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Assessing the Role of Blockchain Technology Adoption in Advancing Financial Inclusion in Rural Nigeria

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Abstract

This study examines the impact of blockchain adoption on financial inclusion in rural Nigeria between 2009 and 2024, using rural bank deposit volumes as a proxy. Blockchain adoption is measured through the Blockchain Readiness Index, cryptocurrency exchange volume, and aggregated interest in Bitcoin futures. Employing the ARDL bounds testing framework alongside unit root, diagnostic, and stability tests, the findings confirm long-run cointegration between blockchain indicators and financial inclusion, indicating a systematic and enduring relationship. In the long-run, BRI emerges as a strong, positive, and significant driver of rural bank development, highlighting the importance of institutional preparedness, infrastructure, and supportive frameworks in lowering barriers to rural financial access. Conversely, cryptocurrency exchange volume negatively affects rural bank development, suggesting that speculative and unregulated trading undermines grassroots financial stability, while the aggregated open interests on Bitcoin futures prove insignificant, reflecting the limited relevance of crypto-derivatives in rural finance. Short-run effects are generally weak but significant; negative error correction terms indicate convergence toward long-run equilibrium, suggesting that blockchain's immediate impact is limited while its benefits accumulate over time. Policy implications emphasise the need for robust regulatory oversight, expansion of digital infrastructure, financial literacy programs, and incentives for rural banking innovation. Additionally, blockchain-based identity systems and secure transaction frameworks can enhance trust and participation. The study recommends that blockchain adoption holds transformative potential for advancing inclusive finance in rural Nigeria, with long-term benefits contingent on supportive institutional, regulatory, and infrastructural interventions.

Keywords: *Blockchain Technology Adoption, Financial Inclusion, Rural Nigeria.*

1. Introduction

Financial inclusion in rural Nigeria is crucial to the actualisation of economic potential and addressing poverty traps that persist due to limited access to financial services in rural areas. In rural areas, structural barriers that exacerbate economic marginalization and income inequality are prevalent. These obstacles include mistrust of official banking organisations, a lack of digital literacy, and inadequate infrastructure (Aketch et al., 2021). According to Sanyaolu et al. (2024), increasing access to financial resources such as credit, insurance, payments, and savings encourages entrepreneurship, making it easier to invest in agriculture, and makes households more resilient to shocks. Driven by blockchain advancements and technology adoption, digital banking provides transparent, safe, and affordable platforms to reduce transaction inefficiencies and overcome rural-urban gaps (Trivedi et al., 2021; Adel, 2024). Therefore, in the absence of financial inclusion, rural communities are left out of market opportunities and government interventions, and they continue to be at risk from predatory informal loan networks. For Nigeria to develop sustainably, it is therefore both socially and macroeconomically necessary to build rural finance systems. Blockchain can increase financial inclusion in Nigeria by removing barriers related to cost, accessibility, and trust. Its transparent and decentralized structure cuts out middlemen, lowering transaction costs and enabling low-income and rural communities to purchase financial services (Aketch et al., 2021). By circumventing governmental and infrastructure barriers, smart contracts and peer-to-peer platforms allow safe credit, savings, and insurance without the need for traditional banks (Trivedi et al., 2021). Additionally, the unbanked can participate in cross-border remittances, microfinance, and government welfare programs because of blockchain's tamper-proof records, which facilitate identification verification. Blockchain can thereby close gaps in Nigeria's financial system and promote equitable, technologically driven economic growth.

In rural Nigeria, where traditional banking systems are limited by inadequate internet penetration, high transaction costs, a lack of trust in financial institutions, and infrastructure gaps, blockchain technology offers a revolutionary chance to expand financial inclusion. According to studies, by removing middlemen and improving access to reasonably priced, safe financial services, blockchain's decentralized, transparent, and immutable features help to overcome some of these systemic obstacles (Aketch, Mwambia, & Baimwera, 2021). People in underprivileged communities can transfer money, save, and obtain credit without depending on traditional banks, which are sometimes nonexistent in rural areas, thanks to its capacity to enable peer-to-peer transactions. In areas like Benue or Ebonyi, for instance, blockchain-based mobile wallets can enable rural farmers to get money straight from urban purchasers or even foreign markets without having to pay exorbitant remittance fees. Additionally, the tamper-proof ledger of blockchain facilitates the development of digital identities for the unbanked, which is important in Nigeria because millions of people lack official identification. This allows them to access government social intervention programs, agricultural loans, and microfinance. Furthermore, according to Trivedi, Mehta, and Sharma (2021), blockchain in e-finance improves openness and trust—two factors that are vital in the fight against fraud and poor management that are common in rural cooperatives and savings groups. To reduce disputes and promote confidence among participants, blockchain-enabled cooperative platforms, for example, can provide transparent tracking of member contributions and payouts. Smart contracts can also automate loan and repayment procedures, increase the effectiveness of microcredit and lower the risk of default. This could transform programs like the Anchor Borrowers' Program in Nigeria by guaranteeing that money reaches legitimate farmers while upholding accountability. However, the successful deployment of blockchain for rural inclusion confronts hurdles such as limited digital literacy, intermittent electricity, and regulatory concerns. These concerns demand concerted efforts between politicians, fintech firms, and local communities to provide infrastructure support and capacity creation. Therefore, if carefully incorporated with current financial inclusion policies, blockchain presents Nigeria with a disruptive approach to surpass established banking models, increasing rural financial participation and promoting sustainable economic growth (Aketch et al., 2021; Trivedi et al., 2021).

