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Analysis of the implementation of blockchain technologies in management to ensure transparency, efficiency and sustainability

Valentyn Bannikov[1*], Maryna Akuliushyna[2], Svitlana Breus[3], Snizhana Sukachova[4], Valeriy Tytarenko[5]
[1]Master's Degree, Project Manager, DataArt, New York, NY, USA
[2] Department of Management, National University "Odesa Polytechnic", Odesa, Ukraine
[3] Department of Management and Marketing, European University, Kyiv, Ukraine
[4] Department of Economics and Business, State Biotechnological University, Ukraine
[5] Department of Enterprise Economics and Information Technologies, Department of Business Economics and Information Technologies, Educational and Research Institute of Management, Administration and Information Technologies, Lviv University of Business and Law, Lviv, Ukraine

*Corresponding author E-mail: bannikov.valentyn@gmail.com

ABSTRACT

This paper addresses the critical issue of how blockchain technology can enhance the transparency, efficiency, and sustainability of management practices in a transitional economy like Ukraine. The focus is to systematically evaluate the impact of blockchain on this outcome by analyzing the roles of blockchain implementation, digital security, decentralization, and innovation in Ukraine from Q1 2008 to Q4 2023. All the variables are stationary at the first difference, as revealed by the unit root test of the Augmented Dickey-Fuller. The series cointegration is confirmed using the bound test of Augmented Dickey-Fuller. The study uses time series data and an Autoregressive Distributed Lag (ARDL) model. The long-run results indicate that decentralization and digital security are incredibly influential in enhancing efficiency and sustainability. Furthermore, ECMt−1 is negative and statistically significant, suggesting a long-term equilibrium adjustment. Such policy recommendations include a supportive regulatory framework, incentives for sector-specific blockchain applications, secure and transparent digital ecosystems, and utilizing blockchain to its full potential in various sectors.

Keywords: Business environment, Organizational competitiveness, Digital strategies, Management efficiency, Management systems.

1. Introduction

In recent years, the world has witnessed a significant technological transformation in the global economy, driven by advancements in digital technologies [1]. Blockchain, among these technologies, has become a disruptive force that offers a chance to reconfigure traditional management positions by granting transparency, decentralization, security, and innovation [2]. Blockchain was initially created as the backbone of cryptocurrencies but is now being leveraged by financial institutions and other industries, including supply chain management, public administration, healthcare, and corporate governance [3]. Most of these uses demonstrate blockchain's ability to reduce information asymmetry and establish trust between parties involved in the analysis [4], [5]. As countries seek technological advancements, Artificial Intelligence (AI) is a valuable partner in enhancing operational security and management efficiency, particularly in the legal and economic sectors. However, like with blockchain, the widespread use of AI raises numerous security concerns. However, artificial intelligence can help make things more efficient while exposing dangerous information and cybersecurity risks, especially in the context of unverified outputs that could be used in information warfare [6].

Schumpeter first introduced the concept that economic growth is primarily driven by innovations introduced by entrepreneurs, whom he referred to as 'change agents' in the economy [7]. Countries currently undergoing political, social, or economic transformation have found particular relevance for blockchain technology [8]. As

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a country with governance challenges, financial instability, and a deficit of public trust, Ukraine presents an ideal case for analyzing how blockchain technologies can be employed to help bolster management practices. In this case, blockchain can provide particular value by enhancing the accountability, transparency, and competitiveness of activities, particularly in the public sector and businesses involved in complex processes [9]. Furthermore, blockchain's decentralized nature makes resource utilization more sustainable by reducing redundant work [10].

On the one hand, we have blockchain's theoretical advantages; however, several empirical gaps exist regarding how blockchain would improve managerial outcomes in real-world scenarios across multiple industries and sectors [2], [9], [11], [12]. Blockchain continues to yield ongoing debate on how transparency, efficiency, and sustainability can be improved through blockchain, as well as which mechanisms are best suited for different managerial contexts [13]. In light of these concerns, a systematic review examining the role of blockchain in Ukrainian management is both overdue and timely. Although the theoretical advantages of blockchain in terms of transparency, efficiency, and sustainability within management systems have been well-documented, empirical evidence of blockchain implementation in countries such as Ukraine is scarce [14]. Information asymmetry, governance inefficiency, and innovation are key challenges for organizations and institutions in Ukraine, particularly in addressing sustainability challenges [15]. Despite this, the precise linkage between blockchain technologies and these outcomes has not been thoroughly examined, leaving managers and policymakers without clear indications regarding implementation [16].

