

Leveraging Blockchain and Smart Contracts as Institutional Levers for Economic Transformation in Africa: A Multi-Case Analysis

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ABSTRACT

Despite its resource wealth, Africa continues to struggle with institutional inefficiencies, financial exclusion and weak governance systems that constrain inclusive development. This paper examines how blockchain technology and smart contracts can contribute to economic empowerment, institutional transparency and governance reform across the continent. Drawing on a qualitative multiple-case study approach, the analysis synthesizes documentary evidence from blockchain initiatives implemented in financial services, land administration, public governance and agricultural supply chains across eleven African countries. Through cross-case comparison, four interrelated strategic pathways for blockchain adoption are identified: regulatory and governance reform; infrastructure and connectivity; capacity building and local innovation; and sectoral pilot and integration. The analysis further identifies a consistent gap between observed outcomes and expected outcomes, which reflect the aspirational projections found in policy narratives and project plans. While regulatory clarity and infrastructure readiness are associated with enabling conditions, lasting developmental impact appears to depend on complementary investments in enforcement capacity, human capital and alignment with national digital strategies. This paper offers a documentary evidence-based framework to guide policymakers and development partners in progressing from isolated proofs-of-concept toward scalable, institutionally embedded blockchain solutions. It concludes that meaningful blockchain-driven transformation in Africa requires a coordinated, multi-stakeholder approach deliberately tailored to specific national contexts.

KEYWORDS: Africa, Blockchain Technology, Digital Transformation, Economic Transformation, Inclusive Growth, Smart Contracts, Sustainable Development.

I. INTRODUCTION

Africa occupies a paradoxical position in global development. The continent holds vast natural resources, a young and growing population and expanding digital infrastructure, yet persistent institutional weaknesses, financial exclusion and governance deficits continue to constrain economic transformation. Conventional technological interventions have achieved modest gains but have frequently failed to resolve the deeper problems of institutional trust, accountability and systemic transparency. This observation points to a need for technologies that do not merely digitize existing processes but can potentially reconfigure the incentive structures and verification mechanisms on which economic and social coordination depend. Blockchain technology and smart contracts have attracted growing scholarly and policy attention in this context. As decentralized systems built on immutability, cryptographic security and distributed consensus (Kundu, 2019), blockchain introduces a novel architecture for organizing economic interactions without reliance on centralized intermediaries. Davidson, De Filippi and Potts (2018) conceptualize blockchain as a new type of economic institution, a

coordination mechanism that embeds rules of exchange directly into technical protocol. For Africa, this framing carries potential significance. Many of the continent's development constraints stem not from an absence of activity but from the limited capacity of existing institutions to credibly enforce property rights, authenticate transactions and prevent rent extraction by intermediaries.

Despite this potential, blockchain applications across Africa remain largely fragmented. Initiatives in financial inclusion, land registration, agricultural supply chains and public governance have typically operated as isolated pilots, often dependent on external donors, disconnected from national digital strategies and lacking the institutional infrastructure needed to sustain or replicate their results. The scholarly literature largely mirrors this fragmentation, focusing on sector-specific pilots or cataloguing enabling and constraining factors without offering an integrated account of how countries can move from experimentation to systemic adoption (Frizzo-Barker et al., 2020; Kshetri, 2021). This study addresses that gap by introducing a strategic framework for blockchain integration into Africa's socio-economic architecture. Through qualitative multi-case analysis of documentary evidence from eleven African countries over the period 2016–2025, the study identifies four interdependent pathways that appear essential for scalable adoption: (i) regulatory and governance reform; (ii) infrastructure and connectivity; (iii) capacity building and local innovation; and (iv) sectoral pilots and integration. The framework is not a checklist. It is a process-oriented account of how enabling conditions interact, sequence and reinforce one another and why their fragmentation so consistently appears to prevent pilot successes from becoming systemic change. The study's contribution is primarily analytical and policy-oriented. Rather than claiming to document definitive causal outcomes, it synthesizes comparative evidence into a coherent framework that can guide policymakers and development partners in designing blockchain strategies suited to Africa's institutional diversity, infrastructural realities and socio-economic conditions.

II. LITERATURE REVIEW

This section reviews existing conceptual and empirical scholarship on blockchain technology and smart contracts, situating the study within broader debates on sustainable development, financial inclusion and institutional reform in Africa.

A. Blockchain and Smart Contracts: A Conceptual Overview

Blockchain is a distributed ledger technology that records transactions across a network of nodes in a transparent, tamper-resistant manner (Ibor et al., 2023). Unlike conventional databases that rely on a trusted central authority, blockchain achieves data integrity through cryptographic hashing and consensus mechanisms. Each block of transaction data is linked to the preceding block via a cryptographic hash, forming an immutable chain that makes unauthorized alterations computationally prohibitive (Bidve et al., 2024). As illustrated in Figure 1, each block has a BlockHash, a reference to the Previous BlockHash, a Timestamp, Transaction Data and a Merkle Root. The Merkle Root is particularly significant because it provides a cryptographic summary of all transactions in a block, enabling efficient and tamper-evident verification. The chain structure means that altering any historical record would require recalculating all subsequent block hashes across the distributed network which is a task that is computationally infeasible at scale. Key characteristics such as decentralization, immutability, transparency and consensus-driven validation, position blockchain as a potentially viable architecture for environments where institutional trust is weak or contested (Curry, 2025).

Smart contracts extend blockchain's utility by enabling automated execution of predefined agreements. These are self-executing programs, typically written in languages such as Solidity or Go, that trigger actions when specified conditions are met without requiring a human

intermediary (Gao, 2020). When combined with blockchain's immutable record-keeping, smart contracts can be associated with reductions in the time, cost and principal-agent risks involved in complex multi-party transactions (Ibekwe et al., 2025). The convergence of these two technologies has generated interest across sectors including finance, healthcare, supply chain management and public administration (Ahmed, 2025).

Several blockchain frameworks are currently deployed in development contexts. Public chains such as Ethereum offer openness and interoperability but face scalability constraints. Permissioned systems such as Hyperledger Fabric allow institutions to control participation and data access while retaining distributed verification, a configuration often considered more suitable for government applications (Androulaki et al., 2018). The choice of architecture carries significant implications for context-appropriateness, energy consumption and institutional compatibility, all of which are particularly relevant in Africa's heterogeneous governance environments.