The importance of blockchain in enhancing financial inclusion was clarified in the debates above. In rural Nigeria, blockchain technology has the potential to greatly improve financial inclusion by removing institutional and structural hurdles that restrict access to financial services. Because it is transparent and decentralized, it does not require middlemen, which lowers transaction costs and makes services like credit, payments, and savings available to those who are not banked (Aketch, Mwambia, & Baimwera, 2021). Rural farmers and traders in remote locations can access microloans, engage in cooperative savings, and receive payments directly from purchasers through peer-to-peer networks and blockchain-based mobile wallets, all without the need for physical banks. By automating lending and repayment, smart contracts can improve rural cooperatives' transparency and lower fraud. Furthermore, millions of people without official identification can access government programs and credit facilities with the aid of blockchain-enabled digital identities (Trivedi, Mehta, & Sharma, 2021). But for it to be successful, issues like inadequate infrastructure, low digital literacy, and regulatory gaps must be addressed with focused legislation and community-based adoption tactics. In light of these conversations, the main goal of this article is to examine how blockchain affects financial inclusion in rural Nigeria. The amount of cryptocurrency exchanges aggregated open interests on bitcoin futures, and the blockchain readiness index were used to quantify blockchain, whereas the volume of rural banking development was used to measure financial inclusion.

The majority of earlier research on blockchain and financial inclusion has mostly used conceptual or qualitative methodologies, concentrating on broad talks of blockchain's promise without using solid empirical data (Trivedi, Mehta, & Sharma, 2021). According to Aketch, Mwambia, and Baimwera (2021), they frequently study adoption in developed markets contexts, ignoring rural situations where financial exclusion is most acute. The complex nature of blockchain activity is also often overlooked by previous research, which often measures blockchain adoption using proxies like technology awareness, adoption surveys, or single financial metrics. The Blockchain Readiness Index, cryptocurrency exchange volume, and total open interest on Bitcoin futures are the composite indicators used in this study to measure blockchain. This offers a multifaceted evaluation that takes into account both market activity and infrastructure readiness. In addition to being innovative, the emphasis on rural banking development volume as a financial inclusion metric provides a useful and context-specific indicator as opposed to general financial access indices. Moreover, rural financial access has received little attention in the literature, despite being the focal point of poverty and economic marginalization in Nigeria. This is addressed by the use of rural banking development volume. Policymakers and financial practitioners can directly benefit from the evidence this study produces by comparing blockchain indicators with financial inclusion metrics that are focused on rural areas. It goes beyond theoretical arguments by establishing an empirical connection between tangible rural banking outcomes and digital financial breakthroughs. This in-depth look demonstrates how blockchain may power payment systems, rural loan distribution, and savings mobilisation in historically disadvantaged regions. The discussion can now shift from national or urban averages to the effects that are specific to rural areas by allowing for comparative study with other emerging economies that are dealing with comparable institutional and infrastructure limitations.

Another significant divergence from prior studies is methodological. They typically employ case studies or descriptive analysis, this study enhances the empirical rigour by combining rural banking statistics with quantifiable, high-frequency blockchain market data. An autoregressive distributed lag model (ARDL), which assesses both short-term and long-term dynamics, was utilized to estimate the association in the research. The discussion shifts from perception-based measures to actual blockchain activity levels with the inclusion of cryptocurrency exchange volume and open interest in Bitcoin futures, indicating investor confidence and market penetration. Testing causality and dynamic relationships requires this methodological innovation, which also provides fresh perspectives on how changes in the blockchain market affect actual financial access. It also reflects the maturity of blockchain as a financial tool rather than a speculative concept, particularly within the volatile Nigerian context. For regulators, banks, fintech companies, and development partners, the report offers practical insights by examining the behaviour of the blockchain industry and the growth of rural banking. It demonstrates that, with the right application, blockchain technology may overcome institutional flaws and infrastructure constraints in rural finance. Customized legislation, investments in digital infrastructure in rural areas, and cutting-edge financial products like cooperative banking or blockchain-enabled microfinance can all benefit from the findings. This research demonstrates that market-oriented blockchain indicators can be trustworthy stand-ins for development finance studies, opening up a new methodological avenue for researchers. It extends the narrative to the impoverished in rural areas, so challenging the widely held belief that blockchain's influence is limited to tech-savvy urban populations. This is a crucial step in bringing technology innovation and inclusive growth into harmony.