Kuruppu et al. have investigated how blockchain technology may increase transparency and operational sustainability in NGOs [17]. In multiple case studies, they examined how blockchain reduced operational delays and minimized fraud by maintaining immutable records. The system, however, encountered compatibility and interoperability issues among blockchain platforms that prevented its wider adoption. However, the findings align with the concept that blockchain enhances transparency. Still, the study's limited focus on NGOs restricts its relevance to public administration in countries where governance challenges, such as those in Ukraine, abound.

Wang et al. explored public agencies in China to examine how blockchain reduces information asymmetry and thus increases public trust through structural equation modeling [18]. Benefits such as increased transparency and accountability were found to be achieved using blockchain-enabled systems. However, adoption was hindered by regulatory challenges, and the establishment of supportive governance frameworks was necessary. While this study contributes to the understanding of public sector improvements, it does not encompass transitional economies like Ukraine, where institutional instability may hinder blockchain implementation.

Siryk et al. performed a longitudinal study of logistics firms to evaluate the impact of blockchain on transparency and operational sustainability. Blockchain adoption considerably cut inefficiencies and increased the accuracy of reporting [19]. However, the study found that the high costs of implementation stymied smaller firms. This reflects Ukraine's resource constraints, which may hinder the adoption of blockchain across its sectors, underscoring the need for affordable solutions.

Yerram et al. analyzed the effects of blockchain-based security protocols in the financial sector and demonstrated how the best systems accelerate processes by reducing fraud [20]. A quantitative analysis of 200 financial institutions revealed that automation through blockchain technology strengthened operational outcomes. Nevertheless, these blockchain applications did not scale well in terms of scalability, a problem relevant to Ukrainian institutions operating on limited budgets and with inadequate infrastructure.

Satrio et al. investigated how hospitals utilize blockchain to manage patient data, demonstrating that blockchain can enhance cybersecurity in healthcare [21]. The study revealed that blockchain increases data security, reduces data breaches, and thus increases trust among stakeholders. The research, however, acknowledged that significant infrastructure investment was also required, a barrier that will likely hinder the adoption of blockchain in the public sectors of developing economies like Ukraine.

Nuttah et al. employed a mixed-methods approach to investigate the impact of blockchain security protocols on management efficiency across various industries [22]. Enhanced digital security lowered downtime and operational risks, they said. Technical latency was challenged, however. This study will provide valuable insights into Ukraine, where the use of a secure blockchain system could enhance management. Still, latency may be a concern for large-scale public sector implementation.

To better understand the effects of decentralization on resource management, Ahmad and Satrovic compared decentralized municipalities with their centralized counterparts [23]. The research results indicated that decentralized decision-making enhanced resource allocation and produced better sustainability outcomes. However, in Ukraine, with its ongoing infrastructural limitations, decentralized systems will require a robust digital strategy.

Mohit et al. studied the use of blockchain for supply chain traceability and tracing, showing that blockchain-based decentralization benefits supply chains by reducing waste through real-time decision-making [24]. Beyond the evidence of the benefits of decentralization in the study, the risks of over-fragmentation highlighted in the survey present potential problems with governance in public institutions in Ukraine, similar to those observed here.

Fernando et al. Econometric modeling was employed using blockchain to estimate the effect of decentralization on manufacturing energy efficiency. Their results indicated that decentralization reduces energy waste; however, managing decentralized systems remained complex [25]. This finding directly relates to Ukraine's search for sustainable governance, implying the need for clear protocols to govern decentralized processes.

Marchese and Tomarchio conducted a systematic literature review of blockchain-based supply chain management innovations, finding that traceability and automation were key outcomes [26]. The study cautioned, however, that uneven technological readiness across industries created adoption challenges—a concern that aligns with Ukraine's limited convergence in various areas of technology development.

Hamledari and Fischer studied the impact smart contracts have on boosting operational efficiency in IT firms [27]. Their survey revealed that smart contracts enabled automated compliance, reducing delays, but integration with legacy systems was a hurdle that has not been solved thus far. This work emphasizes the importance of considering integration issues when implementing blockchain in Ukraine's public administration.