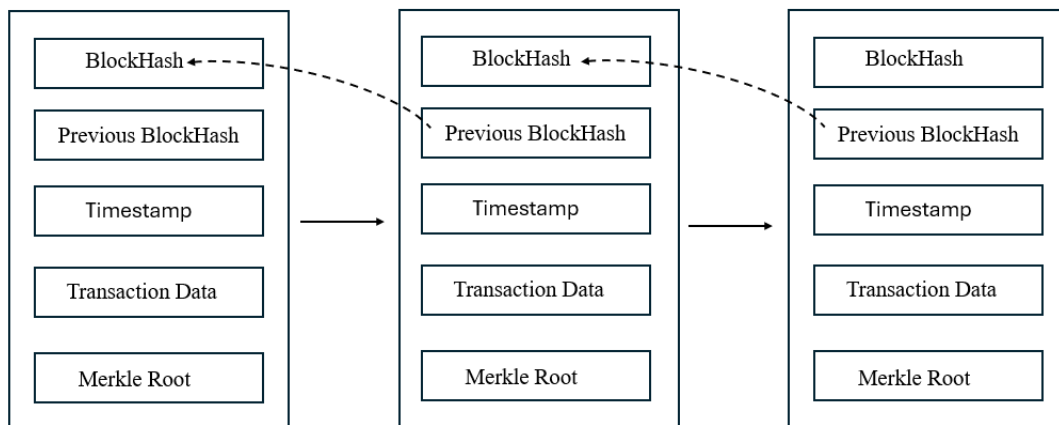


Figure 1: Basic structure of blockchain

B. Theoretical Foundations

Three complementary theoretical frameworks guide this study's analysis:

- (a). *Institutional Economic Theory*, principally associated with the work of North (1990), holds that institutions which comprises of formal rules, informal norms and enforcement mechanisms that govern social interaction determine economic performance by shaping incentives and reducing transaction costs. Where institutions are weak, verification costs rise, market participation narrows and corruption thrives. In much of Africa, property rights enforcement is unreliable, contract enforcement depends on relationships rather than rules and public administration is characterized by information asymmetry and rent-seeking. From this perspective, blockchain may be understood as a potential technical substitute for inclusive institutional functions (Acemoglu & Robinson, 2012) that are absent or dysfunctional, embedding enforcement directly into code rather than relying on state capacity. This theoretical lens informs Pathway 1 (Regulatory and Governance Reform) and underpins the study's attention to institutional legitimacy as a precondition for scale.
- (b). *The Technology–Organization–Environment (TOE) Framework*, developed by Tornatzky and Fleischer (1990), offers a structured approach to understanding technology adoption. It identifies three contextual dimensions: the technological (the perceived attributes of an innovation, including its complexity and compatibility); the organizational (internal readiness, resources, and capacity for change); and the environmental (regulatory frameworks, market structures, and infrastructural conditions). In the African context, the

TOE framework helps account for why blockchain adoption has been uneven, the same technology confronts dramatically different organizational and environmental conditions across countries and sectors (Oliveira & Martins, 2011). This study draws on the TOE framework to analyze pathway-specific enablers and barriers, particularly in Pathways 2 and 3.

- (c). *Innovation Systems Theory* conceptualizes technological change as a systemic, interactive process shaped by the dynamic interplay of governments, firms, research institutions and civil society (Freeman, 1987). Nelson (1993) and Patel (1994) emphasize that innovation depends not only on technical capacity but also on institutional arrangements, knowledge networks and learning mechanisms within a given national or sectoral context. Applied to blockchain in Africa, this framework suggests that adoption difficulties often reflect systemic weaknesses such as fragmented regulation, limited absorptive capacity and missing linkages between innovators and institutions rather than purely technical shortcomings. Innovation Systems Theory directly informs Pathway 3 (Capacity Building and Local Innovation) and the study's emphasis on absorptive capacity as a condition for sustainability.

Together, these three frameworks provide a multi-level analytical lens that integrates institutional, organizational and systemic dimensions of blockchain adoption. They inform both the derivation of the four strategic pathways and the analysis of observed versus expected outcomes presented in Section IV.

C. Blockchain as an Institutional Technology

Moving beyond its technical architecture, blockchain may be understood as an institutional technology, one that potentially reconfigures the foundations of trust, accountability and coordination in socio-economic systems. Traditional institutions achieve these functions through hierarchies, regulations and intermediaries. Blockchain replaces or supplements these mechanisms with cryptographic consensus and automated enforcement (Davidson et al., 2018). Tapscott and Tapscott (2016) describe this shift as moving from institutions built on human trust to systems built on mathematical proof. In the language of Institutional Economics, blockchain embeds the 'rules of the game' directly into digital protocol, potentially reducing the discretionary authority and the associated potential for abuse of intermediaries. This reframing is particularly relevant for Africa, where governance failures are often associated with the discretionary behavior of intermediaries rather than a mere absence of formal rules. Where property records, public expenditures, or supply chain transactions are placed on an immutable ledger, the scope for manipulating information may be reduced and accountability may become more structurally embedded. This is the theoretical logic underpinning many of the blockchain applications reviewed in this study. However, as Atzori (2017) and Reijers et al. (2016) caution, the institutional promise of blockchain should not be overstated. Immutable records are only as reliable as the data entered into them. Without robust identity verification and off-chain governance mechanisms, blockchain may replicate or even entrench existing power asymmetries under a veneer of technological legitimacy. This tension between blockchain's institutional promise and its practical limitations runs through the comparative analysis presented in Section IV.

D. Blockchain for Sustainable Development and Inclusive Growth

The literature increasingly situates blockchain within discussions of the Sustainable Development Goals (SDGs), particularly those related to poverty reduction, gender equality and institutional strengthening (United Nations Development Programme, 2023). By potentially improving transparency in public finance, enabling identity systems for the unbanked and reducing transaction costs in agricultural markets, blockchain is associated with theoretical contributions to SDG 1 (No Poverty), SDG 8 (Decent Work and Economic Growth), SDG 10 (Reduced Inequalities) and SDG 16 (Peace, Justice, and Strong Institutions). These associations remain largely theoretical pending robust evaluation evidence. Evidence from high-income contexts provides partial support for these claims. Estonia's e-governance model suggests that blockchain-based public records may be associated with improvements in data integrity and citizen access to services (Ojo & Adebayo, 2017). Singapore's use of blockchain in trade finance has been documented in association with reductions in settlement times and documentary fraud (Alekseenko, 2022). However, Frizzo-Barker et al. (2020) caution that blockchain's developmental applications remain largely at proof-of-concept stage, with limited rigorous evidence of sustained impact at scale. The gap between theoretical promise and demonstrated outcomes is a central concern of this study. In the African context, pilot initiatives in Kenya, Nigeria, Ghana, Rwanda and Ethiopia have been associated with potential for addressing financial exclusion, land tenure insecurity and agricultural supply chain inefficiencies (Mhlanga, 2023; Acheampong & Bellini, 2025). Yet adoption remains fragmented, donor-dependent and constrained by infrastructure gaps and regulatory uncertainty. Marr and Morales (2020) and Kshetri (2021) argue that realizing blockchain's development potential in low and middle-income contexts requires not just technical deployment but coordinated institutional reform, stakeholder engagement and sustained investment in human capacity.

E. Sectoral Applications in Africa

The following subsections review existing evidence on blockchain applications in four domains most relevant to Africa's development agenda. For each domain, specific documented cases are cited as the evidentiary basis for the claims made.

(a). Digital Payments and Financial Inclusion

Approximately 57 percent of adults in Sub-Saharan Africa lack access to formal financial services (World Bank, 2024). Blockchain-based payment systems and decentralized finance (DeFi) platforms have attracted attention as potential channels for reaching the unbanked by reducing the cost of transactions and eliminating the need for traditional banking infrastructure. Cross-border remittances are a prominent use case. Ahishakiye et al. (2018), drawing on Uganda's experience, document that blockchain-based platforms are associated with settlement times and fee reductions below those of conventional remittance corridors. In Nigeria, the Central Bank's regulatory sandbox introduced in 2021 facilitated fintech pilots that demonstrated measurable cost reductions for SME cross-border payments. Insights from this process subsequently informed the National Blockchain Policy (NITDA, 2023). Central bank digital currencies (CBDCs) represent a further frontier, with Nigeria's eNaira offering an early though uneven example of a state-sponsored digital currency aimed at financial inclusion (Ozili, 2023). The evidence is, however, mixed. Ozili (2020) finds that while mobile money has been associated with expanded financial access in East Africa, more complex DeFi products face significant barriers including digital literacy deficits, device ownership gaps and unreliable connectivity. The distinction between mobile payment adoption and blockchain-

specific adoption is also frequently conflated in the literature, making it difficult to attribute outcomes specifically to blockchain's technical architecture rather than to broader digital payment trends.