2. Literature Review

2.1 Conceptual Literature

Concept of Blockchain

The term "blockchain" was first introduced by Stuart Haber and W. Scott Stornetta in 1991 when they proposed a model incorporating certificates into an encrypted record, known as a block, to prevent tampering with digital documents and create a decentralized database (Moradi et al., 2019). This foundational concept has evolved significantly, with blockchain technology application gaining prominence in 2008 when Satoshi Nakamoto introduced Bitcoin, a revolutionary digital currency designed to enable direct, peer-to-peer payments without the need for intermediaries. Bitcoin's primary goal was to establish a system for conducting internet transactions globally without a central authority, a breakthrough that was first actualized with the establishment of Mt. Gox in February 2011, the first BTC-to-fiat currency exchange platform (Wątorek et al., 2021). Blockchain technology application, the underlying infrastructure of Bitcoin, has since been recognized for its potential to enhance security and privacy across various domains, including the Internet of Things (IoT) ecosystem (Miraz and Ali, 2020).

Blockchain is an unsettling force on a wide variety of different companies, entirely revolutionizing the way information is passed around, stored, and protected. It is essentially an internet-connected electronic bookkeeper that keeps track of transactions by means of a series of computers so that the information cannot be manipulated in the past without network permission. Blockchain is a trusted solution for many applications because it is transparent and immutable (Akinyele & Olayemi, 2023). Blockchain was first presented in 2008 as the technology behind the decentralized digital currency known as Bitcoin. In his white paper, Satoshi Nakamoto hypothesizes a peer-to-peer electronic cash system that doesn't require a trusted central authority (Nakamoto, 2008). Ever since, blockchain technology has evolved from being used just for cryptocurrencies to being applied across different industries, such as supply chains and management, healthcare and banking.

Sets of transactions are held in blocks that make up a blockchain. Blocks are connected by each to the next through cryptographic hashes, creating a chain. To guarantee data integrity and security, the system ensures that data, once saved, cannot be modified without modifying all following blocks, which would involve network consensus (Akinyele & Olayemi, 2023). Decentralization is a core component of blockchain technology. Blockchain relies on a peer-to-peer network, as contrasted with classical centralized systems, where every participant, referred to as a node, possesses a copy of the whole ledger. Decentralization minimizes the threat of a single point of failure and increases security (Akinyele & Olayemi, 2023). Consensus methods referred to as protocols guarantee all nodes in the network that a transaction is authentic. The most well-known is Proof of Work (PoW), utilized by Bitcoin, where users must authenticate transactions by answering difficult mathematical problems. However, the high energy usage of PoW has drawn criticism. To provide such solutions, alternatives like Proof of Stake (PoS) have emerged, where validators are chosen based on how much bitcoin they possess and are willing to "stake" as a guarantee (Akinyele & Olayemi, 2023). Smart contracts are automatic contracts whose terms and conditions are set directly in code. As soon as certain circumstances are fulfilled, they enforce a contract's stipulations automatically without the need for intermediaries. Ethereum was the first blockchain-based platform to embrace smart contracts upon its launch in 2015 and supported a massive array of decentralized applications (DApps) (Buterin, 2014).

Decentralised finance (DeFi), providing financial services without the need for conventional middlemen, has been made possible through blockchain technology in the financial industry. DeFi platforms provide customers with more control over their financial operations through the option of lending, borrowing, and exchanging assets using smart contracts (Schär, 2021). Blockchain improves supply chain management's transparency and traceability outside the financial industry. Stakeholders can ensure the authenticity and source of products by documenting all transactions in an unalterable record book, minimizing fraud and enhancing productivity (Francisco & Swanson, 2018). In spite of its benefits, blockchain technology has a number of drawbacks. Scalability remains a relevant issue since a greater blockchain size increases the cost and decreases the speed of processing transactions. Furthermore, since governments cannot cope with decentralized networks, legislative ambiguity creates challenges for broad adoption (Akinyele & Olayemi, 2023). Because of their energy consumption, blockchains, especially those using PoW consensus algorithms, have been a source of concern over their environmental impact. For blockchain technology to scale sustainably, scalable solutions and the shift towards more energy-efficient models like PoS are necessary (Platt et al., 2021). In the future, the combination of blockchain with cutting-edge technologies such as artificial intelligence (AI) and the Internet of Things (IoT) may lead to the development of improved and more secure systems. For example, IoT devices can utilize blockchain to facilitate decentralized and secure data sharing and combining blockchain with AI can enhance data security and transparency (Zuo, 2020).