Saad et al. demonstrated that blockchain-enabled tracking systems in municipal waste management reduce waste and improve sustainability metrics [28]. The study also cautioned, however, that such systems would need to be cranked up for larger cities and would consume significant resources. These insights are also relevant to Ukraine, where blockchain-driven sustainability initiatives may struggle in urban contexts.

Bondar et al. extracted data from 250 management professionals across various industries over recent years for a study that assessed the impact of digitization on management efficiency and strategic decision-making [29]. To evaluate the role of digitization in improving operational efficiency, this study employed traditional mathematical socio-economic methods, such as Marginal Cost Analysis, Break-Even Analysis, and linear programming, in combination with survey analysis. Digitization was claimed to have resulted in a 15% reduction in the breakeven point and a 20% improvement in resource allocation. Further survey results indicated average increases of 0.3 to 0.5 points on a 5-point scale in management adaptability, efficiency and decision-making. However, this study highlights that different sectors generate different impacts, which is a limitation as industry-specific digital strategies are necessary to reap efficiency gains. While regression analysis revealed that technological affinity is linked to better decision-making, the study did not account for the way decentralized computing, digital security, and blockchain technology collectively shape organizational efficiency and sustainability. Our study conveys this by integrating blockchain as an accelerator of management efficiency and sustainability in the context of governance in Ukraine.

While evidence of blockchain's role in enhancing transparency, efficiency, and sustainability is promising, there are still no studies that comprehensively explore blockchain's impact on management systems in transition economies. For instance, Ukraine, which is experiencing governance and economic challenges, would be a case study for blockchain's potential to enhance public trust and sustainable management. It also highlights the need for further study in existing research on the interplay between decentralization, digital security, and innovative blockchain solutions. This research will fill gaps by analyzing the effects of blockchain adoption on temporal changes in a collective management performance index, a case study of Ukraine.

Based on the research problem, this study formulated the following research question: How does the incorporation of blockchain technologies into management systems in Ukraine impact transparency, operational efficiency, and sustainability? The study's research objectives are as follows: To explore the effects of blockchain adoption on management openness, effectiveness and stability in Ukraine. To examine the role of blockchain and digital strategies in improving management outcomes. To analyze the obstacles and unfairness

of blockchain management systems. To recommend to policymakers and managers to effectively adopt blockchain management practices.

This study aims to systematically analyze the configurations between blockchain technologies and management practices in Ukraine, focusing on transparency, efficiency, competitiveness, and sustainability. Based on empirical evidence on blockchain implementation, this paper aims to provide practical advice to managers and policymakers on leveraging blockchain successfully.

This study is unique in that it focuses on Ukraine as a case study attempting to present ways blockchain could be applied in a transition economy in the real world. There are numerous studies on the technical possibilities of blockchain, but this paper presents a systematic review of blockchain in the context of management. It also identifies critical gaps in empirical evidence and provides specific recommendations for countries facing economic and governance challenges.

2. Research method

2.1. Data and its source

The study examined quarterly data from 2008 Q1 to 2023 Q4 in Ukraine. The data for the study was drawn from official government reports, blockchain adoption surveys, public databases, and industry-specific case studies in Ukraine. Performance is used as a dependent variable in this study, measured as follows: the Transparency Index, adapted from Transparency International's public institution reports. Operational Efficiency Metrics: From World Bank governance indicators and industry benchmarks. It is a time and cost reduction in the management process. Sustainability Index[1]: Utilizing resource efficiency and waste management metrics in accordance with the UN Sustainable Development Goals (SDGs). In comparison, the independent variables are blockchain implementation, based on a survey from blockchain research institutes, with a binary value (1 for adoption, 0 for non-adoption). Digital Security: Measured by the number of blockchain-based security protocols implemented and the currencies enabled. Decentralization: Evaluated by case studies of centralized (public or private) decision-making in Ukrainian public and private organizations. Innovative Solutions: This is measured by the number of blockchain-based innovations introduced in management [30], [31], [32].

2.2. Background of the model

This research employs systematic review methods to assess the impact of blockchain implementation on management systems [33]. The model analyses blockchain's influence on three primary outcomes: sustainability, transparency and operational efficiency. They are treated as dependent variables, measured through both qualitative assessments and quantitative indicators. Independent variables also represent specific blockchain-related factors, including blockchain implementation, digital security, decentralization, and innovative solutions. Given Ukraine's focus on improving governance and management efficiency, this study identifies the following hypotheses:

H1: Management transparency in Ukraine improves when engaging in blockchain adoption.
H2: Blockchain-enabled decentralization enhances operational efficiency.
H3: Processing optimization contributed to sustainable management practices using blockchain.

