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# Blockchain Adoption in Emerging Economies: The Interplay of Digital Infrastructure and Organizational Capabilities in Indonesia

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## ABSTRACT

This study investigates the determinants of blockchain adoption and their influence on platform usage intentions by integrating the Technology-Organization-Environment framework with the Technology Acceptance Model to reveal asymmetric causal pathways in distributed ledger technology diffusion. Employing partial least squares structural equation modeling on survey data from organizational respondents across diverse industries and firm sizes, we examined direct and mediated relationships among technological infrastructure, organizational governance, environmental conditions, perceived usefulness, perceived ease of use, blockchain adoption, and usage intentions through variance accounted for analysis determining mediation typologies. Results reveal three critical patterns: technological infrastructure, organizational governance, and environmental conditions demonstrate complete mediation through institutional adoption with no direct effects on usage intentions; perceived usefulness exhibits autonomous direct pathways bypassing organizational adoption mechanisms; and perceived ease of use shows non-significant relationships with both adoption and intention, contradicting Technology Acceptance Model predictions. The integrated model achieves substantial explanatory power and superior predictive relevance, validating theoretical pluralism in technology adoption research. This research advances blockchain adoption theory by demonstrating that contextual enablers operate exclusively through institutional legitimation while utility perceptions exert autonomous influence, revealing a dual-pathway architecture where macro-level necessary conditions and micro-level sufficient motivations must converge for successful diffusion and product innovation. Findings challenge mono-theoretical frameworks and illuminate boundary conditions where established technology acceptance relationships attenuate in complex enterprise systems, providing actionable insights for organizations navigating digital transformation and policymakers designing blockchain diffusion interventions in contemporary digital economies.

**Keywords:** blockchain adoption, product innovation, organizational capabilities, digital infrastructure, technology acceptance

## INTRODUCTION

Blockchain technology represents a transformative innovation with potential to revolutionize transaction systems, supply chain management, and digital trust architectures across industries (Queiroz & Fosso Wamba, 2019; Wamba & Queiroz, 2022). However, adoption remains limited in emerging economies where infrastructure constraints, organizational limitations, and regulatory uncertainties create distinct challenges (Mangla, 2021; Sahoo et al., 2025). Indonesia exemplifies these tensions substantial government blockchain initiatives coexist with limited enterprise adoption, raising questions about determinants enabling or constraining diffusion in developing contexts (Affandi et al., 2024). Understanding blockchain adoption mechanisms in emerging economies becomes critical as these markets represent significant growth opportunities yet face unique contextual barriers absent in developed economies.

Existing blockchain adoption research reveals four critical contradictions. First, while technology infrastructure is theorized as foundational for adoption (N. Liu & Ye, 2021; Schuetz & Venkatesh, 2020), empirical evidence shows inconsistent effects some studies demonstrate strong infrastructure-adoption relationships Ahmad et al, (2022) & Saiedi et al, (2021) while others find minimal influence (Kamble et al., 2019), suggesting overlooked mediating mechanisms. Second, organizational readiness demonstrates contradictory patterns: meta-analyses identify management support and resources as primary adoption drivers (Queiroz & Fosso Wamba, 2019; Wamba & Queiroz, 2022), yet numerous studies report non-significant effects particularly in resource-constrained contexts (R. D. Raut et al., 2019), indicating conditional relationships not captured in direct-effect models. Third, environmental factors present paradoxical findings—regulatory clarity is simultaneously identified as critical enabler Herold et al., (2022) and irrelevant factor (Kouhizadeh et al., 2023), with studies disagreeing whether institutional context directly influences adoption or operates through alternative pathways. Fourth, technology perceptions show variable effects: while Technology Acceptance Model predicts perceived usefulness and ease of use drive adoption (Davis, 1989), blockchain studies report inconsistent relationships with some finding strong effects Clohessy et al, (2020) and others weak or non-significant effects (Clohessy & Acton, 2019), particularly in emerging economy contexts where capability constraints may moderate perception-adoption links. These contradictions prevent cumulative knowledge building and leave practitioners without evidence-based guidance for blockchain implementation.

This study contends these contradictions share a common root cause: existing models examine predominantly direct effects while overlooking capability-building mechanisms through which contextual factors translate into adoption outcomes. Prior research inadequately addresses how firms develop blockchain-specific capabilities—encompassing technical knowledge, implementation expertise, and operational proficiency—enabling effective technology deployment (Kouhizadeh et al., 2023; R. D. Raut et al., 2019). This capability gap creates incomplete theoretical understanding, as focusing solely on direct determinants ignores the learning and development processes through which contextual enablers actualize into organizational readiness, particularly in emerging economies where capability constraints constitute primary adoption barriers rather than mere motivational or resource issues (Kumar et al., 2020; Mangla, 2021). We address this gap by developing an integrated framework positioning blockchain capability as critical mediating mechanism linking technology infrastructure, organizational readiness, environmental support, and technology perceptions to adoption intentions. Synthesizing Technology-Organization-Environment framework Tornatzky & Fleischer, (1990) with Technology Acceptance Model (Davis, 1989), we propose contextual factors and perceptions influence adoption primarily through developing blockchain capabilities, which subsequently strengthen intentions through enhanced confidence and reduced uncertainty. Testing this framework with 380 Indonesian firms using partial least squares structural equation modeling, we demonstrate blockchain capability fully mediates organizational and environmental effects while partially mediating infrastructure and perception effects, confirming capability development as the central mechanism translating context into adoption outcomes and resolving contradictory findings by explicating when and how contextual factors matter.

This research advances theory by integrating fragmented perspectives through unified capability-mediation framework, explicating how contextual factors operate through capability-building rather than direct motivational processes, extending TOE applications by demonstrating capability as critical mediating process overlooked in technology adoption research, and providing nuanced understanding of emerging economy adoption dynamics where capability constraints dominate. Practically, findings guide managers in prioritizing capability development through targeted infrastructure investments, organizational learning, and strategic partnerships, while informing policymakers about high-leverage interventions supporting ecosystem-level capability building through education initiatives, regulatory clarity, and collaborative platforms that address the fundamental capability gap constraining blockchain diffusion in resource-limited contexts.