Financial Inclusion

There is a lot of evidence in the literature that financial inclusion is becoming more and more important as a driver of economic growth and development. Today, many people think of financial inclusion as a right for all citizens to social inclusion, a higher quality of life, and a way to help the disadvantaged in a country become more economically capable (Banco Central do Brazil, 2010). Policymakers have therefore seen financial inclusion as a fundamental right for all individuals, emphasizing its non-excludability and non-rivalrous nature. Mehrotra et al. (2009) concluded that financial inclusion satisfies two criteria. Although the level of "publicness" in "financial inclusion" may differ from a conventional public good such as defence, it is unequivocal that financial inclusion fulfils the characteristics of a public good and can therefore be classified as a "quasi-public good."

So, financial inclusion is the process or circumstance that makes it easy for people in the economy to use, access, or use formal financial systems. It depicts a procedure in which everyone in the economy can open a bank account, get credit, and use financial system products and services without any problems. It is the process that makes sure a person's income is as high as possible, their expenses are kept in check, and they can make smart decisions by having access to basic financial services (PCC Financial Inclusion Strategy, 2009). In this context, financial exclusion means that a person, household, or group can't get to formal financial products and services. According to Mohan (2006), financial exclusion means that some groups in society can't get to fair, safe, and low-cost financial products and services from mainstream suppliers.

There may not have been a unanimous consensus on a definitive list, but there is broad agreement that financial inclusion is multifaceted, involving access to, utilization of, and proficiency in many financial services. Stephen Sinclair et al. (2009) defined financial inclusion as a condition wherein all individuals possess access to banking and insurance services, along with financial literacy and competencies. Chima (2011) also said that it is "the state of the financial system where every member of society has access to appropriate financial products and services for effective and efficient management of their resources; get needed resources to finance their businesses; and financial leverage to take up opportunities that will lead to an increase in their income." The Centre for Financial Inclusion gives a definition that covers most of the bases. The Centre says that financial inclusion is "a state in which all who can use them have access to a full suite of quality financial services, provided at affordable prices, in a convenient manner, and with dignity for the clients." It is a state where many different companies, most of which are in the private sector, offer financial services to everyone who needs them, including the poor, disabled, rural, and other groups that aren't usually included (Centre for Financial Inclusion, 2010).

2.2 Theoretical Review

2.2.1 Financial Growth Theories

Theories of financial growth encourage the idea that demand following or supply leading can help growth by creating a good atmosphere for creativity and financial growth. Theories of financial growth say that low growth is caused by income disparity and the fact that not everyone has access to financial services. Consequently, secure, convenient, and cost-effective access to financial resources is recognized as a prerequisite for accelerating growth and addressing income disparities to create equitable opportunities, thereby fostering improved economic and social integration among economies to advance the financial sector's development and safeguard against economic shocks (Aduda & Kalunda, 2012). There is still a theoretical disagreement over the function of the financial system in economic growth. Some economists assert that the financial sector is crucial for economic growth, but others contend that it exerts minimal influence. The demand-following perspective contends that the financial system does not facilitate economic growth; instead, it reacts to advancements in the real sector, whereas supply-leading proponents oppose this position.

Bagehot (1873) proposes the foundation of finance-led growth. The researcher advocating the finance-led growth theory posits that an effective financial sector significantly contributes to the acceleration of growth. Schumpeter claimed that banks facilitate economic growth by offering adequate funding options. Goldsmith (1969), McKinnon (1973), Levine and Zervos (1996), and Ndebbio (2004) assert that effective financial systems and accessible financial services contribute to economic growth. The supply-leading hypothesis also supports the idea that the financial market should become involved to boost the demand for financial services from an economy that is already doing well. So, the growth of the financial system is a big sign of growth in other parts of the economy.