2.3. Empirical model

The study follows a multivariate regression analysis to quantify the relationship between blockchain adoption and management outcomes [34], [35], [36], [37]. The general form of the empirical model is:

$$Performance_t = \alpha_1 + \alpha_2 BI_t + \alpha_3 DS_t + + \alpha_4 Decentralisation_t + \alpha_5 IS_t + \varepsilon_t \quad (1)$$

Where $Performance_t$= transparency, efficiency, sustainability index. BI_t represents blockchain implementation (binary: 1 if blockchain is used, 0 otherwise). DS_t is a digital security (measured by several security protocols in place). *Decentralization is the extent of decentralized* decision-making. The innovative solution is demonstrated by the ISt, as measured by several blockchain-based innovations introduced. ε_t is the error term of the equation. The coefficients α_2, α_3, α_4 and α_5 represent the marginal effect of each independent variable on the respective outcome.

[1] https://ukraine.un.org/en/sdgs

2.4. Econometric techniques

2.4.1. Econometric techniques

The results from regression analysis should be interpreted with caution because time series data sometimes exhibit a unit root problem [38]. The augmented Dickey-Fuller test indicated a stationary level in the model series of this study. However, the ADF test can be more powerful and permit more complex models than the test [39]. A possible econometric equation is

$$\Delta y_t = JD_t + \gamma y_{t-1} + \sum_{h=1}^{j} \delta_k \Delta y_{t-k} + \varepsilon_t \tag{2}$$

The null hypothesis of the ADF unit root test is that the data is non-stationary. At the same time, the D_t root indicates the deterministic vector, and the error term is represented by ε_t.

2.4.2. Co-integration Tests

Cointegration among the series is tested using the Autoregressive Distributive Lag (ARDL) bound test [40]. Through the ARDL technique, we can estimate both the long- and short-run model components simultaneously, thereby eliminating the need to account for omitted data or autocorrelation difficulties [41]. For all of the models employed in this study, ARDL employs the following econometric methodology:

$$\begin{aligned}\Delta Performance_t = {} & \alpha_1 + \alpha_2 t + \alpha_3 Performance_{t-1} + \alpha_4 BI_{t-1} + \alpha_5 DS_{t-1} + \alpha_6 Decentralization_{t-1} + \alpha_7 IS_{t-1} + \\ & + \sum_{q=0}^{r} \lambda_q \Delta Performance_{t-q} + \sum_{s=0}^{r} \lambda_s \Delta BI_{t-s} + \sum_{u=0}^{r} \lambda_u \Delta DS_{t-u} + \sum_{v=0}^{r} \lambda_v \Delta Decentralization_{t-v} + \sum_{w=0}^{r} \lambda_w \Delta IS_{t-w} + \mu_t\end{aligned} \tag{3}$$

Where, in equation (3)

H0: $\alpha_3 = \alpha_4 = \alpha_5 = \alpha_7 = \alpha_8$

H1: $\alpha_3 \neq \alpha_4 \neq \alpha_5 \neq \alpha_7 \neq \alpha_8$

H0 represents the null hypothesis, and H1 denotes the alternative hypothesis.

The bound test rejects the null hypothesis of no co-integration, as the F value exceeds the upper bound value, thereby rejecting the null hypothesis [40]. According to ref. [42], The long-term relationship among the variables in such a model leads to an error correction model (ECM) defined by the ARDL approach. ECM is useful for determining both the model's long-run equilibrium and short-run parameters, and its equational form can be written as follows [43]:

$$\begin{aligned}\Delta Performance_t = {} & \alpha_1 + \alpha_2 t + \sum_{q=0}^{r} \lambda_q \Delta Performance_{t-q} + \sum_{s=0}^{r} \lambda_s \Delta BI_{t-s} + \sum_{u=0}^{r} \lambda_u \Delta DS_{t-u} + \\ & + \sum_{v=0}^{r} \lambda_v \Delta Decentralization_{t-v} + \sum_{w=0}^{r} \lambda_w \Delta IS_{t-w} + \phi ECT_{t-1} + \mu_t\end{aligned} \tag{4}$$

The one-period lagged ECTt-1 represents the error correction term in equation (4). The speed of adjustment from short-run to long-run equilibrium is defined by ECM [44]. The term denotes the value of ECM coefficients ϕ, and it should be negative. Diagnostic tests were also performed to ensure the model's structural integrity, including the normality test for residual terms, the ARCH test, and the Lagrange Multiplier (LM) test for serial correlation.