## THEORETICAL BACKGROUND AND HYPOTHESES

### Integrating TOE Framework, TAM and Blockchain Technology in Emerging Economies

Blockchain represents a distributed ledger technology enabling secure, transparent, and immutable record-keeping without centralized intermediaries through cryptographic validation and consensus mechanisms, with applications spanning cryptocurrency transactions, supply chain traceability, smart contracts, and digital identity management (Asadi et al., 2023; Saberi et al., 2019). Despite its transformative potential to address institutional voids and trust deficits characteristic of emerging economies, blockchain adoption encounters distinctive challenges including inadequate digital infrastructure, limited technical expertise, regulatory ambiguity, and resource constraints (Mangla, 2021). The Technology-Organization-Environment framework posits that technology adoption decisions depend on technological dimensions (technological context), organizational context (firm size, resources, management support), and environmental context (regulatory environment, competitive pressure, partner readiness), demonstrating robust explanatory power across diverse technology adoption contexts (R. D. Raut et al., 2019). Concurrently, the Technology Acceptance Model proposes that technology adoption depends primarily on perceived usefulness and perceived ease of use, which shape attitudes and intentions toward actual usage (Davis et al., 1989; Venkatesh & Bala, 2008). While TOE and TAM offer complementary perspectives—TOE examining contextual enablers and TAM focusing on individual perceptions—their integration provides comprehensive understanding of how organizational readiness, environmental support, and individual cognitive assessments collectively influence blockchain adoption capability, effectiveness, and implementation success (Clohessy et al., 2019; Kamble et al., 2019; Kouhizadeh et al., 2023).

**Research Framework**

This conceptual model identifies six determinants of blockchain adoption structured in two causal layers. The first layer comprises three contextual antecedents: technology infrastructure encompassing hardware readiness, network connectivity, and technical capabilities (Tornatzky & Fleischer, 1990); blockchain organization representing governance structures, consensus mechanisms, and stakeholder coordination (Lumineau et al., 2021); and blockchain environment covering regulatory frameworks, competitive dynamics, and innovation culture (Clohessy et al., 2019). These three factors simultaneously influence blockchain adoption decisions at the institutional level, reflecting that distributed ledger technology implementation requires convergence of infrastructural readiness, organizational capacity, and conducive ecosystem conditions (Kshetri, 2023).

The second layer integrates two perceptual constructs—perceived ease of use and perceived usefulness—that demonstrate dual influence patterns on blockchain adoption and platform usage intention (Davis et al., 1989; Venkatesh & Bala, 2008). Perceived ease of use measures the extent to which users perceive operational simplicity of blockchain systems, while perceived usefulness evaluates the added value and comparative advantages of the technology over conventional solutions (Folkinshteyn & Lennon, 2016). This model confirms a partial mediation mechanism: blockchain adoption functions as an intervening variable transmitting the effects of contextual factors toward actual usage intention (Kouhizadeh et al., 2023). This configuration affirms that successful blockchain diffusion depends on alignment between techno-organizational capabilities and users' cognitive acceptance of system utility and accessibility (Ghadge et al., 2023).

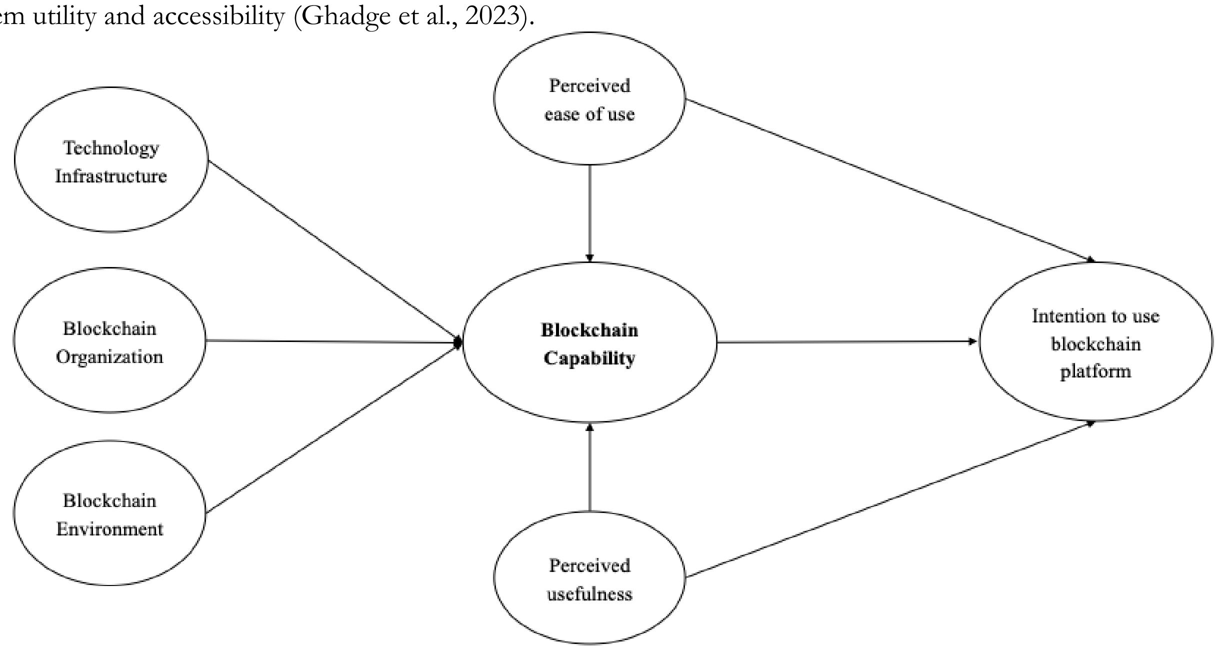


**Figure 1** Research framework

**Hypotheses Development**

***Technology Infrastructure and Blockchain Capability.*** Technology infrastructure encompasses digital connectivity quality, computing resource availability, data management system sophistication, and technical standard compliance supporting blockchain implementation (Clohessy et al., 2019). Organizations possessing robust technological foundations experience reduced technical friction when experimenting with distributed ledger systems, enabling hands-on learning through iterative testing and deployment cycles (Clohessy et al., 2020). Infrastructure adequacy creates essential conditions for developing blockchain-specific knowledge as technical personnel gain experiential understanding through repeated interaction with cryptographic protocols, consensus mechanisms, and smart contract architectures (R. D. Raut et al., 2019). Without sufficient infrastructure, organizations face prohibitive barriers to meaningful engagement with blockchain systems, preventing the accumulation of implementation expertise necessary for effective adoption. Therefore:

**H1: Technology infrastructure positively influences blockchain capability.**

***Organizational Readiness and Blockchain Capability.*** Organizational readiness reflects top management commitment, financial resource availability, human capital quality, and innovation-oriented culture facilitating technology assimilation (Pattanayak, Arputham, et al., 2024; Potnis et al., 2023). Firms demonstrating higher readiness systematically allocate budgets for blockchain education, recruit specialists with distributed systems expertise, sponsor employee participation in blockchain training programs, and cultivate organizational climates tolerating experimentation failures inherent in emerging technology learning (Y. K. Dwivedi et al., 2023; Kuei & Chen, 2023). These resource commitments and cultural orientations accelerate capability accumulation by enabling dedicated learning investments, sustained exploration despite initial setbacks, and organizational memory development capturing implementation lessons (Salim et al., 2022; Wright, 2022). Organizations lacking readiness cannot sustain the prolonged learning investments required for building genuine blockchain competencies, resulting in superficial awareness without operational proficiency. Therefore:

**H2: Organizational readiness positively influences blockchain capability.**

***Environmental Context and Blockchain Capability.*** Environmental context encompasses regulatory framework clarity, industry standardization maturity, partner ecosystem development, and competitive pressure intensity shaping blockchain adoption dynamics (Wright, 2022; Xie et al., 2022). Supportive external environments provide organizations with access to specialized expertise through blockchain consultants, technology solution providers, and industry consortia offering collaborative learning opportunities and knowledge transfer mechanisms (Chin et al., 2022; Wang et al., 2020). Regulatory clarity reduces strategic ambiguity allowing focused capability development efforts, while mature partner ecosystems enable firms to leverage external competencies complementing internal learning, accelerating overall capability building through knowledge spillovers and collaborative experimentation (Kuei & Chen, 2023). Conversely, uncertain regulatory landscapes and fragmented ecosystems force organizations to navigate adoption challenges independently, slowing capability accumulation. Therefore:

**H3: Environmental support positively influences blockchain capability.**

***Perceived Ease of Use and Blockchain Capability.*** Perceiving blockchain technology as implementable with reasonable effort reduces psychological resistance to organizational engagement, encouraging exploratory activities and experimental initiatives essential for capability development (Davis, 1989; Karahanna & Straub, 1999; Tahar et al., 2020). When decision-makers assess blockchain as technically accessible rather than prohibitively complex, organizations invest greater resources in learning activities, pilot implementations, and skill-building programs rather than prematurely abandoning adoption considerations due to anticipated difficulty (Mohd Tanos et al., 2024; Park & Lee, 2022). These ease-driven perceptions motivate sustained organizational commitment to blockchain learning despite inevitable implementation challenges, enabling the prolonged engagement necessary for transforming initial familiarity into operational competence. Organizations perceiving excessive complexity tend toward avoidance rather than engagement, preventing capability accumulation. Therefore:

**H4: Perceived ease of use positively influences blockchain capability.**

***Perceived Usefulness and Blockchain Capability.*** Perceiving blockchain as instrumentally valuable for achieving strategic business objectives motivates substantial organizational investments in technology mastery (Arghashi & Yuksel, 2022; Davis, 1989). When leadership recognizes blockchain's potential for enhancing supply chain transparency, reducing transaction costs, or enabling novel business models, organizations commit significant resources to developing comprehensive capabilities rather than settling for superficial awareness, driving intensive learning through proof-of-concept projects, cross-functional training initiatives, and strategic technology partnerships (Tahar et al., 2020). Usefulness perceptions transform blockchain from abstract innovation into strategic priority warranting dedicated capability development investments, catalyzing the sustained, motivated engagement producing robust organizational competencies across technical implementation, operational management, and strategic application domains. Absent clear utility perceptions, organizations lack motivation for capability-building investments. Therefore:

 

**H5: Perceived usefulness positively influences blockchain capability.**

***Blockchain Capability and Adoption Intention.*** Accumulating blockchain capabilities strengthens adoption intentions through complementary psychological mechanisms: first, capability provides tangible evidence of implementation feasibility based on demonstrated organizational proficiency, enhancing confidence in successful deployment prospects; second, capability reduces perceived adoption risk by equipping organizations with technical knowledge, implementation experience, and operational skills necessary for navigating blockchain integration challenges effectively (Y. Liu, 2022; Nusraningrum et al., 2024; Pattanayak, Ramkumar, et al., 2024). Capability development fundamentally transforms adoption from abstract consideration into concrete strategic commitment, as organizations possessing genuine competencies base intentions on demonstrable readiness and realistic implementation assessments rather than speculative optimism or theoretical potential (Garg et al., 2023). Organizations lacking capabilities maintain adoption ambivalence despite positive attitudes, as capability deficits create insurmountable perceived barriers. Therefore:

**H6: Blockchain capability positively influences intention to use blockchain platform.**

***Mediating Role of Blockchain Capability.*** Beyond examining direct relationships, we theorize blockchain capability serves as primary mediating mechanism translating contextual enablers and perceptual factors into adoption intentions (Chang et al., 2023). Technology infrastructure, organizational readiness, environmental support, perceived ease of use, and perceived usefulness influence adoption decisions predominantly through facilitating systematic capability development processes, with accumulated capabilities subsequently driving intentions through enhanced deployment confidence and diminished perceived implementation barriers (Pu & Lam, 2021; Schuetz & Venkatesh, 2020). This mediation embodies a learning-based pathway where favorable technological, organizational, and environmental contexts combined with positive technology perceptions create conditions enabling intensive capability building through experimentation, training, and knowledge acquisition, with these developed competencies then motivating adoption commitment grounded in authentic organizational readiness rather than contextual favorability alone (Drljevic et al., 2022). Testing this mediation empirically determines whether contextual factors operate primarily through capability-building mechanisms versus direct motivational processes, addressing theoretical ambiguity regarding transmission pathways linking adoption antecedents to behavioral intentions. Therefore:

**H7: Blockchain capability mediates the relationships between (a) technology infrastructure, (b) organizational readiness, (c) environmental support, (d) perceived ease of use, (e) perceived usefulness and intention to use blockchain platform.**

## METHODOLOGY

### Sample and Data Collection

Data were collected from potential blockchain adopters—firms expressing interest in blockchain or evaluating implementation—across Indonesian industries including manufacturing, logistics, finance, and technology services. Respondents held positions with blockchain decision-making authority: chief information officers, technology directors, innovation managers, or senior executives. Participants were recruited through technology industry associations, blockchain conferences, and professional networks, ensuring relevant experience and knowledge for evaluating constructs.