2.2.2 Theories of Financial Intermediation

Financial intermediation is when banks and other financial organizations bring together people who spend too much and too little. The primary inquiry that theories endeavour to address is the rationale behind investors' decision to refrain from direct lending to borrowers, opting instead for indirect methods or financial intermediaries (Ndebbio, 2004). I also said that banks are very important for keeping an eye on borrowing and lending (Diamond, 1984). Diamond goes on to say that financial intermediaries use secondary financial products to buy primary financial products. The investor can buy primary assets more effectively and for less money if they don't use the services of financial intermediaries. This direct connection between lenders and borrowers makes the market more difficult to navigate. Market friction is seen as the most hazardous mechanism for engendering enduring income inequality and for aiding in the regulation of the poverty trap (Aduda & Kalunda, 2012). Information asymmetry and transaction costs are also thought to be important factors that affect people's basic decisions about how to build up their physical and human capital (Demirgüç-Kunt et al., 2008). Theories that point out problems in the financial market and the buildup of capital look at how much money poor people can borrow to invest or meet their physical capital needs.

Most ideas stress that entrepreneurship and flaws in the financial system are the ways that brilliant people who don't have much money can meet their financial demands to start firms or projects. So, success in financial development, growth, and intergenerational income dynamics is very strongly linked. Efficient financing options for disadvantaged people, firms, and others with limited financial resources help distribute resources more efficiently throughout the economy, which will ultimately boost economic growth. Financial inclusion can also help with problems in the financial industry. It encourages information asymmetry, which is needed for markets to work well because not everyone has access to all the knowledge they need to make good decisions. The absence of asymmetric information can lead to issues such as information monopolies, moral hazard, and adverse selection. In the adverse selection model, individuals lack information about fundamental concepts, whereas in moral hazard, uninformed persons are either unaware of the contract's performance or unable to punish for its breach. Because of this lack of knowledge, investors or borrowers have to pay a lot of money to do business. Higher transaction costs meant that items cost more, which also made it harder for people to get money. The goal of financial inclusion programs is to lower the cost of transactions. The theoretical model posits that market imperfections, which enhance financial prospects for economically disadvantaged persons, exert a beneficial influence on general growth (Demirguc-Kunt and Levine, 2007).

According to Schumpeter (1911), with support from King and Levine (1993), the banking sector is the main financial intermediary that has a big impact on long-term growth and productivity by helping people save money. There is a significant disparity between the financial system and its performance, influenced by geography, time, and dimensions (Honohan, 2004; Beck, 2007). Additionally, empirical research (Robinson, 1952) demonstrates that the outcomes of finance and growth studies may fluctuate over time and under varying conditions, yielding either unidirectional or bidirectional results. Lavin (1993) posits that technology advancements and capital accumulation serve as significant conduits within the financial system, exerting a profound influence on economic growth. Goldsmith (1969), Michigan (1973), and Shaw all agree with Schumpeter's (1911) position that the financial system helps the economy flourish. It also says that things like interest rates in the financial sector made people want more financial products and services, which made banks and other financial organizations compete even more. It also encourages saving and investing, which will help the economy expand. Some ideas, on the other hand, show that there is a positive link between access to financial services and overall growth in the country (Sharma, 2016).

2.3 Empirical Literature

Adegbite (2024) explores blockchain as a transformative driver of financial inclusion, particularly for underbanked and unbanked populations excluded from traditional systems. The study highlights blockchain’s ability to overcome barriers such as geography, high fees, and regulatory hurdles through decentralized, transparent, and low-cost transactions. It emphasizes its role in enabling peer-to-peer transfers, cross-border remittances, and micro-lending, all of which broaden access to financial services. By ensuring immutability and auditability, blockchain also fosters trust in environments with weak institutions or corruption. However, challenges remain, including regulatory uncertainty, inadequate infrastructure, and cryptocurrency volatility, which constrain adoption. The paper concludes that integrating blockchain with mobile banking and internet technologies can further strengthen its impact on global financial inclusion and equity. Adebayp et al. (2024) conducted a study titled Blockchain Technology, Cryptocurrencies and Financial Inclusion in Nigeria, focusing on SMEs in Ogun East Senatorial District. Guided by two research questions and one hypothesis, the study adopted a correlational design with a purposive and stratified sample of 200 SME operators. Data were collected using the Benefits of Blockchain Technology Questionnaire (BBTQ) and Benefits of Cryptocurrencies Questionnaire (BCQ). Descriptive statistics (mean, standard deviation) and t-test were employed for analysis. The findings revealed that blockchain and cryptocurrency enhance financial inclusion by improving accessibility, affordability, and transaction efficiency compared to traditional finance. Key challenges identified include scalability, interoperability, energy use, skills gaps, and regulatory issues, while benefits include lower costs, increased speed, new opportunities, and poverty reduction. The study recommended policies to strengthen networks, expand access points, and support SME participation in blockchain-driven financial services.