3. Results and discussion

3.1. Descriptive statistics and correlation coefficients

The descriptive statistics reveal that blockchain implementation and decentralization steadily increased during the analyzed period, as reflected in the growing mean values (see Table 1). Management outcomes, such as

performance efficiency, improved, with transparency reaching a maximum of 75% by 2023. This trend suggests that blockchain adoption contributed positively to governance and operational processes.

The correlation matrix indicates a strong positive correlation between blockchain implementation and innovative solutions ($r = 0.97$), suggesting that blockchain significantly enhances accountability. Additionally, decentralization is positively correlated with performance efficiency ($r = 0.94$), highlighting the role of distributed decision-making in enhancing performance. The results align with the study's hypotheses, demonstrating blockchain's positive impact across management dimensions.

3.2. Results of unit root tests

After presenting the descriptive statistics, we estimated the ADF tests for each series. Table 2 presents the results from the ADF unit root test, which indicates that all variables exhibit unit root problems; none of the variables is stationary at the level. However, upon considering the first difference, they become stationary.

3.3. Results of unit root tests

Selecting the lag length is crucial before estimating long-run parameter estimates using the ARDL model. The VAR lag order selection criteria are applied to specify the correct lag length, and the results are presented in Table 3.

3.4. Results of co-integration test

A co-integration test for the ARDL bound test is applied. The predicted F-statistic value is greater than the upper bound critical value at a 1% significance level (23.456). Performance, digital security, decentralization, and innovative solutions are co-integrating in Ukraine. The long-run elasticity results from the ARDL model and supporting statistics are presented in Table 4. All tests are passed in the long-run relationship model, indicating that it is robust to policy modeling.

3.5. The ARDL estimates

Then, the short-run and long-run relationship between the model's variables is estimated through ARDL after co-integration identification. Interactions between long-term (seasonality) and short-term (autocorrelation) trends significantly affect behavior in time series. The overall trend in the data over a more extended period is referred to as a long-term trend. It captures or identifies the series' rise or fall and determines the series's primary trend or direction. In contrast, the short-term trend focuses on changes or changes that occur over shorter periods. They corrupt the data and are typically caused by variables such as seasonal cycles, random noise, or short-term events. These are referred to as these oscillations [45], [46]. This method enables us to distinguish between transient and chronic deviations. Table 5 describes the results of short-run and long-run relationships.

The long-term results of the ARDL in Table 5 demonstrate the relationship between blockchain-related variables and management outcomes. Blockchain Implementation: Consistent and positive across all models, suggesting that blockchain adoption leads to improvements in management outcomes, including transparency, efficiency, and sustainability. Decentralization: The highest coefficient likely indicates that decentralization is the most crucial factor, as it enables better decision-making through the adoption of blockchain. Innovative Solutions: This demonstrates the positive impact of moderate blockchain innovations, which have led to long-term sustainability.

Figure 1 visualizes trends in transparency, efficiency, and sustainability scores from Ukraine from 2015 to 2023. The transparency increases from 45 to 75 as blockchain adoption grows in all three metrics, indicating that accountability is improving. This also increases efficiency, achieving 78 in 2023 — that's faster and cheaper processes driven by decentralization. Following the 60 trendlines, sustainability advances at a moderate pace, with at least 60 demonstrating a gradual shift toward blockchain-driven resource management practices. These results suggest that blockchain adoption has a positive impact on these management outcomes over time.

3.6. Discussion

The study finds that blockchain technologies significantly enhance transparency, operational efficiency, and sustainability in management systems. Immutable records created by the blockchain are a crucial feature that enhances transparency, particularly in public administration and corporate governance. Figure 1 shows that the growing adoption of blockchain is correlated with an upward trend in transparency scores. This finding aligns with the literature, which states that blockchain mitigates information asymmetry and reduces the risk of fraud by enabling logs to be audited.

High coefficients in all models have identified the most causal factor of decentralization. This result is consistent with studies that the decentralized nature of the blockchain facilitates reducing bureaucratic bottlenecks and speeding up the decision-making process by assigning authority to multiple nodes. Decentralized governance models have enhanced the cycles and cost efficiency in Ukraine's supply chain management or public services.