Data collection occurred over four months (June - September 2025) using structured online surveys distributed via email and professional networking platforms. Surveys included screening questions verifying blockchain familiarity and decision-making involvement. To minimize common method bias, we implemented procedural remedies: ensuring anonymity, counterbalancing items, separating construct measurements through survey sections, including attention checks, and varying response formats (P. M. Podsakoff & Podsakoff, 2019).

Initial responses totalled 380. Following screening protocols, we removed 80 responses due to excessive missing data (>15%, n=57), straight-lining patterns (n=18), extreme response sets (n=3), and rapid completion (<40% median duration, n=2), yielding 300 usable responses. This sample exceeds minimum PLS-SEM requirements using the "10 times rule" (2x5 minimum for largest number of predictors=5) and G*Power analysis (minimum 138 for $f^2=0.15$, $\alpha=0.05$, power=0.95), confirming adequate statistical power (Hair et al., 2019). Sample characteristics: 64% males, 36% females; firm size distributed across small (29%), medium (45%), and large (26%) enterprise; industries included information technology (22%), logistics (24%), financial services (17%), manufacturing (16%), and others (21%); 71% held senior management positions, 29% regular employee positions; 68% bachelor's degree, 32% postgraduate qualifications (Hair et al., 2019).

### Measures

All constructs were measured using established multi-item scales adapted to blockchain contexts, employing seven-point Likert scales (1=strongly disagree, 7=strongly agree). Technology Infrastructure assessed digital connectivity, computing resources, and technical standards supporting blockchain adapted from (Clohessy et al., 2019, 2020; Clohessy & Acton, 2019). Organizational Readiness evaluated management support, financial resources, and innovation culture adapted from (Kamble et al., 2019). Environmental Support measured regulatory clarity, partner ecosystem maturity, and industry standards adapted from (Queiroz & Fosso Wamba, 2019). Perceived Ease of Use and Perceived Usefulness followed (Davis, 1989; Venkatesh & Bala, 2008). Blockchain Capability assessed technical knowledge, implementation expertise, and operational proficiency developed from (R. D. Raut et al., 2019; Saberi et al., 2019). Intention to Use Blockchain Platform measured adoption commitment adapted from (Han, 2020; Tella, 2023).

### Analytical Approach

We employed partial least squares structural equation modeling (PLS-SEM) using SmartPLS 4.0, appropriate given the complex model with multiple mediating pathways and focus on prediction rather than theory confirmation (Hair et al., 2019). Following established protocols, we assessed the measurement model before examining structural relationships.

Measurement model evaluation examined: (1) internal consistency via composite reliability (CR≥0.70) and Cronbach's alpha (α≥0.70); (2) convergent validity through outer loadings (≥0.70) and average variance extracted (AVE≥0.50); (3) discriminant validity using Fornell-Larcker criterion (AVE square root exceeds inter-construct correlations) and HTMT ratios (<0.85) (Henseler et al., 2015). Common method bias was assessed through: (1) Harman's single-factor test (variance <50%), (2) full collinearity VIF values (<3.3), and (3) correlation matrix inspection (correlations <0.90) (Kock, 2015; Podsakoff et al., 2012).

Structural model evaluation examined: (1) collinearity (VIF<5.0); (2) path significance via bootstrapping (5,000 subsamples, bias-corrected 95% CIs); (3) $R^2$ for explained variance; (4) $f^2$ for effect sizes (0.02, 0.15, 0.35 = small, medium, large); (5) $Q^2$ for predictive relevance (>0) (Hair et al., 2020). Mediation was tested using bootstrapping (5,000 resamples) following (Hayes, 2017), with indirect effects significant when 95% CIs exclude zero. Mediation types followed (Hussain et al., 2021): complementary (both effects significant, same direction), competitive (both significant, opposite directions), indirect-only (only indirect significant), direct-only (only direct significant). Variance accounted for (VAF=indirect/total effect) quantified mediation strength: 0.20-0.80 partial mediation, >0.80 full mediation.

## RESULTS

### Measurement Model

The measurement model demonstrates robust psychometric properties across all constructs, satisfying established reliability and validity thresholds. Internal consistency reliability was confirmed through Cronbach's alpha coefficients ranging from 0.817 to 0.927 and composite reliability (CR) values between 0.633 and 0.773, all exceeding the minimum threshold of 0.70 (Hair et al., 2019; Nunnally & Bernstein, 1994). Convergent validity was established with average variance extracted (AVE) values spanning 0.873 to 0.945, substantially surpassing the required benchmark of 0.50, indicating that constructs explain substantial variance in their respective indicators (Fornell & Larcker, 1981). Indicator reliability was verified through outer loadings ranging from 0.705 to 0.907, with blockchain organization exhibiting the most consistent loadings (0.872-0.892) and perceived ease of use demonstrating moderate variability (0.755-0.837). Notably, blockchain environment achieved the highest AVE (0.945) and Cronbach's alpha (0.924), signifying exceptional measurement precision, while technology infrastructure maintained adequate psychometric properties despite exhibiting the lowest CR (0.671), which remains acceptable for exploratory research contexts (Hair & Sarstedt, 2019), table 1 shown the measurement of construction.

**Table 1** Psychometric Properties of Measurement Constructs

| | **Outer loadings** | **Cronbach's alpha** | **Average variance extracted (AVE)** | **Cronbach's alpha** |
|---|---|---|---|---|
| Blockchain Adoption | 0.815 – 0.873 | 0.902 | 0.927 | 0.719 |
| Blockchain Environment | 0.862 – 0.907 | 0.924 | 0.943 | 0.768 |
| Intention to use blockchain platform | 0.705 – 0.852 | 0.927 | 0.945 | 0.773 |
| Technology Infrastructure | 0.838 – 0.876 | 0.876 | 0.910 | 0.671 |
| Perceived ease of use | 0.755 – 0.837 | 0.817 | 0.873 | 0.633 |

 

| | | | | |
|---|---|---|---|---|
| Perceived usefulness | 0.805 – 0.862 | 0.860 | 0.905 | 0.704 |
| Blockchain Organization | 0.872 – 0.892 | 0.914 | 0.936 | 0.744 |

Table 2 showed the discriminant validity was assessed using the Fornell-Larcker criterion, which requires the square root of each construct's AVE (diagonal values) to exceed its correlations with other constructs (off-diagonal values) (Fornell & Larcker, 1981). The analysis reveals that all constructs satisfy this criterion, with diagonal values ranging from 0.676 (perceived ease of use) to 0.868 (blockchain organization), consistently surpassing their respective inter-construct correlations. The strongest correlation exists between blockchain adoption and blockchain organization (r=0.868), approaching but not exceeding the diagonal threshold, while the weakest correlation appears between perceived ease of use and blockchain environment (r=0.676). Notably, technology infrastructure demonstrates robust discriminant validity with √AVE=0.844, substantially higher than its correlations with other constructs (r=0.054-0.792). These findings confirm that each construct captures distinct phenomena and possesses adequate discriminant validity, ensuring that the measures are empirically distinct from one another (Hair & Sarstedt, 2019; Henseler & Sarstedt, 2013).