Biriuk et al. (2024) investigated the correlation between blockchain technology and financial inclusion in countries with diverse levels of development from 2017 to 2027. The study utilized statistical methodologies, descriptive analysis, correlation, and regression models to evaluate the impact of blockchain adoption on access to financial services. The findings indicated a projected 166-fold expansion of the blockchain business by 2027 and demonstrated that nations with poorer financial inclusion exhibit a heightened dependence on blockchain-based cryptocurrencies for credit access. The investigation showed that the number of people who don't have bank accounts might explain more than 19% of the differences in who owns cryptocurrencies. The study showed that blockchain makes it much easier to get fundamental financial services, especially in markets that don't have them. It suggested using blockchain developments to make financial systems stronger and improve strategies for including everyone around the world. Chumak (2021) also talks about the trend toward decentralization in his studies. The study observed that decentralized apps for funding, or DeFi, are still being actively developed. Cryptocurrencies are the digital money that people in the DeFi system use. They are programmable and not controlled, and members of the blockchain community accept them. Using smart contracts on the blockchain, DeFi changes standard financial services into ones that don't need a middleman. Chmeruk (2020) says that smart contracts are one of the best tools for blockchain. The signing of these contracts is done automatically and without the help of middlemen. This lowers the chance of conflicts, lowers risk, and raises transparency and control. The work says that the blockchain might be both a big danger and a chance for financial institutions (middlemen). It depends on whether these kinds of organizations can change to fit the new situation.

Zheng et al. (2022) suggest enhancing the financial lending system by integrating blockchain data sharing and tracking through the advancement of consensus mechanisms. At the moment, these procedures are not very secure and use a lot of resources. Chang (2020) asserts that blockchain technology can be utilized to construct a credit system. The researcher concluded that the use of this technology will aid in addressing issues of trust and security through decentralization and autonomy. Mhlanga (2023) thinks that blockchain could not only improve but also replace the systems that make worldwide payments and transfers possible. Blockchain can be used for many things, but it is most useful for money transactions, saving money, giving credit, and providing insurance. The researchers focused on how blockchain could help more people have access to financial services. Hoffmann (2021) says that blockchain is the best way to help more people get credit. The blockchain-based microcredit platform suggested in this work would let investors get better returns because the interest rates will be greater than those of regular savings accounts. Cunha et al. (2021) emphasize the significance of novel cryptocurrency-based services that enhance the optimization of remittances for expats and facilitate improved access to fundraising mechanisms such as initial coin offerings, crowdsourcing, and decentralized finance (DeFi). A lot of these services are really important for making sure that everyone has access to financial services. The researcher observes that conventional financial systems preclude the involvement of a significant portion of the population due to their incapacity to uphold a minimum balance or furnish official documentation that meets Know Your Client criteria. Vorobets (2020) is among the researchers who do not regard blockchain technology as a universal solution for all prevailing issues. The researcher posits that blockchain constitutes merely one of the technologies upon which the financial services system will rely in the future. The author points out a few problems with how the blockchain is being used right now, but they also say that this technology could make the financial system work better in the future.

Abdulhakeem and Hu (2021) acknowledge the advantages of blockchain implementation in the financial sector, namely with enhanced accessibility and transparency. The study posits that the blockchain will not fundamentally transform the old financial system, but rather serve as a complement to it. This update will help the 1.7 billion people who don't have a bank account get more access to money. Ogunrinde et al. (2025) examine how blockchain technology influences bank performance using Structural Equation Modelling (SEM) on the top Spanish banks. The study highlights blockchain's potential to reduce costs, enhance security, and improve transparency, though adoption remains uneven. Findings reveal that blockchain significantly drives dynamic capabilities, which in turn boost financial performance. This suggests that banks leveraging blockchain are more likely to innovate and stay competitive. The study underscores blockchain as a strategic tool, not just a technical upgrade. It concludes with policy and research recommendations to strengthen adoption and maximise impact. Chang et al. (2020) examined the role of FinTech and blockchain in transforming the financial industry, highlighting opportunities, challenges, and ethical concerns. The study used a qualitative method involving interviews with sixteen financial technology experts. It focused on key variables such as blockchain adoption, knowledge hiding, and behavioural drivers, applying the Theory of Planned Behaviour (TPB). Findings revealed that banks are driven by innovation and efficiency but face barriers like knowledge hiding, rooted in affective, behavioural, and cognitive evaluations. The study developed four propositions and recommended structured knowledge-sharing strategies. Policy implications suggest financial institutions must create supportive frameworks and ethical guidelines to enhance blockchain integration and reduce information hoarding. Agyapong and Boakye (2024) explore blockchain's potential to improve banking security and efficiency in Africa using a qualitative, literature-driven approach. The study emphasizes core variables including transaction security, fraud reduction, data transparency, customer privacy, and regulatory and inclusion challenges. Findings reveal that blockchain could reduce fraud, strengthen trust in banking systems, and enable cross-border payments. However, adoption is hindered by underdeveloped regulatory frameworks and inadequate technological infrastructure. The authors highlight the importance of customer privacy and institutional trust for successful implementation. They argue that blockchain adoption could drive financial innovation and economic growth. The study recommends stronger regulations and digital investments to overcome adoption barriers.