(b). Agricultural Supply Chains

Blockchain-based traceability systems in agricultural value chains address a specific, well-documented problem such as information asymmetry between smallholder farmers and buyers, which allows intermediaries to undervalue produce and obscures provenance for export certification. Pilot systems in Uganda's coffee sector (Distor et al., 2023), Ethiopia's agricultural pilot initiatives (Mwewa et al., 2024) and Kenya's supply chain pilots (Kaluvu et al., 2025) are associated with reductions in information asymmetry, enhanced trust with buyers, and improved negotiating positions for smallholder farmers. Kshetri (2021) situates these initiatives within a broader argument that blockchain may contribute to reducing rent extraction and improving market efficiency in commodity-dependent economies. However, the same author cautions that without sufficient connectivity, device access and farmer training, blockchain systems risk replicating existing inequalities in a digital form. These findings directly inform the evidence base for Pathways 3 and 4 in Section IV.

(c). Land Registration and Property Rights

Land tenure insecurity is among Africa's most persistent development constraints, driving conflict, limiting access to credit and suppressing agricultural investment. Blockchain-based land registries offer the possibility of tamper-resistant records that may reduce fraud, lower transaction costs and enable unregistered land to serve as verifiable collateral, directly addressing the 'dead capital' problem identified by De Soto (2000). Rwanda's land administration system represents one of the more advanced cases, having built on prior digitization efforts to pilot blockchain-based records, document improvements in auditability; Hughes et al. (2022). Ghana's Bitland and BenBen initiatives explored similar possibilities in customary land contexts (Mintah et al., 2021). Peiró and Martínez García (2017) review international evidence from Georgia and several European jurisdictions, finding that blockchain land registries are associated with reductions in fraud and improvements in administrative efficiency where pre-existing digital infrastructure is adequate. Kaczorowska (2019) cautions, however, that the complex rules governing land transfer and registration as well as the significant socio-economic importance of real estate transactions as unique high-value assets must be carefully considered in any implementation design. These cases provide the specific evidentiary grounding for the infrastructure pathway analysis in Section IV.

(d). Governance, Public Administration and Funds Management

Blockchain applications in public governance span electoral systems, digital identity, healthcare administration and development fund management. In Sierra Leone's 2018 general election, a blockchain-based parallel vote tabulation system was piloted. Subsequent analysis clarified that official results remained managed through conventional channels, illustrating the distinction between technical feasibility and institutional integration (Kumbharkar et al., 2024). Separately, South Africa's Project Khokha 2.0 for low-income populations, integrating blockchain with biometric smart cards has been associated with a documented 30 percent reduction in identity fraud in the evaluated context (Mandinyanya & Malele, 2025). Uganda's partnership with MediConnect to track prescription medications illustrates blockchain's potential use in pharmaceutical supply chain integrity (Wilhelm, 2019). The World Bank's FundsChain initiative, tested across several African countries including Ethiopia, Kenya, and

Mauritius, documented associations between distributed ledger use and improvements in the transparency of development project disbursements and audit trails (World Bank Group, 2025). Across these cases, Olnes et al. (2017) observe that governance applications of blockchain tend to be more complex than those in commerce, because they involve not just trust between parties but the legitimate authority of the state, legal enforceability and the participation of citizens as rights-holders rather than market actors. This observation is borne out across the cases reviewed in Section IV.

F. Identified Research Gaps

Existing studies on blockchain in Africa have made important contributions in documenting pilot initiatives and cataloguing enabling factors and barriers. However, as Frizzo-Barker et al. (2020) and Kshetri (2021) note, this body of work remains fragmented, dominated by isolated case studies, sector-specific analyses, and factor inventories that offer limited guidance on the process of moving from pilot success to systemic adoption. A second gap concerns the relationship between documented outcomes and anticipated impacts. Much of the literature conflates technical feasibility with developmental impact, presenting successful pilot demonstrations as evidence of blockchain's transformative potential without adequately interrogating the institutional and organizational conditions required for scale and durability. This study addresses both gaps. It reframes familiar enabling factors such as regulation, infrastructure, capacity and pilots within a dynamic, pathway-oriented model that explains how they interact and sequence over time. It also introduces an explicit and operationalized distinction between observed and expected outcomes (see Section IV and Table 2), grounding the analysis in what documentary evidence actually shows rather than what policy narratives project.

III. METHODOLOGY

This study employed a qualitative multiple-case study design (Yin, 2018) to investigate the strategic pathways and contextual determinants of blockchain adoption across Africa for economic transformation. The case study approach is appropriate when the research question concerns a 'how' or 'why' question about a contemporary phenomenon in context, particularly where the boundaries between phenomenon and context are not sharply defined. It is not intended to support statistical generalization but to enable analytical generalization, the development of theoretically grounded propositions from comparative documentary evidence. The methodology involved a systematic, four-phase process of case selection, data collection, thematic analysis and pathway synthesis, as shown in Figure 2. The four sequential phases: Case Selection, Data Collection & Triangulation, Thematic Analysis and Pathway Synthesis reflect the progressive movement from evidence gathering to interpretive framework building. Findings were checked back against case evidence before final pathway formulation.

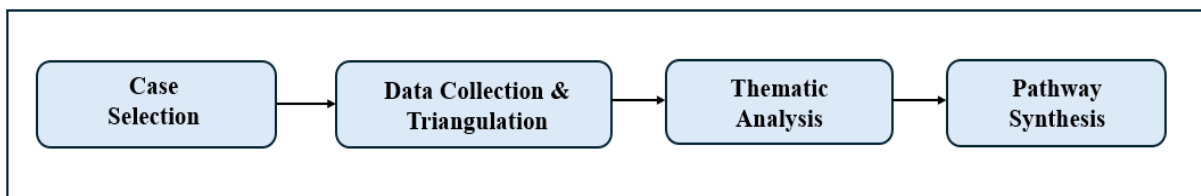


Figure 2: Research Design and Analytical Process

A. Case Selection

Eleven African countries were selected as primary cases: Kenya, Nigeria, Ghana, Rwanda, Ethiopia, South Africa, Botswana, Uganda, Sierra Leone, Zambia and Mauritius. Selection followed three explicit criteria. First, each country had documented evidence of blockchain or smart contract initiatives with relevance to public governance or development-oriented applications, making them information-rich cases for qualitative analysis (Patton, 2015). Second, the cases collectively represented sectoral diversity, spanning digital financial services, land administration, public governance and agricultural supply chains. Third, the cases were selected to reflect regional heterogeneity across East, West, Southern and North Africa, capturing variation in institutional maturity, digital infrastructure and regulatory environment. To contextualize African experiences within broader international trends, secondary comparator cases from Singapore, Estonia, Georgia, Brazil and India were also examined. These were selected on the basis of their well-documented blockchain governance models, offering benchmarks for regulatory frameworks, technical deployment and scaling strategies. The comparator cases inform the analysis but are not treated as the primary unit of analysis.