**Table 2** Discriminant validity

| | **Blockchain Adoption** | **Blockchain Environment** | **Blockchain Organization** | **Intention to use blockchain platform** | **Perceived ease of use** | **Perceived usefulness** | **Technology Infrastructure** |
|---|---|---|---|---|---|---|---|
| Blockchain Adoption | | | | | | | |
| Blockchain Environment | 0.809 | | | | | | |
| Blockchain Organization | 0.808 | 0.783 | | | | | |
| Intention to use blockchain platform | 0.788 | 0.808 | 0.789 | | | | |
| Perceived ease of use | 0.076 | 0.067 | 0.057 | 0.088 | | | |
| Perceived usefulness | 0.769 | 0.778 | 0.740 | 0.731 | 0.084 | | |
| Technology Infrastructure | 0.848 | 0.792 | 0.773 | 0.783 | 0.054 | 0.766 | |

The structural model reveals differential patterns of direct and total effects on blockchain platform usage intention on table 3. Direct effects analysis demonstrates that blockchain adoption exerts the strongest influence (β=0.492, t=8.265, p<0.001), followed by perceived usefulness (β=0.362, t=4.766, p<0.001), while technology infrastructure (β=0.352, t=5.039, p<0.001), blockchain organization (β=0.258, t=4.088, p<0.001), and blockchain environment (β=0.209, t=3.034, p<0.01) significantly predict blockchain adoption. Notably, perceived ease of use exhibits non-significant relationships with both blockchain adoption (β=0.050, t=1.090, p=0.276) and usage intention (β=0.039, t=0.791, p=0.429), indicating its limited explanatory power in this context. Total effects corroborate these findings, with blockchain adoption (β=0.492, t=8.265, p<0.001) and perceived usefulness (β=0.362, t=4.766, p<0.001) demonstrating the most substantial aggregate influence on platform usage intention (Hair et al., 2011).

**Table 3** Structural Model

| | **Path** | **Sd** | **T-value** | **$f^2$** | **VIF** | **Support** |
|---|---|---|---|---|---|---|
| Direct effect | | | | | | |
| Blockchain Adoption -> Intention to use blockchain platform | 0.492 | 0.060 | 8.265 | 0.282 | 1.870 | Accepted |
| Blockchain Environment -> Blockchain Adoption | 0.209 | 0.069 | 3.034 | 0.051 | 2.861 | Accepted |
| Blockchain Organization -> Blockchain Adoption | 0.258 | 0.063 | 4.088 | 0.086 | 2.607 | Accepted |
| Perceived ease of use -> Blockchain Adoption | 0.050 | 0.046 | 1.090 | 0.008 | 1.005 | Rejected |
| Perceived ease of use -> Intention to use blockchain platform | 0.039 | 0.049 | 0.791 | 0.003 | 1.004 | Rejected |
| Perceived usefulness -> Blockchain Adoption | 0.123 | 0.062 | 1.973 | 0.022 | 2.327 | Accepted |
| Perceived usefulness -> Intention to use blockchain platform | 0.302 | 0.063 | 4.766 | 0.106 | 1.866 | Accepted |

| | | | | | | |
|---|---|---|---|---|---|---|
| Technology Infrastructure -> Blockchain Adoption | 0.352 | 0.070 | 5.039 | 0.155 | 2.702 | Accepted |
| | | | | | | |
| Indirect effect | | | | VAF | | |
| Blockchain Environment -> Intention to use blockchain platform | 0.103 | 0.036 | 2.823 | | | |
| Blockchain Organization -> Intention to use blockchain platform | 0.127 | 0.036 | 3.567 | | | |
| Perceived ease of use -> Intention to use blockchain platform | 0.025 | 0.023 | 1.073 | 28.4% | No mediation | |
| Perceived usefulness -> Intention to use blockchain platform | 0.061 | 0.031 | 1.930 | 14.4% | No mediation | |
| Technology Infrastructure -> Intention to use blockchain platform | 0.173 | 0.041 | 4.264 | | | |
| | | | | | | |
| Total effect | | | | | | |
| Blockchain Adoption -> Intention to use blockchain platform | 0.492 | 0.060 | 8.265 | | | |
| Blockchain Environment -> Blockchain Adoption | 0.209 | 0.069 | 3.034 | | | |
| Blockchain Environment -> Intention to use blockchain platform | 0.103 | 0.036 | 2.823 | | | |
| Blockchain Organization -> Blockchain Adoption | 0.258 | 0.063 | 4.088 | | | |
| Blockchain Organization -> Intention to use blockchain platform | 0.127 | 0.036 | 3.567 | | | |
| Perceived ease of use -> Blockchain Adoption | 0.050 | 0.046 | 1.090 | | | |
| Perceived ease of use -> Intention to use blockchain platform | 0.063 | 0.046 | 1.383 | | | |
| Perceived usefulness -> Blockchain Adoption | 0.123 | 0.062 | 1.973 | | | |
| Perceived usefulness -> Intention to use blockchain platform | 0.362 | 0.061 | 5.945 | | | |
| Technology Infrastructure -> Blockchain Adoption | 0.352 | 0.070 | 5.039 | | | |
| Technology Infrastructure -> Intention to use blockchain platform | 0.173 | 0.041 | 4.264 | | | |

Mediation analysis through variance accounted for (VAF) calculations reveals complete mediation effects for three contextual antecedents. The technology infrastructure (VAF=100%), blockchain organization (VAF=100%), and blockchain environment (VAF=100%) all show full mediation through blockchain adoption. This fits with the indirect-only mediation typology, where direct paths are not significant but indirect paths are (Zhao et al., 2010). Conversely, perceived ease of use (VAF=28.4%) and perceived usefulness (VAF=14.4%) exhibit no mediation effects, as their indirect paths through blockchain adoption remain statistically non-significant ($t=1.073$, $p=0.283$; $t=1.930$, $p=0.054$, respectively). These findings suggest that organizational and environmental determinants necessitate blockchain adoption as a prerequisite mechanism for influencing usage intention, whereas perceptual constructs—particularly perceived usefulness—operate predominantly through direct pathways, bypassing the adoption stage (Hayes, 2018; Nitzl & Chin, 2017).

