is driven by blockchain's demonstrated capacity to enhance operational efficiency, create innovative revenue opportunities, and maintain competitive advantage in progressively digitalized business environments, as organizations continue to recognize and harness its transformative potential across various sectors.

3.6. Adoption in Industries and Regions

In recent years, blockchain adoption has demonstrated significant growth across various sectors in South America. A recent analysis reveals a 30% increase in blockchain applications within the agribusiness sector between 2018 and 2023, highlighting how emerging economies are leveraging this technology's potential to enhance operational efficiency, ensure process transparency, and access key services in strategic industries such as agribusiness [73].

Regarding cryptocurrency adoption, Latin America has experienced substantial growth. Countries including Colombia, Peru, Chile, Mexico, and Brazil exhibit cryptocurrency usage rates ranging from 45% to 11%, reflecting structural changes in international trade dynamics and demonstrating the

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momentum toward digitalization in emerging economies [74]. This integration into the Fintech ecosystem is fundamentally transforming the foundations of commerce and investment.

A notable example of blockchain implementation in specific industries can be observed in Mexico's Campeche region, where this technology is being employed to optimize supply chain management on oil platforms. Through its capacity to ensure data immutability, blockchain is reducing operational demands while improving information quality [75]. Furthermore, technology has been successfully integrated across diverse sectors, including agriculture, education, finance, and logistics, owing to its inherent transparency and traceability features [76].

Within the agricultural sector, blockchain has demonstrated both adaptability and practical utility. Agros, a Colombian company, has utilized this technology to create digital identities for small-scale farmers, enabling them to access services and improve digital inclusion. Similarly, Agrotoken has employed smart contracts to tokenize agricultural products, providing liquidity and secure financing for producers in Argentina, Brazil, Uruguay, and Paraguay [77].

These cases illustrate blockchain's transformative potential for key productive sectors in emerging markets. While Agros focuses on digitalization and technical assistance, Agrotoken facilitates access to financing through tokenized assets. Both examples demonstrate the technology's flexibility and the opportunities it presents for regional industries, showcasing how blockchain applications can address diverse challenges while promoting economic development in South America.

3.7. Barriers to Adoption

Although blockchain technology has generated high expectations due to its advantages, its adoption by companies has not been as fast as expected. One of the main reasons is that implementation entails a considerable cost, and many small or medium-sized companies do not have the necessary budget to do so [78, 79].

Another significant issue is the lack of trained personnel in this area. Companies must invest not only in technology but also in staff training, which can be challenging [42].

On the other hand, there is some resistance within organizations. When people do not fully understand the benefits of the technology or perceive that it will involve significant change, it is natural for them to prefer to continue with their current practices [80]. Furthermore, in some cases, they do not even know how to integrate blockchain into their daily work.

Sometimes, the systems they already have installed are not compatible or do not allow for the incorporation of these types of innovations. There are also doubts about whether blockchain is truly sustainable or if it could generate environmental problems, which is a concern for many companies aiming to be environmentally responsible [81].

The lack of clear laws regarding the use of blockchain also generates uncertainty. Many companies prefer to wait before making such a significant investment if they do not have the necessary legal certainty [82].

Despite these obstacles, blockchain is perceived as having the potential to become an essential part of business in the future. Over time, with proper education and preparation, it is likely that more companies will adopt the technology, overcoming the barriers that currently limit its implementation.

3.8. Investment Dynamics

In recent years, there has been significant growth in investment directed toward blockchain-based technologies. This trend extends beyond sector-specific startups to encompass venture capital funds, government entities, and traditional financial market players. A prominent example is Andreessen Horowitz (a16z), which allocated $4.5 billion in 2022 to a dedicated crypto and blockchain fund [83] reflecting institutional investors' confidence in the technology's disruptive potential.

Latin America has actively participated in this movement. Companies such as Rappi have secured investments approaching $1 billion, with participation from major players like SoftBank. According to the Latin American Private Capital Association [84], while not all these projects focus exclusively on

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blockchain, many incorporate it as a strategic component, demonstrating that technological innovation has become a priority for addressing regional challenges.

Blockchain's impact transcends financial applications. In agriculture, initiatives like Agrotoken enable small-scale producers to utilize commodity-backed tokens (soy, corn) to access credit, thereby mitigating structural barriers [85]. Such developments confirm the technology's capacity to generate tangible solutions for longstanding social issues.

Governments are also driving adoption through strategic investments. South Korea, for instance, committed $14.5 million to blockchain initiatives to reinforce its technological leadership [86]. Similarly, Singapore partnered with banking institutions like DBS Bank [87] to pilot blockchain applications for government subsidies, enhancing transparency in public resource allocation.

This investment landscape reveals a multisectoral consensus regarding blockchain's potential to drive structural transformation. Technology's evolution from a cryptocurrency niche to a cross-sector enabler of efficiency and inclusion marks its maturation as a general-purpose technology with transformative socioeconomic implications.