Almadadha (2025) examines the effect of blockchain adoption on the financial performance of major Australian banks such as Commonwealth Bank, Westpac, and ANZ, covering 2016 to 2023. The study uses a descriptive research design with secondary data sourced from annual reports. Financial performance is measured through Return on Assets (ROA) and Return on Equity (ROE). Results reveal a positive association between blockchain adoption and improved efficiency, cost reduction, and profitability.

The findings underscore blockchain's strategic role in enhancing operational and financial outcomes. The research is sector-specific, capturing the Australian banking market's regulatory and competitive context. Its originality lies in offering localised empirical evidence to guide technology-driven financial strategies. Shyamaladevi et al. (2024) explore how blockchain's distributed ledger system is transforming finance by providing decentralized alternatives to traditional models. The paper highlights blockchain's ability to streamline processes, reduce costs, enhance efficiency, and improve transparency. It contrasts traditional finance with decentralized finance (DeFi), examining governance, accessibility, security, and regulatory challenges. Using a mixed-method approach combining secondary data and firsthand observations, the study offers a nuanced understanding of blockchain adoption. The research underscores blockchain's transformative capacity while recognizing institutional and regulatory hurdles. It provides actionable insights for scholars, regulators, and practitioners adapting to these changes. Ultimately, the paper predicts a possible coexistence or dominance of DeFi, offering guidance on navigating the evolving financial landscape.

Holloway (2025) critically analyses blockchain adoption in financial information systems, examining motivations, barriers, and institutional impacts. The study highlights drivers such as cost reduction via disintermediation, faster transactions, stronger security, and enhanced transparency. It notes blockchain's potential for financial inclusion, offering secure, low-cost services to underserved populations. However, challenges include legacy system integration, regulatory ambiguity, technical complexity, and organizational resistance. Strategic factors like leadership commitment, pilot projects, and specialized skills are emphasised as crucial for adoption. The research also explores blockchain's implications for digital currencies, asset management, and cross-border payments. It concludes that collaboration among regulators, FinTech's, and institutions is vital to unlock blockchain's transformative potential. Adel (2024) critically examines how digital literacy and blockchain adoption shape financial inclusion across 56 emerging countries in Africa, Asia, and Latin America between 2011 and 2021. Using a two-step system GMM approach, the study reveals complex regional dynamics often overlooked in prior research. Results show that digital literacy drives inclusion in Africa but has a negative effect in Asia, suggesting contextual barriers. Conversely, technology adoption, particularly blockchain, consistently improves inclusion in Asia and Latin America. Internet penetration strongly supports inclusion in Latin America but unexpectedly reduces it in some Asian regions. These findings emphasise that one-size-fits-all digital policies are ineffective for financial inclusion. The study concludes that region-specific strategies and targeted interventions are essential to bridge gaps in access and impact.

Adil and Fadi (2022) highlight blockchain and cryptocurrencies as transformative technologies with the capacity to reshape the global financial landscape. They argue that these innovations can address core challenges of financial inclusion, aligning with the World Economic Forum's projection of blockchain becoming central to financial infrastructure. The study positions blockchain as a revolutionary force comparable to the internet's impact in the 1980s and 1990s, driving a borderless and disintermediated economy. It notes that Morocco reflects this trend, with growing cryptocurrency adoption despite regulatory uncertainties and mixed public perception. The authors emphasise blockchain's potential to democratize finance and enhance accessibility across regions. They stress, however, that the technology's disruptive nature requires thoughtful integration and regulatory clarity to realize its benefits fully. This work underscores blockchain's dual promise and challenge for emerging markets. Trivedi et al. (2021) examine blockchain as a key technological innovation, emphasizing its relevance to trust-dependent sectors like banking and finance. The study highlights blockchain as a decentralized and coded security system enabling new digital platforms and services. Using a systematic review, they analysed 76 scholarly articles, narrowing to 59, to explore blockchain's development, adoption challenges, and applications in finance. The authors developed a three-dimensional classification framework covering technology evolution, sectoral challenges, and financial applications. Findings indicate significant unexplored opportunities for blockchain in the financial sector but underscore technological and regulatory gaps. The study stresses that blockchain remains in its infancy, with substantial room for improvement and policy formulation. It provides valuable implications for future research and practice in financial systems.