On the one hand, organizations increasingly turn to security protocols to build stakeholder trust. On the other hand, blockchain-based security protocols have a profound impact on management outcomes. Blockchain innovations also facilitate the adoption of sustainable practices by increasing resource utilization and automating processes. The positive relationship between blockchain innovations and sustainability demonstrates how organizations utilize blockchain technologies in energy-efficient solutions and waste management systems. All of the above factors make it possible to improve an organization's competitiveness without incurring additional costs.

Significant research has been conducted in the literature to investigate how blockchain technology can enhance transparency, efficiency, and security in various contexts. According to a recent study by Tan and Saraniemi [47], blockchain fosters trust by creating immutable records and eliminating the need for mediating groups. However, blockchain is argued to have a limited impact on developing or transitioning economies due to regulatory uncertainty and limited technological infrastructure [48].

Using empirical evidence from Ukraine, this study extends previous research by confirming the effects of decentralization in two ways: the effects of decentralization are the most significant determinants of efficiency gains, and local needs are more effectively met through decentralization. Our results align with the literature focused on the technical aspects of blockchain but align with the management advantages of blockchain, as stressed by Toufaily and Zalan [49]. This paper differs from earlier works in emphasizing the synergistic effect of blockchain innovation on sustainability.

Our findings support that blockchain adoption enhances transparency. This finding is consistent with Zadeh and Safaei, who found that blockchain-based audits can also lead to similar improvements in public sector accountability [50]. The consistency with previous work suggests that information immutability is a universal approach to enhancing transparency, regardless of a country's governance structure.

This corroborates Adana et al., who found that decentralization reduces the time spent on decision-making in logistics management [51]. Nevertheless, our work contributes to the literature by finding that decentralization is also advantageous for the public administration arena in Ukraine.

A previous study by Sahoo et al. observed the value of blockchain in reducing waste through smart contracts; however, this study further demonstrates how blockchain can enhance sustainability improvements in governance processes [52]. The study demonstrates that blockchain facilitates the automation of redundant processes, promoting sustainable resource management practices. Table 1 shows that we find support for the conventional wisdom surrounding blockchain benefits (e.g., decentralization, transparency) but that these apply specifically to Ukraine’s public sector and its sponsorship of sustainability practices. It also closes the gaps in previous work, focusing on governance contexts to facilitate the transition of economies.

Table 1. Comparison of study findings with existing literature

Key Finding	Your Study’s Results	Supporting Literature	Contrasts/Extensions
Transparency	Blockchain’s immutable records improve transparency in governance and supply chains.	- Tan and Saraniemi: Blockchain builds trust via immutability and disintermediation [47]. - Zadeh and Safaei: Blockchain audits enhance public sector accountability [50].	Extends evidence to Ukraine’s context, showing applicability despite regulatory challenges in transitioning Economies.

Key Finding	Your Study's Results	Supporting Literature	Contrasts/Extensions
Decentralization	A strong causal link exists between decentralization and efficiency gains, such as reduced bureaucracy.	- Adana et al.: Decentralization speeds up logistics decisions [51]. - Toufaily and Zalan: Highlights management advantages of blockchain [49].	A novel focus on public administration, using the Ukrainian case, demonstrates the scalability of decentralization beyond corporate contexts.
Sustainability	Blockchain automates processes, improving resource utilization and waste management.	- Sahoo et al.: Smart contracts reduce waste [52]. - Literature gaps: Few studies have linked blockchain to the sustainability of governance processes.	Demonstrates synergy between blockchain and sustainability in governance, such as energy-efficient solutions, a less-explored area in prior work.
Security & Trust	Security protocols enhance stakeholder trust and management outcomes.	- Consensus in literature: Blockchain's cryptographic security reduces fraud. - Criticism: Limited impact in developing economies due to infrastructure gaps [48].	Validates security benefits empirically while acknowledging Ukraine's regulatory hurdles, thereby bridging the debate between optimism and realism.
Operational Efficiency	Cost and time savings in supply chains and public services through decentralized models.	- Aligned with general blockchain efficiency claims (e.g., IBM reports). - Contrast: Some studies warn of scalability issues (e.g., VISA vs. Bitcoin throughput).	Provides concrete evidence from Ukraine's supply chains, addressing scalability concerns in real-world settings.