B. Data Collection

Data were collected from documentary sources covering the period 2016–2025. This timeframe was selected to capture the emergence, pilot phase and early institutionalization of blockchain applications in public and development contexts across Africa. Three categories of source were used: (i) peer-reviewed academic literature identified through systematic keyword searches in databases including Scopus, Web of Science, and Google Scholar; (ii) policy and regulatory documents including national blockchain strategies, regulatory sandbox frameworks, legislative texts, and official consultation papers; and (iii) credible institutional reports published by governments, multilateral organizations, development agencies and recognized industry bodies. Inclusion criteria required that sources document identifiable blockchain or smart contract initiatives, provide sufficient contextual detail on implementation design or observed outcomes and be publicly accessible and verifiable. Purely speculative sources, promotional materials lacking empirical basis and sources without adequate documentation of implementation context were excluded. This reliance on documentary evidence has inherent limitations: documents represent the perspectives of their authors, may not capture informal implementation barriers and may reflect advocacy rather than objective assessment. These limitations are discussed in Section V.

C. Analytical Procedure

Data analysis followed a structured thematic content analysis approach (Braun & Clarke, 2006, 2023), implemented through an iterative, two-author process to enhance reliability. Analysis proceeded in three stages.

In the first stage (within-case analysis), each country was analyzed across four pre-defined dimensions derived from the integrated theoretical framework: regulatory and governance context; infrastructure and connectivity; human and organizational capacity; and sectoral implementation outcomes. Primary coding of all materials was carried out and then subsequent independent coding of 30% of samples was also carried out. Discrepancies which arose in approximately 12 percent of coded segments were resolved through structured discussion, refining the codebook before proceeding to axial coding that grouped initial codes into coherent thematic categories within each dimension. In the second stage (cross-case synthesis), coded data were organized into the comparative matrix presented in Table 3 to identify recurrent

patterns across cases. Both authors engaged in constant comparison, iteratively discussing and refining emerging themes to ensure they were substantiated by evidence from multiple national contexts rather than single cases. In the third stage (pathway synthesis), patterns corroborated by evidence from at least two primary African cases were abstracted into higher-order thematic constructs. These constructs were subject to debate between authors, and consensus was reached on their formulation and scope.

D. Coding Transparency: Illustrative Examples of Raw Data to Theme Translation

To enhance transparency and reproducibility, Table 1 below illustrates how selected raw documentary statements were assigned to initial codes, grouped into axial categories and ultimately abstracted into the four strategic pathways. Please, note that these are just few examples drawn from the cases examined.

Table 1: Sample Coding Process for the different Pathways

Country / Case	Raw Documentary Statement (Source)	Initial Code	Axial Category	Strategic Pathway
Sierra Leone – Electoral Governance	"The Sierra Leone pilot shows the potential for blockchain to provide secure and transparent elections" (Qureshi, 2024; Kumbharkar et al., 2024; Farhan et al., 2024; Williams & Agbesi, 2022; Isibor, 2023; Jafar et al., 2021; Zambrano et al., 2018, Ohize et al., 2024)	Pilot-level transparency without legal enforceability	Regulatory void constraining institutionalization beyond pilot	Pathway 1: Regulatory & Governance Reform
Rwanda – Land Administration	"In Rwanda, the Ubutaka app prevented the double selling of land and the forgery of signatures by recording key authorizations and approvals on the blockchain."; "In general, barriers to the technology diffusion and adoption in Rwanda include high cost of local data hosting, low device and internet penetration" (Hughes et al., 2022; Distor et al., 2023; Sabiiti, 2021; Bandara, 2021; Ndemo, 2026)	Advanced ICT enabling auditability gains; internet penetration as scale barrier	Infrastructure as partial enabler; internet penetration gap constraining national rollout	Pathway 2: Infrastructure & Connectivity
Ethiopia – Agricultural Supply Chains	"Ethiopia faces a skills gap, with few individuals and organizations having the expertise to develop and implement blockchain solutions." (Mwewa et al., 2024; Mihret, 2025; Abebe & Semegn, 2020)	Skill deficit and vendor lock-in undermining post-funding sustainability	Human capacity deficit constraining institutional ownership	Pathway 3: Capacity Building & Local Innovation
Multi-Country – FundsChain (Ethiopia, Kenya, Mauritius)	"FundsChain enables development partners to track funds throughout the lifecycle of a project, and to prepare comprehensive project execution reports, allowing for robust data analysis." (World Bank Group, 2025; Chowdary et al., 2024)	Multi-country pilot validating transparency gains; scaling conditional on national integration	Donor-driven pilot with fragile institutionalization path	Pathway 4: Sectoral Pilot & Integration

It is important to be clear about the epistemological character of the findings: the pathways are analytically derived constructs grounded in documentary evidence, not empirically tested causal models. They represent the authors' best interpretive account of the conditions and

sequencing that the evidence suggests are important for blockchain adoption, rather than experimentally verified propositions.

IV. RESULTS AND ANALYSIS

This section presents the findings from the qualitative multi-case analysis. Through systematic thematic and comparative synthesis of documentary evidence, four interdependent pathways emerged as central to scalable, inclusive and sustainable blockchain adoption across Africa: (i) regulatory and governance reform; (ii) infrastructure and connectivity; (iii) capacity building and local innovation; and (iv) sectoral pilot and integration (Figure 3). Each pathway captures a distinct dimension of blockchain readiness: institutional, technical and human that must be addressed in combination rather than isolation as suggested by the evidence.

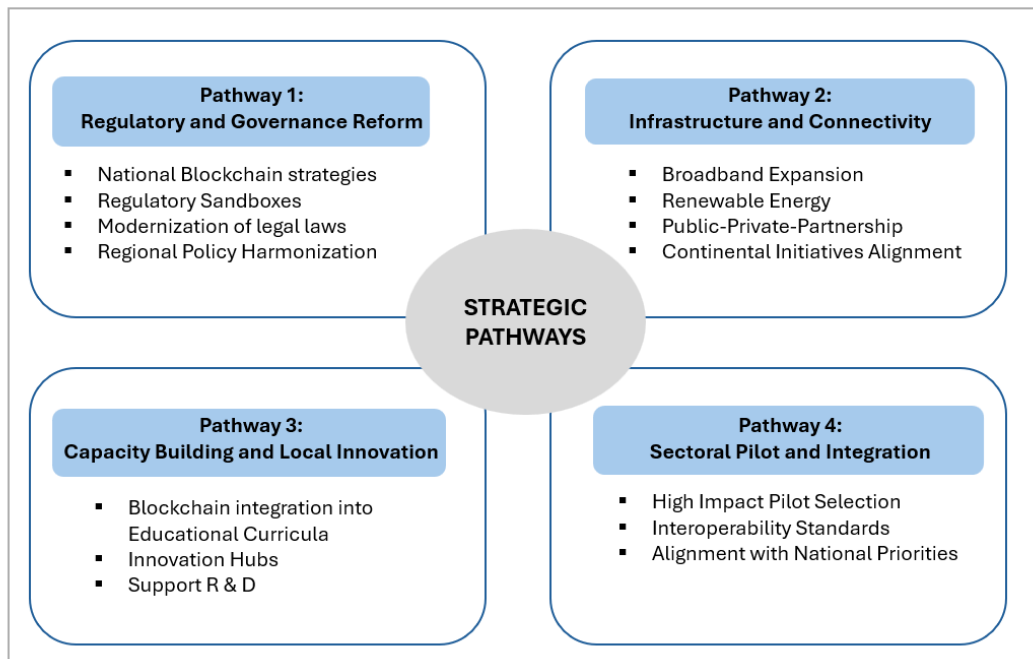


Figure 3: Strategic Pathways for Blockchain and Smart Contract Adoption in Africa