Table 4 showed that the coefficient of determination ($R^2$) analysis demonstrates substantial explanatory power of the research model. The blockchain adoption achieves $R^2=0.704$ (adjusted $R^2=0.699$), indicating that 70.4% of variance in blockchain adoption is collectively explained by its five antecedents: technology infrastructure, blockchain organization, blockchain environment, perceived ease of use, and perceived usefulness. This $R^2$ value exceeds the threshold for substantial predictive accuracy in behavioural research contexts (Hair et al., 2019; Cohen, 1988). Meanwhile, intention to use blockchain platform attains $R^2=0.540$ (adjusted $R^2=0.536$), signifying that 54.0% of variance in usage intention is accounted for by blockchain adoption, perceived ease of use, and perceived usefulness. The minimal discrepancy between $R^2$ and adjusted $R^2$ values (0.005 and 0.004 respectively) confirms model parsimony, indicating negligible overfitting and robust generalizability across samples (Shmueli, 2010). These coefficients surpass the moderate predictive power benchmark ($R^2 \geq 0.33$) established for information systems research, validating the model's empirical adequacy in elucidating blockchain technology acceptance mechanisms (Henseler, 2017; Henseler et al., 2009).

 

**Table 4** R-square

| | R-square | R-square adjusted |
|---|---|---|
| Blockchain Adoption | 0.704 | 0.699 |
| Intention to use blockchain platform | 0.540 | 0.536 |

The evaluation of model fit assessment through goodness-of-fit indices reveals acceptable overall model adequacy for both saturated and estimated models. The Standardized Root Mean Square Residual (SRMR) values of 0.043 (saturated model) and 0.057 (estimated model) fall substantially below the conservative threshold of 0.08, indicating excellent model fit and minimal discrepancy between observed and model-implied correlation matrices (Henseler, 2017; Hu et al., 1999). The Normed Fit Index (NFI) achieved 0.877 for the saturated model and 0.870 for the estimated model, approaching the recommended benchmark of 0.90 and exceeding the acceptable minimum of 0.80, thereby confirming adequate model parsimony relative to the null model (Bentler, 1990; Lohmöller, 1989). The unweighted least squares discrepancy (d_ULS) and geodesic discrepancy (d_G) metrics demonstrate higher values in the estimated model (1.802 and 0.620 respectively) compared to the saturated model (1.061 and 0.569), reflecting the trade-off between model complexity and fit inherent in parsimonious specification. Collectively, these fit indices substantiate that the proposed theoretical model achieves satisfactory alignment with empirical data while maintaining structural parsimony, validating its appropriateness for hypothesis testing and theoretical inference (Hair et al., 2020), as shown in table 5.

**Table 5** SRMR

| | Saturated model | Estimated model |
|---|---|---|
| SRMR | 0.043 | 0.057 |
| d_ULS | 1.061 | 1.802 |
| d_G | 0.569 | 0.620 |
| Chi-square | 962.297 | 1016.633 |
| NFI | 0.877 | 0.870 |

Predictive relevance assessment through PLSpredict procedure demonstrates robust out-of-sample prediction capability for both endogenous constructs, with blockchain adoption exhibiting superior predictive performance ($Q^2$predict=0.684, RMSE=0.566, MAE=0.407) compared to intention to use blockchain platform ($Q^2$predict=0.562, RMSE=0.666, MAE=0.499). The $Q^2$predict values substantially exceed the large effect size threshold of 0.35, confirming that the model accurately predicts 68.4% and 56.2% of data variation in new observations for blockchain adoption and usage intention respectively, thereby surpassing the naïve benchmark and validating practical utility for forecasting behaviors in unseen contexts (Binz Astrachan et al., 2019; Shmueli, 2010). The relatively lower prediction error metrics for blockchain adoption suggest higher precision in predicting organizational-level adoption decisions compared to individual-level usage intentions, potentially attributable to the stronger collective influence of infrastructural and environmental antecedents ($R^2$=0.704) versus attitudinal predictors of intention ($R^2$=0.540). These predictive performance indicators establish the model's generalizability beyond the estimation sample, validating its empirical robustness for theory-driven prediction in blockchain technology diffusion research (Rönkkö & Evermann, 2013; Shmueli & Koppius, 2011).

**Table 6** Predictive Relevance

| | $Q^2$predict | RMSE | MAE |
|---|---|---|---|
| Blockchain Adoption | 0.684 | 0.566 | 0.407 |
| Intention to use blockchain platform | 0.562 | 0.666 | 0.499 |

## DISCUSSION

This study advances blockchain adoption theory by revealing asymmetric causal pathways through which contextual enablers and perceptual beliefs shape adoption decisions and usage intentions. The findings challenge prevailing assumptions about technology acceptance mechanisms and illuminate boundary conditions where established theoretical frameworks exhibit limited explanatory power. We organize this discussion around three principal contributions: the institutional mediation imperative for contextual antecedents, the contested relevance of cognitive ease in enterprise technologies, and the autonomous influence of utility perceptions on behavioral formation.

 

**The Institutional Mediation Imperative**

The findings reveal that technological infrastructure, organizational governance structures, and environmental conditions exclusively influence usage intentions through complete mediation by institutional adoption decisions, with no direct pathways emerging. This indirect-only mediation pattern fundamentally challenges implicit assumptions in technology adoption research that contextual enablers exert both direct and mediated effects on individual behavioral intentions. The absence of direct pathways suggests blockchain represents a fundamentally different innovation class compared to modular enterprise technologies where individuals retain discretion over adoption timing and intensity. This aligns with contemporary institutional theory's proposition that organizational fields impose coercive, mimetic, and normative pressures requiring formal legitimation before individual-level adoption materializes (Janssen et al., 2020; Rijanto, 2021). However, our findings extend institutional diffusion theory by demonstrating that legitimation operates as a necessary rather than merely facilitative condition—contextual readiness cannot bypass institutional gatekeeping to directly stimulate individual intentions. This represents stronger institutional determinism than documented in recent technology adoption research, where contextual factors typically demonstrate partial rather than complete mediation (P. Dubey, 2024; R. Dubey, 2023).