3.9. Impact on Smart SMEs

In developing countries, the adoption of Industry 4.0 technologies by small and medium-sized enterprises (SMEs) represents a strategic opportunity to overcome persistent challenges such as low productivity and limited access to global markets. Technologies including IoT, big data, artificial intelligence, and blockchain facilitate digital transformation, process optimization, and service improvement [88]. A notable case is a waste management company in Montalbo (Cuenca), which implemented a blockchain-based solution to enhance traceability in its treatment plant through a private network that securely and efficiently tracks waste materials [89].

However, while demand for and access to these technologies has grown in recent years, their mere implementation does not guarantee market success. Adopting Industry 4.0 tools requires a fundamental restructuring of organizational processes how companies create, deliver, and capture value as perceived by consumers. Consequently, workforce training and fostering a culture oriented toward change and experimentation are essential to ensure that SMEs not only survive but also thrive in an increasingly globalized economy.

3.10. Transformation of Digital Markets

Digital markets are undergoing an unprecedented metamorphosis due to blockchain technology, which is redefining traditional value-exchange paradigms. This transformation is particularly evident in three key domains:

3.10.1. E-Commerce Reconfiguration

The e-commerce landscape is being reshaped by the emergence of stable digital assets. In Brazil, Mercado Pago (part of the Mercado Libre conglomerate) achieved a milestone in 2024 with the launch of "Meli Dólar," a solution combining cryptocurrency flexibility with the stability of the U.S. dollar. Financial analysts report that this innovation has reduced cross-border transaction costs for small merchants by up to 30% [90].

3.10.2. New Labor Paradigms

The freelance sector is experiencing a revolution in compensation models. Platforms like Braintrust lead this shift by offering payments in USDC, an alternative particularly valuable in high-inflation economies. Recent data indicate that over 60% of independent contractors in Argentina and Venezuela prefer receiving at least partial payment in this format [91].

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3.10.3. Reinvention of the Art Market

The digital art market continues to evolve through NFTs, albeit with notable adjustments. While speculative prices corrected in 2024, legitimate transactions between artists and collectors increased by 40% compared to the previous year. Blockchain has enabled innovative smart royalty models, ensuring automatic compensation for creators in secondary sales [92].

This digital transformation extends beyond technology, representing a cultural shift in the conception of value and ownership. Regulatory challenges remain significant, particularly concerning consumer protection and financial stability. Nevertheless, cases like Brazil's Meli Dólar demonstrate that innovative balances between regulation and technological progress are achievable.

3.11. Growth and Global Adoption of Blockchain Technology

The global blockchain technology market has experienced exponential growth in recent years and is expected to maintain this upward trend. In 2024, the market was valued at USD 27.85 billion and is projected to reach USD 746.41 billion by 2032, reflecting a compound annual growth rate (CAGR) of 49.7% during the forecast period [93].

As illustrated in Figure 2 of the report, key contributions to market growth are demonstrated through relevant numerical data. The graph highlights sustained increases in technological investment and the diversification of blockchain applications across critical sectors, providing precise figures on annual investments and the progression of adoption in areas such as financial services, logistics, and telecommunications.