The four quadrants depicted in Figure 3 represent interdependent conditions rather than sequential steps. Pathway 1 (Regulatory and Governance Reform) establishes institutional legitimacy, Pathway 2 (Infrastructure and Connectivity) provides the technical substrate, Pathway 3 (Capacity Building and Local Innovation) develops the human and organizational engine of sustainability and Pathway 4 (Sectoral Pilot and Integration) operationalizes the three preceding conditions through problem-driven, institutionally anchored implementation. The center ('Strategic Pathways') emphasizes that the quadrants are mutually reinforcing. Weakness in any one dimension appears to constrain progress across the others, as documented in Section IV.B.

A. Analytical Rationale for Pathway Derivation

The four pathways were inductively derived through cross-case thematic analysis grounded in observed documentary patterns rather than deduced from theory alone. A key analytical move in this process was formally distinguishing between observed and expected outcomes. To operationalize this distinction, each outcome documented in the sources was classified against the following criteria as illustrated in Table 2 below:

Table 2: Operational Definitions for Outcome Classification

Outcome Type	Operational Definition	Evidence Standard
Observed Outcome	A result directly documented in an independently verifiable source (peer-reviewed study, government audit, multilateral evaluation) as having occurred within the bounds of a specific initiative.	Cited in at least one peer-reviewed or credible institutional source; describes a specific, bounded result; uses past-tense attribution.
Expected Outcome	A result projected, anticipated or claimed in policy narratives, project plans, or advocacy documents as the intended or hoped-for benefit of a blockchain initiative.	Sourced from policy documents, project design documents, or aspirational literature; uses future-oriented or conditional language; not independently verified post-implementation.
Gap Score	Assessed qualitatively as Narrow, Moderate or Wide based on the degree of alignment between observed and expected outcomes across a case.	Narrow: observed outcomes largely aligned with expected; Moderate: partial alignment with significant conditions unmet; Wide: observed outcomes confined to pilot, expected outcomes systemic.

Using these criteria, outcomes were classified during the within-case coding phase and validated during cross-case synthesis. Table 3 below presents the results of this classification across all primary African cases examined in the study.

Key Comparative Insight: The cross-case matrix presented in Table 3 reveals three analytically important patterns. First, all cases with a 'Wide' gap share at least one of three common barriers: the absence of a supportive legal/regulatory framework, infrastructure & connectivity or the absence of domestic capacity to maintain the system beyond the pilot phase. Second, the only cases with a 'Moderate' gap (Nigeria, Mauritius and Rwanda) are those where pre-existing institutional infrastructure such as a functioning regulation in Nigeria and Mauritius, a pre-digitized land registry as in Rwanda, provided a partial foundation for blockchain integration. Third, no case in the matrix achieved the transition from 'Observed' to 'Expected' outcome, suggesting that the gap between pilot success and systemic transformation is a structural feature of current adoption conditions rather than an anomaly in any individual case.

Table 3: Cross-case mapping of blockchain adoption pathways in Africa

Pathway	Country / Sector	Enablers Observed	Barriers Observed	Observed Outcomes	Expected Outcomes	Gap*
Regulatory & Governance Reform	Nigeria – Financial Services	Regulatory sandbox; CBN coordination	Limited enforcement capacity; underdeveloped data governance	Reduced SME transaction costs; accelerated fintech experimentation (NITDA, 2023)	Scalable national financial system integration	Moderate
	Mauritius – Financial Services	Legal recognition of digital assets; coordinated oversight	Inter-agency fragmentation	Procedural legitimacy; controlled innovation environment	Systemic financial sector transformation	Moderate
	Sierra Leone – Electoral Governance	Political commitment; transparency objectives	Weak legal enforceability; limited institutional continuity	Improved procedural transparency in vote reporting – pilot only (Kumbharkar et al., 2024)	Long-term institutionalization; electoral reform	Wide

Infrastructure & Connectivity	Rwanda – Land Administration	Pre-existing digital registries; centralized ICT systems	Legacy system interoperability	Enhanced record transparency and auditability (Hughes et al., 2022)	Nationwide land registry deployment	Moderate
	Ghana – Land Administration	Digitization of cadastral records	High integration costs; fragmented data architecture	Localized efficiency gains; improved transparency in pilot areas (Mintah et al., 2021)	National-scale land governance transformation	Wide
Capacity Building & Local Innovation	Ethiopia – Agricultural Supply Chains	Donor-funded technical expertise	Persistent local skill gaps; vendor dependence; absence of supportive policies	Improved provenance verification; enhanced value-chain coordination (Mwewa et al., 2024)	Long-term sustainability; institutional ownership	Wide
	Kenya – Agricultural Supply Chains	Stakeholder coordination; platform deployment	Uneven institutional capacity; fragile local ownership; absence of supportive policies	Improved traceability and trust within piloted supply chains (Kaluvu et al., 2025)	Institutional resilience; domestic technical capacity	Wide
Sectoral Pilot & Integration	Multi-Country – Finance, Land, Agriculture	External funding; innovation flexibility	Lack of national scaling frameworks; donor dependency; weak institutional anchoring	Proof-of-concept validation; limited functional success within pilot parameters	Systemic adoption; integration into national digital strategies	Wide

***Gap Score:** *Narrow = observed outcomes largely aligned with expected; Moderate = partial alignment with significant unmet conditions; Wide = observed outcomes confined to pilot, expected systemic outcomes never materialized. Classified per operational definitions in Table 2.*

B. Blockchain Adoption Pathways for Economic Transformation in Africa

(a) Pathway 1: Regulatory and Governance Reform

Across the cases examined, the regulatory and governance context emerged as the most fundamental precondition for blockchain adoption. Its importance is not primarily about enabling innovation. Sandboxes and pilots can proceed in conditions of regulatory uncertainty, but it is about creating the institutional legitimacy that appears necessary for pilots to mature into sustainable, scalable systems. Where legal frameworks are absent or ambiguous, judicial bodies are unlikely to recognize blockchain records, investors face unacceptable legal risks, and public institutions tend to resist integration (Atzori, 2017). Nigeria's experience illustrates both the value and the limits of proactive regulation. The Central Bank of Nigeria introduced a regulatory sandbox in 2021, allowing fintech firms to test blockchain-based cross-border payment services under controlled conditions. This approach was associated with reduced innovation-related risks and generated evidence that informed the National Blockchain Policy released in 2023 (NITDA, 2023). Within the sandbox, participating firms documented measurable reductions in transaction costs and settlement times for SME cross-border payments. Yet this technical success has not been associated with systemic financial integration. Two structural gaps remain, namely the limited enforcement capacity of regulatory agencies relative to the complexity of the systems they now oversee and data governance

frameworks that have not kept pace with the volume and sensitivity of information traversing these platforms.