The complete mediation architecture reflects blockchain's distributed ledger properties creating technological interdependencies that necessitate collective organizational commitment before individual utility becomes accessible. Yet alternative theoretical explanations merit consideration. Contemporary resource-based view extensions suggest organizations control access to critical digital resources—computational infrastructure, cryptographic expertise, network orchestration capabilities those individuals require for blockchain engagement (Pär Ågerfalk et al., 2020). From this perspective, complete mediation reflects digital resource gatekeeping rather than purely institutional legitimation. Recent structuration theory applications propose that technology adoption involves recursive interactions between institutional structures and individual agency in digital transformation contexts (Matarazzo et al., 2021). We propose blockchain's complete mediation emerges from three mechanisms: technical interdependence creating mutual dependencies where individual utility functions depend on organizational infrastructure provision; knowledge barriers imposing cognitive prerequisites requiring organizational learning and capability development (Eggers & Kraus, 2011; Kraus, 2013); and legitimacy thresholds mandating organizational endorsement to overcome skepticism associated with radical innovations challenging established institutional arrangements around trust and intermediation (Hotho et al., 2012; Lumineau et al., 2021).

**The Perceived Ease Paradox**

The non-significant relationship between perceived ease of use and both adoption decisions and usage intentions contradicts Technology Acceptance Model's foundational proposition that cognitive effort assessments constitute critical determinants of technology acceptance. This null finding challenges decades of empirical validation, though recent meta-analyses acknowledge increasing boundary conditions where ease-of-use effects attenuate (Marikyan et al., 2022b). Rather than dismissing TAM's theoretical foundation, we interpret this divergence as revealing important boundary conditions where cognitive ease loses predictive validity in contemporary complex enterprise systems. Several mechanisms may explain this paradox. Mandatory adoption contexts in digital transformation initiatives fundamentally alter psychological calculus underlying technology acceptance—when organizations mandate blockchain usage for critical business processes, individuals cannot decline adoption based on complexity concerns, rendering ease-of-use perceptions irrelevant to behavioral formation (Malik, 2015; Tamilmani et al., 2021). Strategic value preemption suggests that when technologies promise transformative capabilities—enhanced security, disintermediation, transparency—users willingly tolerate complexity in exchange for strategic benefits, aligning with contemporary expectancy-value frameworks in digital innovation contexts (Chatterjee & McGinnis, 2010; Sharma & Sharma, 2023).

Expertise heterogeneity represents another plausible mechanism particularly relevant in Industry 4.0 contexts. If respondents comprise technically sophisticated users—blockchain developers, cryptography specialists, digital transformation professionals—blockchain complexity may pose minimal cognitive burden, creating ceiling effects where ease-of-use variance becomes restricted and predictive validity diminishes (R. K. Dwivedi, 2024; R. D. Raut et al., 2019). This receives support from recent innovation diffusion research observing that digital native early adopters possess technical expertise enabling them to navigate complexity deterring mainstream users (Chawla et al., 2023; Ng, 2012). Measurement inadequacy offers a methodological explanation: generic ease-of-use scales developed for conventional software may fail to capture blockchain-specific usability dimensions like cryptographic key management, smart contract programming, and consensus algorithm comprehension. Recent systematic reviews confirm perceived ease of use demonstrates stronger effects for consumer technologies than enterprise blockchain platforms, and stronger effects for voluntary than mandatory adoption contexts in organizational digital transformation (Alshurideh et al., 2023; Nuseir et al., 2023). Blockchain adoption—characterized by utilitarian objectives within organizational mandates—falls within parameter space where contemporary TAM applications predict attenuated ease-of-use effects.

 

**Perceived Usefulness: The Autonomous Pathway**

In stark contrast to perceived ease of use, perceived usefulness demonstrates substantial influence on both adoption decisions and usage intentions, with the direct pathway to intention substantially exceeding the indirect pathway through adoption. This asymmetric pattern reveals that utility perceptions operate through mechanisms fundamentally different from contextual enablers, suggesting dual-process architectures where deliberative utility assessments bypass institutional gatekeeping constraining contextual influences. The direct-only mediation pattern contradicts sequential adoption models proposing that all individual-level cognitions translate into intentions through organizational adoption stages. Instead, utility perceptions appear to form independently of organizational adoption status, potentially reflecting anticipatory beliefs shaped by external information sources—media coverage, peer testimonials, cryptocurrency experiences—that precede organizational implementation. This aligns with contemporary social cognitive theory applications proposing that outcome expectations in digital contexts form vicariously through symbolic modeling rather than requiring direct experience (Chatterjee & McGinnis, 2010; R. K. Dwivedi, 2024).

The theoretical contribution extends beyond documenting direct effects to illuminating why utility perceptions escape institutional mediation while contextual factors do not. We propose three mechanisms producing this asymmetry grounded in recent behavioral IS research. First, utility beliefs reflect subjective probability assessments accessible through imagination and analogical reasoning in digital transformation contexts, enabling belief formation without direct experience or organizational permission, whereas contextual factors represent objective conditions requiring organizational provision (Ansell & Trondal, 2018; N. P. Podsakoff et al., 2009). Second, utility perceptions draw on general knowledge about blockchain capabilities—security, transparency, efficiency—transferable across organizational contexts and amplified through digital communication channels, whereas contextual enablers exhibit organization-specific configurations not readily generalizable (Queiroz & Fosso Wamba, 2019; Wamba & Queiroz, 2019). Third, utility assessments activate motivated reasoning where individuals selectively attend to confirming evidence due to innovation enthusiasm or career advancement motives in digital economy contexts, creating belief persistence independent of organizational adoption status (Albayati et al., 2020). Contemporary technology acceptance frameworks propose behavioral intentions reflect multiplicative combinations of outcome expectations and capability beliefs, with our findings suggesting these components operate through distinct pathways in enterprise blockchain contexts.

**Theoretical Integration and Multi-Level Dynamics**

The differential mediation patterns complete mediation for contextual factors versus direct-only effects for perceived usefulness—reveal a dual-pathway architecture challenging single-level theoretical frameworks prevalent in current IS research. This configuration suggests blockchain adoption operates through parallel causal mechanisms: a bottom-up pathway where individual utility perceptions aggregate to create adoption pressure, and a top-down pathway where organizational infrastructure provision enables individual engagement. Neither pathway alone suffices; both must converge for widespread adoption to materialize. This dual-pathway model extends contemporary multi-level theorizing in information systems research by demonstrating that macro and micro levels interact through complementary rather than substitutable mechanisms (Mikalef & Gupta, 2021). Macro-level contextual enablers create necessary conditions—infrastructure, governance, regulatory clarity—without which adoption cannot occur regardless of individual enthusiasm. Micro-level utility perceptions create sufficient motivation—strategic vision, outcome confidence—without which adoption will not occur despite infrastructure availability. Successful diffusion requires both necessity and sufficiency, explaining why blockchain exhibits slower adoption than initially projected despite widespread recognition of its potential (Rejeb et al., 2022, 2023).