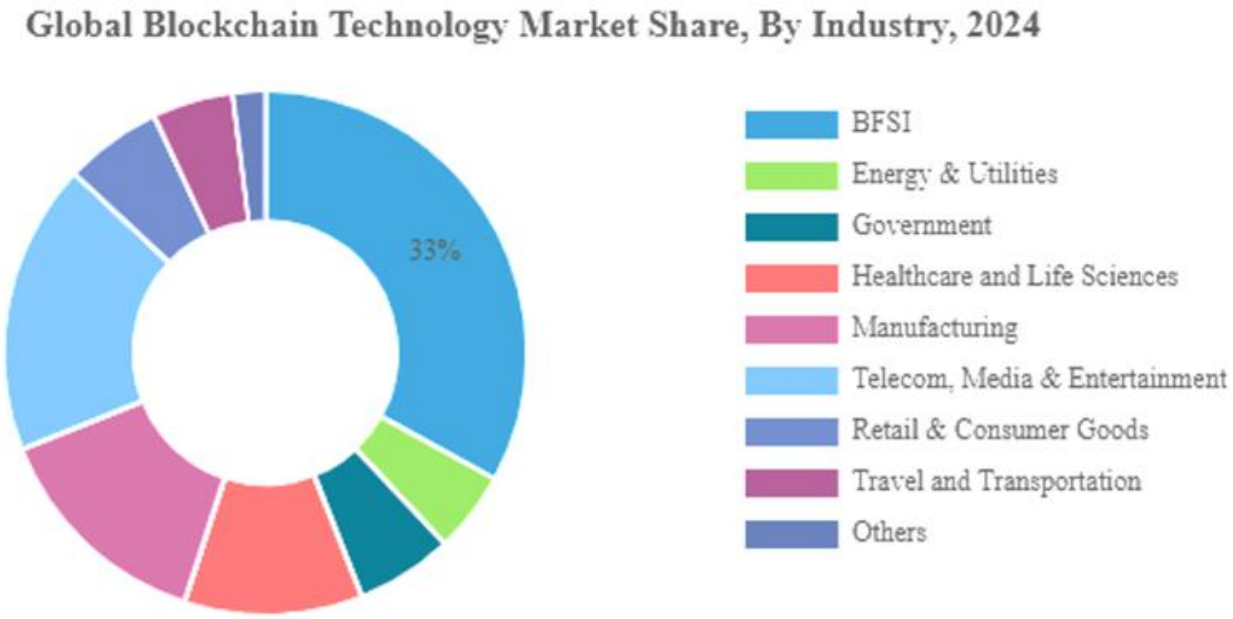

Figure 2.
Global Blockchain Technology Market Share, By Industry, 2024.
Note. Taken from Fortune Business Insights [93].

An analysis of these figures reveals that market dynamism is primarily fueled by strategic investments in digital infrastructure. The disparities in adoption rates across industries demonstrate that while blockchain technology provides universal advantages such as enhanced security and transparency, its effective implementation necessitates customized solutions adapted to each sector's unique requirements. The BFSI (Banking, Financial Services, and Insurance) sector currently dominates with a 33% market share in 2024, followed by telecommunications, media, and entertainment at

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approximately 16%, and manufacturing at around 14%. Conversely, industries like travel and transportation or retail and consumer goods exhibit significantly lower adoption rates, each accounting for less than 6% of market penetration. This divergence highlights the critical need for tailored blockchain integration strategies to optimize operational efficiency and address industry-specific challenges.

Current projections by Carter [94] indicate substantial market expansion, with the global blockchain sector expected to attain a valuation of USD 1,431.54 billion by 2030, reflecting an impressive 85.9% compound annual growth rate (CAGR) between 2022 and 2030. This growth trajectory suggests a potentially transformative economic impact, potentially contributing USD 1.76 trillion to global GDP by 2030. Technology's adoption has gained momentum in financial services, where 96% of experts acknowledge its widespread implementation, while the manufacturing sector anticipates a 73% adoption growth rate from 2023 to 2026.

The global blockchain market is experiencing remarkable growth, driven by strong investment in digital infrastructure and growing adoption across various sectors. Although some industries lead the implementation of this technology, such as the BFSI sector, adoption remains varied, highlighting the need for specific solutions tailored to the needs of each sector. With projections indicating a significant impact on the global economy, blockchain continues to consolidate as a key tool for digital transformation and operational efficiency improvement across a wide range of industries. In other sectors, such as tourism, it has also been demonstrated how structural changes driven by technological innovation impact the labor market and encourage evolution toward more equitable models [95].

4. Conclusion

Blockchain technology has proven to be a global force, with economic growth and adoption surpassing initial projections. As seen in the results, the global blockchain market could reach 1,431.54 billion dollars by 2030, with a compound annual growth rate of 85.9% between 2022 and 2030. This advancement not only reflects its expansion in the technology sector but also its ability to drive the global GDP by 1.76 trillion dollars by the same date, according to the data analyzed.

Regarding adoption, the results demonstrate that 96% of financial services experts consider blockchain to have achieved widespread implementation. This figure confirms its consolidation in areas such as secure transactions, smart contracts, and asset tokenization. Similarly, within the manufacturing sector, research indicates that blockchain adoption is growing at a rate of 73% between 2023 and 2026, particularly in supply chain optimization and product traceability.

Regionally, the analyzed cases reveal distinct patterns of advancement. In Latin America, countries such as Brazil, Chile, and Colombia are deploying blockchain in government transparency, healthcare, and agriculture, while in Asia, nations like China and South Korea lead in logistics and digital identity management. Conversely, in Europe and North America, its implementation in financial and governmental sectors reinforces its role as a critical tool for operational efficiency.

Nevertheless, significant challenges persist, as previously outlined. High implementation costs and the absence of clear regulatory frameworks in several countries remain substantial barriers, particularly for small and medium-sized enterprises (SMEs). Additionally, the shortage of specialized talent continues to hinder mass adoption, with only 35% of organizations reporting adequately trained personnel.

Within digital markets, the findings suggest that blockchain is reshaping industries such as e-commerce, freelance work, and digital art. Platforms like Mercado Pago and Braintrust, referenced in the study, have successfully reduced costs and enhanced transactional efficiency, demonstrating the technology's potential to revolutionize traditional economic models.

The data analyzed confirms that blockchain has transitioned from an emerging technology to a fundamental component of the digital economy. Its exponential growth, coupled with successful applications across diverse sectors, solidifies its current and future relevance. However, ensuring global scalability will require addressing persistent regulatory, financial, and educational barriers. As this

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research has demonstrated, blockchain's impact is undeniable, yet its continued evolution will depend on the adaptability of both enterprises and governments.

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Transparency:
The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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