Sierra Leone's blockchain-supported electoral pilot improved procedural transparency in vote reporting during the 2018 pilot phase (Kumbharkar et al., 2024). However, subsequent analysis confirmed that official results remained managed through conventional channels, illustrating that technical feasibility does not automatically translate into institutional integration. The absence of legal frameworks recognizing digital evidence and smart contract enforceability was identified as a key barrier to sustained adoption. Mauritius presents a more advanced case, having developed coordinated regulatory guidelines and provided legal recognition for digital assets at a relatively early stage (Fulena, 2025; Charltons, 2021). This environment was associated with structured pilot deployments and signals of openness to innovation. However, the expected outcome of systemic financial sector transformation has not been documented, partly because oversight functions remain fragmented across agencies that have not developed consistent standards or coordination mechanisms.

These cases collectively suggest that regulatory clarity is necessary to initiate blockchain adoption, but insufficient to sustain it. Proactive frameworks such as Nigeria's sandbox regulations (CBN, 2021), Mauritius's regulatory guidelines for digital assets and Kenya's Distributed Ledger Technology Taskforce (Ministry of Information, Communications and Technology, 2019) create the institutional space for experimentation. What may translate experimentation into institutional change is enforcement capacity, inter-agency coordination and the integration of blockchain governance within broader digital public administration frameworks. At the regional level, harmonization efforts through bodies such as the African Union, Economic Community of West African States (ECOWAS) and Southern African Development Community (SADC) offer additional leverage for reducing regulatory fragmentation and improving cross-border interoperability (African Union, 2020).

(b) Pathway 2: Infrastructure and Connectivity

Digital infrastructure including reliable electricity, broadband connectivity, data centers and interoperable ICT systems provides the technical substrate on which blockchain networks must run. Its relevance to adoption outcomes is well established in the literature (Oliveira & Martins, 2011) and the evidence from the cases examined suggests that infrastructure gaps remain one of the most significant structural barriers to blockchain deployment in much of Africa. The heterogeneity of infrastructure across the continent is striking. Countries including Kenya, Nigeria, Mauritius, and South Africa have relatively advanced ICT ecosystems and correspondingly higher levels of documented blockchain activity, particularly in financial services and e-governance. In contrast, landlocked and lower-income countries face fundamental constraints. Unreliable power supply disrupts node participation; low broadband penetration limits access to blockchain interfaces; and high data costs render transaction-heavy applications economically prohibitive for low-income users. Rwanda's blockchain land administration initiative illustrates what is achievable where infrastructure is relatively advanced. By building on pre-existing digitized land registries and centralized ICT systems, the initiative was associated with improvements in data auditability and reduced opportunities for record manipulation at the pilot scale (Hughes et al., 2022). The primary remaining barriers were low internet penetration and interoperability with legacy systems, a technical challenge that arises even in well-resourced settings when new platforms must integrate with older administrative infrastructure.

Ghana's land registration pilots offer a less optimistic picture. While the digitization of cadastral records provided a foundation for blockchain integration, fragmented data architectures across different agencies (some still reliant on paper records) were associated with

high integration costs and limited scope for systemic impact beyond the pilot areas (Mintah et al., 2021). Local efficiency gains were documented, but nationwide transformation was not achievable within the resources and technical conditions available. Addressing infrastructure constraints requires a combination of strategic public investment and partnership-based delivery models. Broadband expansion, renewable energy provision for blockchain nodes and investment in data centers are long-term infrastructure priorities that exceed the resources of most individual blockchain projects. Public-private partnerships offer one mechanism for bridging this gap. Alignment with continental digital infrastructure initiatives including the African Union's Digital Transformation Strategy for Africa (African Union, 2020) and the Smart Africa's digital transformation blueprint (Smart Africa, 2020) is important for situating national investments within a coordinated regional logic. Technical design choices also matter, consensus mechanisms such as Proof-of-Stake are less energy-intensive than Proof-of-Work systems and thus may be more feasible in energy-constrained environments (Sedlmeir et al., 2020). The key analytical point is that infrastructure readiness appears to enable blockchain functionality but does not automatically produce institutional impact. Ghana's digitized records were associated with localized transparency improvements without catalyzing systemic land governance reform. Infrastructure is a necessary condition for blockchain adoption, not a sufficient one.

(c) Pathway 3: Capacity Building and Local Innovation

If regulatory frameworks provide institutional legitimacy and infrastructure provides technical substrate, human and organizational capacity determines whether blockchain systems can be owned, operated, adapted and sustained by domestic actors over time. The evidence across the cases examined is consistent: the absence of localized technical and institutional expertise is associated with one of the most pervasive constraints on sustainable blockchain adoption in Africa. In both Ethiopia and Kenya, blockchain-enabled agricultural traceability systems were deployed with external technical support and donor funding. In Ethiopia, the systems were associated with improvements in provenance verification and value-chain coordination during the pilot phase (Mwewa et al., 2024). In Kenya, blockchain platforms were associated with enhanced trust and information sharing among supply chain actors (Kaluvu et al., 2025). Yet in both cases, the long-term sustainability of these systems appears to have been compromised by the same dynamic: dependence on external vendors and consultants, combined with insufficient transfer of technical and managerial skills to local counterparts. When donor funding cycles ended or external providers withdrew, institutional ownership proved fragile. This pattern reflects what Innovation Systems theory would identify as a deficit in absorptive capacity, the ability of an organization or system to recognize, assimilate and apply new knowledge (Nelson, 1993; Freeman, 1987). Building absorptive capacity requires sustained investment in education, training and knowledge exchange, not one-off deployment projects. The distinction matters because it changes what counts as a successful blockchain intervention. A system that functions well but generates no local capability may be institutionally more fragile than one that functions modestly but builds genuine domestic expertise.

Encouraging counterexamples exist. Kenya's BitHub Africa (BitHub Africa, 2015) and the Blockchain Innovation Hub in Nigeria represent efforts to cultivate indigenous innovation ecosystems, connecting local developers, entrepreneurs and policymakers around blockchain applications suited to domestic contexts. Comparative evidence from India's Skill Digital Hub initiative (Government of India, 2025) and Brazil's blockchain education (Tradingview, 2023) partnerships suggests that embedding digital and blockchain literacy within national education and workforce development frameworks may generate more durable capacity gains than project-based training alone. These examples point toward a model of capacity building that is

integrated with broader national digital literacy programs rather than treated as a technical component of individual blockchain deployments. Addressing capacity constraints also requires attention to governance risk. When technical systems outpace the ability of public institutions to understand and audit them, accountability may shift from elected officials to opaque technical intermediaries, a concern documented by Atzori (2017) and Reijers et al. (2016). Deliberate strategies for ensuring democratic oversight of complex technical systems including plain-language governance documentation, audit mechanisms and civil society engagement are as important as technical training for administrators.