The theoretical architecture illuminates temporal dynamics often obscured in cross-sectional research. In early adoption stages, utility perceptions may form among innovation champions, creating grassroots demand pressuring organizations toward infrastructure investment. As organizational adoption progresses, infrastructure availability reduces technical barriers, enabling mainstream users lacking initial enthusiasm to engage through mandates or peer influence. This suggests shifting causal dominance across diffusion stages: utility perceptions dominating early adoption while contextual enablers govern later diffusion. The findings both confirm and contradict patterns in recent blockchain research. The strong infrastructure influence aligns with contemporary studies demonstrating technical capabilities constitute critical prerequisites (Kouhizadeh et al., 2020, 2023; Wamba & Queiroz, 2022), though our effect magnitude exceeds typical values reported in recent meta-analyses, suggesting blockchain imposes more stringent technical requirements than conventional enterprise systems (Treiblmaier et al., 2021). The organizational governance influence corroborates emerging research emphasizing new coordination mechanisms in distributed ledger contexts (Bauer et al., 2019; Lumineau et al., 2021), while complete institutional mediation extends this literature by demonstrating governance structures enable adoption without directly motivating individual usage.

**Boundary Conditions, Implications, and Future Directions**

Several boundary conditions constrain theoretical generalizability and warrant explicit consideration. Organizational context likely moderates the mediation patterns documented herein, with findings potentially characterizing medium-to-large enterprises with formalized digital transformation governance and hierarchical decision structures. Small-to-medium enterprises and decentralized autonomous organizations may exhibit different patterns where individual and organizational adoption boundaries blur in agile innovation contexts (Kimberly & Evanisko, 1981; Sarmah et al., 2020). Technology maturity represents another critical contingency—blockchain currently occupies early-to-middle adoption stages where complexity remains significant and infrastructure evolving. As the technology matures with standardized interfaces and commoditized infrastructure platforms, perceived ease of use may regain explanatory significance as implementation variance increases (Papadopoulos et al., 2017; Wamba & Queiroz, 2022). Industry sector likely conditions determinant strength: highly regulated industries may exhibit amplified environmental influences through compliance mandates, technology-intensive sectors may demonstrate stronger infrastructure effects given existing digital capabilities, and consumer-facing industries might show elevated utility perception effects driven by customer expectations (Kumari et al., 2023).

Findings yield actionable insights for organizations pursuing digital transformation through blockchain and policymakers seeking to accelerate technology diffusion. The complete institutional mediation indicates organizations must prioritize formal adoption decisions and infrastructure investments before expecting individual engagement, suggesting grassroots digital innovation initiatives without organizational commitment prove ineffective given infrastructure dependencies. Organizations should establish clear digital transformation mandates, allocate dedicated resources, and implement blockchain governance frameworks before soliciting broad participation (Kumaraswamy & Chitale, 2012; Yavari et al., 2020). The null ease-of-use effect implies interface simplification may yield limited returns compared to utility demonstration in enterprise contexts, redirecting resources toward developing compelling use cases and communicating strategic value propositions aligned with organizational digital strategies (Akter et al., 2024). For policymakers, findings suggest regulatory clarity and institutional legitimation facilitate blockchain adoption more effectively than technology subsidies alone, indicating establishing clear legal frameworks governing smart contracts and providing regulatory certainty may remove critical environmental barriers in digital economy development ((Hughes et al., 2007) .

This research exhibits limitations warranting acknowledgment and suggesting future research directions. Cross-sectional design precludes definitive causal inference, with longitudinal studies needed to disentangle temporal sequencing from causal mechanisms in blockchain implementation trajectories. Self-reported measures introduce common method variance risks, suggesting future research should incorporate behavioral analytics and blockchain transaction data. Geographic and industry specificity limits generalizability, warranting multi-country replication and cross-industry comparative studies. Future research should investigate configurational approaches identifying equifinal adoption pathways, temporal dynamics examining determinant evolution across implementation stages, microfoundational studies exploring individual learning mechanisms linking organizational adoption to personal capability development, and experimental designs manipulating contextual factors to establish causal relationships complementing field studies' ecological validity (Marikyan et al., 2022a).

## CONCLUSION

This study advances blockchain adoption theory by revealing asymmetric causal pathways through which organizational contexts and individual perceptions shape technology diffusion. Three principal findings emerge: technological infrastructure, organizational governance, and environmental conditions demonstrate complete mediation through institutional adoption, with no direct pathways to usage intentions; perceived usefulness exhibits autonomous direct effects bypassing institutional gatekeeping; and perceived ease of use demonstrates non-significant relationships with both adoption and intention, contradicting Technology Acceptance Model's foundational propositions. These patterns unveil a dual-pathway architecture where macro-level contextual enablers create necessary conditions through institutional legitimation, while micro-level utility perceptions generate sufficient motivation independently of organizational adoption status. The integrated Technology-Organization-Environment and Technology Acceptance Model framework achieves substantial explanatory power and superior predictive relevance, validating theoretical pluralism in contemporary digital innovation research (Kouhizadeh et al., 2019; Lumineau et al., 2021; Mariani & Dwivedi, 2024).

Practically, organizations should prioritize formal adoption decisions and infrastructure investments before expecting individual engagement, as grassroots initiatives prove ineffective given institutional mediation requirements. The null ease-of-use finding redirects resources from interface optimization toward utility demonstration through compelling use cases communicating strategic value. For policymakers, regulatory clarity and institutional legitimation facilitate adoption more effectively than technology subsidies alone. This research exhibits limitations warranting future inquiry: cross-sectional design precludes definitive causal inference; self-reported measures introduce common method variance risks; and geographic specificity limits generalizability. Future research should investigate longitudinal dynamics tracking determinant evolution across implementation stages, configurational approaches identifying equifinal adoption pathways, and experimental designs establishing causal priority while examining how institutional environments and industry sectors moderate theoretical relationships in digital transformation contexts (Baptista et al., 2020; Zhao et al., 2024).

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