3.7. Limitations of the study

This study has several limitations that may affect the generalizability of the results:

- Data Coverage: The study does not integrate any blockchain developments beyond this period. As a result, recent trends and innovations may not be captured accurately.
- Country-Specific Focus: The Ukraine-centric analysis may not be applicable beyond Ukraine, as it is influenced by distinct economic, cultural, political, and business environments that exist in other countries.
- Measurement Constraints: For specific metrics, such as blockchain implementation or decentralization, we use proxy indicators that may not fully capture the complexity of these concepts.
- Technological Evolution: The paper's findings are valid given the rapid pace of blockchain advancements; however, as new blockchain-based technologies emerge, the relevance of some findings may diminish.

These limitations suggest the need for ongoing research to validate the results across other contexts and over more extended periods.

4. Conclusions

This study systematically analyzes the implementation of blockchain technologies in management, with the rationale being transparency, efficiency, and sustainability in Ukraine. Empirical results show that blockchain adoption significantly improves management outcomes by reducing information asymmetry, decentralizing decision-making, and fostering sustainable practices. Decentralization played the most significant role among all blockchain-related factors in improving operational efficiency. At the same time, digital security must delineate who has the power to build stakeholder trust.

Ukraine is undergoing governance and economic transformations, and the blockchain presents an untapped opportunity to rebuild public trust and support sustainable development. Yet, the study also reveals the need for cybersecurity concerns to be addressed and provisions for regulatory support so that blockchain is a viable solution in all sectors. Based on the results of the study, the following policy recommendations are proposed to enhance the effectiveness of blockchain technologies in management within Ukraine:

Lay out legal frameworks and allow blockchain to be adopted across industries by legally recognizing blockchain-based transactions and records. Adopt a blockchain solution to streamline operations and provide tax relief or subsidies for companies and public institutions that struggle to implement blockchain solutions. Propose the design of mandatory cybersecurity standards for blockchain-based platforms to cover up vulnerabilities in digital security. It is building advanced security infrastructure to protect sensitive data through public-private partnerships, enhancing security for blockchain operations. Facilitate practice experimentation with decentralization policies through decentralized public institutions and corporations, utilizing blockchain-enabled governance frameworks. Helped build local blockchain nodes for government services to alleviate administrative bottlenecks and enhance decision-making efficiency. It utilizes blockchain-based tracking systems for environmental data to enhance resource management and achieve environmental sustainability goals. We encourage industries to utilize smart contracts to automate waste reduction strategies and optimize resource utilization through automation [53]. Develop launch awareness campaigns highlighting the benefits of blockchain to increase trust in the technology and decrease resistance to its adoption. Developing the skills for operating blockchain-based systems is achieved through training programs for employees and government officials. They are incorporating blockchain technology to securely and transparently manage and verify digital credentials within e-learning. This approach maintains decentralized, safe access to learning records while reducing fraud and improving the trustworthiness of online certifications. Such a system will benefit both learners and institutions by reducing errors in verified skills, improving accessibility and allowing accurate time verification of qualifications. The opinion is consistent with Ukraine's digital strategies, implying a prudent path to e-learning and broader management [54]. As a tool for market development and boosting economic activity in Ukraine, supporting other entities in reaching their full potential is essential—commercial entities prove this by helping to address market needs and optimize the business environment. The deeper market relationship in Ukraine, particularly in light of its challenges and opportunities, requires enterprises to achieve high performance, competitive advantages, and sustainable growth. As such, these entities should be supported by policy messages that assist them in innovation, efficient operation, and secure digital operations [55].

The deep infrastructural integration of blockchain will significantly enhance the long-term competitive advantages of the companies involved, adding predictability and stability to their competitive landscape.

Several gaps remain unexplored that present opportunities for future research:

- Sectoral Analysis of Blockchain Adoption: Blockchain may have a positive impact on specific sectors, including healthcare, logistics, and education; future studies can be conducted to explore these areas further.

- Impact of Emerging Technologies: To inspire future research, we must explore how blockchain interfaces with artificial intelligence (AI) and the Internet of Things (IoT) in a management context.
- Longitudinal Studies: However, long-term studies will be essential to measuring the sustainability of the benefits blockchain can bring over time as blockchain adoption continues to evolve.
- Policy-Implementation Gap: However, further studies are needed to address the barriers to blockchain adoption, specifically regarding the regulation of blockchain in relation to the peculiarities of Ukraine and other similar countries.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

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