(d) Pathway 4: Sectoral Pilot and Integration

The fourth pathway concerns how blockchain initiatives are designed and positioned relative to national development systems. The evidence reveals a consistent pattern: pilots appear to succeed at the technical level and fail at the institutional level because they are designed for demonstration rather than integration. When a pilot's primary purpose is to validate the technology, it tends to generate proof-of-concept evidence. When its purpose is to address a specific, institutionally embedded problem within a national system, it appears to have a greater chance of generating durable change.

Cases from financial services illustrate the potential of problem-driven design. Platforms focused on cross-border remittance costs, a concrete, measurable pain point documented across several African countries (Ahishakiye et al., 2018) were associated with genuine efficiency gains and increased user trust. In contrast, blockchain land registry pilots designed primarily to showcase distributed ledger technology, without adequate attention to the legal, administrative and political conditions required for registry reform, tended to remain confined to demonstration areas (Kaczorowska, 2019). Agricultural traceability initiatives in Ethiopia, Ghana and Kenya again illustrate both the promise and the limits of sectoral pilots (Distor et al., 2023). Where systems were explicitly connected to export certification processes that commanded a market premium as in Rwanda's coffee sector, farmers and buyers had real economic incentives to participate and sustain the system. Where the connection to tangible incentives was less clear, participation appears to have remained dependent on project-provided subsidies and dissolved when funding ended.

The most important design implication of this evidence is that sectoral pilots should be designed from the outset with an explicit theory of institutionalization (Olnes et al., 2017). This means identifying, before deployment, how the system will be legally recognized, who will own and maintain it, how it will be funded after donor support ends, how it will interoperate with adjacent administrative systems and how it will be governed when disputes arise. Absent this institutional design work, even technically successful pilots are likely to remain perpetual experiments rather than scalable reforms. Strategic prioritization also matters. High-impact sectors including finance, land governance, agriculture and digital identity offer the clearest pathways from pilot to scale because they address structural constraints that governments and development partners already recognize and have committed to address. Alignment with national digital strategies such as those developed in Kenya, Rwanda, Ghana and with continental frameworks including the Smart Africa Digital Economy Blueprint (Smart Africa, 2020), increases the likelihood that blockchain initiatives will be taken up within existing institutional reform agendas rather than operating alongside them.

C. Observed vs. Expected Outcomes

Using the outcome classification criteria specified in Table 2, the cross-case analysis reveals a consistent and important gap between what blockchain initiatives have documented as outcomes and what policy narratives and project designs projected as their benefits. Observed outcomes are classified as such because they are documented in independently verifiable sources as having occurred within the bounds of specific initiatives. They typically include improvements in operational transparency, reductions in transaction costs within pilot parameters, enhanced traceability in specific value chains and demonstration of technical feasibility. Nigeria's regulatory sandbox generated documented reductions in SME payment costs (NITDA, 2023). Rwanda's land administration initiative produced documented improvements in record auditability (Hughes et al., 2022). Ethiopia's agricultural traceability system was associated with improvements in provenance verification within the pilot area (Mwewa et al., 2024). South Africa's Project Khokha 2.0 documented a 30 percent reduction in identity fraud within the evaluated context (Mandinyenya & Malele, 2025). Expected outcomes typically include nationwide adoption, systemic institutional transformation, broad financial inclusion, and sustained socio-economic impact. They are classified as such because they appear in policy documents, project plans or advocacy literature as intended or anticipated benefits that have not yet been independently verified post implementation. These projections are not unreasonable; they represent plausible destinations if pilots were to scale and conditions were met. However, the evidence consistently suggests that the enabling conditions for this transition are absent or underdeveloped in most cases reviewed.

Zambia maize supply chain and Sierra Leone's electoral pilot are illustrative of a wide gap between observed and expected outcomes. Both initiatives achieved technical feasibility and demonstrated transparency improvements within their pilot parameters. Neither generated the institutional integration required for official recognition and sustained use, because the legal and governance frameworks necessary to support that integration were not in place (Mwewa et al., 2024; Kumbharkar et al., 2024). Ghana's land administration and Kenya's agricultural supply chain pilots similarly documented localized improvements without achieving the systemic transformation projected in their design documents (Mintah et al., 2021; Kaluvu et al., 2025). This gap between observed and expected outcomes is not evidence that blockchain technology is ineffective. It is evidence that the conditions required for scale and durability extend considerably beyond those required for a successful pilot demonstration. Recognizing this gap is important for calibrating expectations, for designing interventions that address the full pathway from pilot to scale and for ensuring that policy decisions are grounded in what the evidence actually shows rather than aspirational projections.

V. DISCUSSION

The findings from this study suggest that blockchain technology holds genuine potential as a catalyst for institutional reform, financial inclusion and governance improvement in Africa. However, this potential appears systematically unrealized because the conditions required for scale and durability are rarely addressed in a coordinated way. The four pathways: regulatory and governance reform, infrastructure and connectivity, capacity building and local innovation, and sectoral pilot and integration are not independent levers that can be pulled in isolation. They are interdependent conditions whose interaction appears to determine whether blockchain moves from demonstration to institutional change.

A. The Interdependence of the Four Pathways

The cross-case evidence suggests that the pathways operate as a system rather than as separate initiatives. Regulatory clarity without adequate infrastructure means that legally recognized blockchain systems cannot function reliably. Infrastructure without capacity means that functional systems cannot be maintained or governed domestically. Capacity without regulatory legitimacy means that locally developed applications lack the institutional standing to affect formal systems. In addition, sectoral pilots without attention to all three preceding conditions are likely to demonstrate technical validity while failing to generate institutional change, as consistently observed across the cases reviewed. This systemic interdependence has practical implications for project design and policy sequencing. Blockchain initiatives evaluated solely on technical performance may appear successful while leaving the system no better prepared for scale. A pilot that achieves excellent provenance verification outcomes but generates no local capacity and no regulatory learning may be technically impressive but institutionally regressive thereby consuming resources without advancing the conditions required for transition.

From an Institutional Economics perspective, the evidence is consistent with the view that regulatory reform is the foundational pathway, not because it is sufficient, but because institutional legitimacy appears to be a prerequisite for the other pathways to operate effectively (North, 1990; Acemoglu & Robinson, 2012). The TOE framework's emphasis on contextual interdependence helps account for why the same technology produces such varied outcomes across countries. The technological context (blockchain's capabilities) is broadly similar, but the organizational and environmental contexts are radically different and those differences appear to drive adoption trajectories (Oliveira & Martins, 2011). Innovation Systems theory points to the importance of the systemic dimension; the knowledge networks, linkages and collective learning mechanisms that allow blockchain's institutional potential to be realized across sectors and over time (Nelson, 1993; Freeman, 1987).

B. Risks, Trade-offs and Failure Modes

Any realistic assessment of blockchain adoption in Africa must grapple with the risks and trade-offs involved, not just the opportunities. Each of the four pathways carries characteristic failure modes that can undermine the broader transformation agenda if not explicitly managed. Within the regulatory pathway, the central tension is between enabling innovation and maintaining accountability. Regulatory sandboxes create protected spaces for experimentation but may generate regulatory arbitrage if enforcement capacity is too limited to monitor what participants actually do within those spaces. Blockchain-based public ledgers also introduce a structural trade-off between transparency and privacy: immutable records of land transactions or public expenditures may increase accountability, but may also expose sensitive personal or commercial information, create irreversible errors and undermine due process if dispute resolution mechanisms are absent (Atzori, 2017). Legal frameworks must therefore address not only the recognition of blockchain records but the conditions under which they can be challenged or corrected.

Within the infrastructure pathway, the dominant risks are technical fragility, cost escalation and exclusion. Blockchain systems deployed in environments with unreliable power or connectivity are inherently vulnerable to node failures that compromise data integrity. The choice of consensus mechanism affects energy consumption, transaction throughput and the minimum hardware required to participate. These technical choices have distributional consequences. High-resource architectures may exclude low-capacity institutions and users, potentially widening rather than narrowing digital divides (Sedlmeir et al., 2020). Within the

capacity-building pathway, the primary risks are elite capture, skills concentration and institutional hollowing. When blockchain systems are operated by a small cadre of technically sophisticated actors, often external consultants or a narrow domestic technical elite, accountability may shift away from the public institutions nominally responsible for governance, as documented in the Ethiopia and Kenya cases reviewed. This can produce a paradox in which blockchain, ostensibly a decentralization technology, in practice concentrates operational control in the hands of technical intermediaries (Reijers et al., 2016). Addressing this risk requires open standards, knowledge transfer obligations for vendors and deliberate strategies to build broad technical literacy within public institutions.

Within the sectoral pilot pathway, the dominant failure mode is perpetual pilotization which is the tendency for technically successful demonstrations to remain demonstrations rather than evolving into institutional systems (Olnes et al., 2017). This failure mode appears to be driven by several factors including donor dependency, which creates incentives to launch new pilots rather than scale existing ones and the absence of explicit scaling frameworks in project design. This is further compounded by weak institutional ownership, which leaves systems vulnerable when external support ends. Risk-aware project design requires addressing all of these factors before deployment.

C. Contribution to the Literature

This study makes two primary contributions to the existing literature on blockchain adoption in Africa. The first is methodological. By applying an explicit and operationalized observed-versus-expected outcomes distinction, the analysis avoids the common conflation of pilot feasibility with developmental impact. A more rigorous standard, one that requires evidence of sustained, scaled and institutionally embedded outcomes before claiming transformative impact is more likely to generate accurate assessments and better-designed interventions. This methodological contribution responds directly to the concerns raised by Frizzo-Barker et al. (2020), who noted the absence of rigorous impact evidence in the existing blockchain-in-development literature. The second contribution is analytical: the four-pathway framework reorganizes familiar enabling factors into an integrated, process-oriented account of how blockchain adoption unfolds. Existing reviews catalog factors (Kshetri, 2021; Frizzo-Barker et al., 2020). This study explains how they interact, sequence and reinforce one another and why their fragmentation appears to produce the persistent gap between pilot success and systemic change. The framework is presented not as a deterministic model or universal recipe, but as a diagnostic tool that can help policymakers and practitioners identify which conditions are missing in specific contexts and why.

D. Policy and Practice Implications

For policymakers, the most important implication of this analysis is that blockchain strategies need to be embedded within broader digital governance frameworks rather than treated as standalone sectoral initiatives. National blockchain policies such as Nigeria's 2023 policy (NITDA, 2023) or Kenya's distributed ledger guidelines (Ministry of Information, Communications and Technology, 2019) are valuable, but their value is realized only when accompanied by investments in enforcement capacity, digital public infrastructure and institutional learning mechanisms. Principle-based, technology-neutral regulation as illustrated by Mauritius reduces the risk that frameworks become obsolete as technology evolves and provides sufficient flexibility for adaptation to local conditions. Regional harmonization through bodies like the African Union and ECOWAS is important for addressing the interoperability constraints that currently limit cross-border blockchain applications (African Union, 2020).

For practitioners in government and development agencies, the evidence argues for a fundamental shift in implementation philosophy. Donors and implementing partners should design blockchain interventions with explicit institutionalization strategies from the outset, including defined exit conditions, capacity transfer obligations and mechanisms for local institutional ownership. Technology vendors should prioritize open standards and interoperability with legacy systems over proprietary architectures that create lock-in. Civil society engagement in blockchain governance should be understood as a substantive accountability mechanism, not merely a communication exercise. For the private sector, particularly fintech firms and technology providers, the evidence suggests that proactive engagement with regulatory sandboxes and policy processes offers a route to building the institutional legitimacy that enables scale. Firms that invest in regulatory co-creation, local capacity development and open-standard architectures appear better positioned for sustainable market growth than those that optimize for short-term pilot performance.

E. Limitations

Several limitations must be acknowledged. This study relies on documentary evidence, which captures the perspectives of those who produce documents rather than offering direct access to on-the-ground implementation dynamics. The experiences of frontline workers, affected communities and informal institutional actors are largely absent from the record on which this analysis draws. A second limitation is scope: the eleven primary cases, while selected to reflect regional and sectoral diversity, cannot represent the full range of blockchain experiences across a continent of 54 countries. The framework's applicability to countries not included in the analysis, particularly those with very low levels of digital infrastructure or very different institutional configurations remains to be tested empirically. Third, the rapidly evolving nature of blockchain technology means that some technical constraints identified in this study may be addressed by ongoing innovation, while new challenges may emerge that are not yet visible in the documentary record. Finally, the qualitative nature of the outcome classification, particularly the 'Gap Score' reflects the authors' interpretive judgment based on the available evidence and should be treated as indicative rather than definitive.

VI. CONCLUSION

This study examined blockchain technology and smart contracts as potential institutional levers for sustainable and inclusive development across Africa. The four strategic pathways identified: regulatory and governance reform, infrastructure and connectivity, capacity building and local innovation, and sectoral pilot and integration capture the range of conditions that appear to need coordinated development for blockchain adoption to move from demonstration to transformation. None of these pathways is individually sufficient and the evidence suggests that the failure of any one of them can limit progress across the others. The observed-versus-expected outcomes analysis makes clear that Africa currently occupies an early position on this journey. Documented outcomes are real but predominantly localized and fragile; expected outcomes of systemic institutional transformation remain largely unrealized in the cases examined. This should not generate pessimism about blockchain's relevance to Africa's development agenda. The evidence reviewed in this study shows genuine, specific achievements. For example, it documents measurable reductions in SME transaction costs in Nigeria's regulatory sandbox (NITDA, 2023). It also reports improvements in land record auditability in Rwanda (Hughes et al., 2022). In addition, it highlights verifiable provenance improvements in East African agricultural supply chains (Mwewa et al., 2024). The study further notes a documented 30% reduction in identity fraud linked to South Africa's Project

Khokha 2.0 (Mandinyenya & Malele, 2025). These results represent meaningful, evidenced gains. However, the key challenge is to build the institutional, infrastructural and human conditions that allow these gains to be sustained, replicated and scaled. This is ultimately a governance and policy challenge, as much as it is a technological one. The framework offered in this study is intended as a practical resource for policymakers, development partners and practitioners. Its value lies not in theoretical elegance but in its fidelity to the documentary evidence. The pathways are derived from what the record actually shows about what has been associated with progress, what has been associated with failure, and why. Used as a diagnostic tool rather than a blueprint, the framework can help identify which conditions are missing in specific contexts and how investments might be sequenced to address them. Africa's digital transformation is underway. Whether blockchain becomes a cornerstone of that transformation or remains a catalogue of promising experiments will depend less on the technology itself than on the institutional choices made in the years ahead.

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