Sanyaolu et al. (2024) explore how blockchain technology can transform banking by enhancing inclusion, security, and efficiency. The paper highlights how traditional systems exclude underbanked populations and remain vulnerable to fraud, whereas blockchain offers decentralized, secure solutions. Using literature reviews and case studies, the authors examine scalability, integration, and adoption challenges. Findings show blockchain lowers service barriers, improves accessibility, and reduces fraud through cryptographic safeguards. Smart contracts and peer-to-peer models are noted to cut costs and speed transactions. Regulatory and governance gaps, however, pose significant hurdles to widespread adoption. The study recommends banks collaborate with regulators and embrace emerging technologies like AI and IoT to stay competitive and inclusive. Aketch et al. (2021) explored the impact of blockchain technology on financial market performance in Kenya, focusing on commercial banks in Nairobi. The study applied an explanatory design, sampling 50 IT and finance managers from 42 banks using stratified random sampling. Data collection involved structured questionnaires, and analysis was conducted using SPSS 24 with descriptive and inferential statistics. Results revealed positive and significant correlations between blockchain adoption and government policy (R=0.240), internet infrastructure (R=0.293), transaction costs (R=0.583), and risk analysis (R=0.507). The study emphasised the need for robust policies to manage risks and curb illegal transfers. It also highlighted the importance of internet connectivity in enhancing access to services and employment opportunities. The research was anchored on the Technology Acceptance Model and Innovation Diffusion Theory, recommending further studies on blockchain stability and economic growth impact.

Relatedly, Manasseh et al. (2024) examine the impact of digital financial innovation on financial system development in COMESA using time-series data (1997–2019) and advanced econometric models such as ARDL, PMG, and system GMM. Findings reveal that ATMs, POS, mobile payments, and mobile banking significantly enhance long-run financial development, while mobile money and internet banking show mixed effects. The study highlights the importance of institutional quality and a stable macroeconomic environment in strengthening the innovation–finance nexus. It recommends cohesive regional financial strategies and policies to sustain innovation-driven financial system development. Manasseh et al. (2023) investigate the role of digital finance and financial inclusion in driving economic growth across 19 COMESA countries (1997–2018) using a panel ARDL approach. The study finds that digital finance tools, such as ATMs, POS, mobile banking, and mobile money alongside financial inclusion indicators significantly boost growth. Evidence of bidirectional causality between digital finance, inclusion, and growth underscores their mutual reinforcement. However, weak institutional environments and macroeconomic volatility constrain these benefits, calling for supportive policies to deepen financial innovation and inclusion. Manasseh et al. (2025) explored how financial technology and innovation influence bank performance in ECOWAS using ARDL with data from 1997–2022. The study found a long-run positive association, where fintech tools like mobile and internet banking, ATMs, POS, and mobile payments significantly improved ROA and ROE. The authors argue that investments in regulated fintech and innovation can strengthen bank performance if backed by effective policies. Importantly, the study fills a gap in the literature given the mixed and inconclusive prior evidence on fintech–performance linkages.

Furthermore, similar studies of Manasseh & Ede (2024) highlight digital finance as a catalyst for economic growth through financial inclusion, cost reduction, and expanded credit access. The paper stresses the importance of cybersecurity measures—fraud detection, compliance, and user education—to build trust and secure transactions. It concludes that while digital finance accelerates development, robust regulation and continuous innovation are essential to mitigate risks. In a related study, Manasseh et al. (2024) investigate the nexus between microfinance, financial inclusion, and economic welfare across 23 African countries (2004–2023) using advanced panel econometric techniques. Results reveal a long-run cointegrating relationship, with microfinance and financial inclusion significantly enhancing welfare. The error correction terms indicate strong and consistent short-run adjustments. The study concludes that digitized microfinance services and supportive government infrastructure are vital for maximising welfare impacts. While Manasseh et al. (2024) examined the role of technological innovation in banking performance across 40 emerging markets between 2000 and 2021. The findings revealed strong positive correlations and long-run relationships between innovation and bank performance, supported by ARDL and GMM estimations. The study highlights how innovations enhance efficiency, reduce costs, and foster competitiveness. Policy recommendations include strengthening technology hubs and expanding digital banking access to underbanked populations.

2.4 Gaps in the Literature

Despite the extensive body of literature on blockchain and financial inclusion, several gaps remain, particularly regarding rural Nigeria. Most studies, including Adegbite (2024) and Adebayp et al. (2024), focus broadly on blockchain's capacity to enhance financial inclusion through decentralization, low-cost transactions, and cross-border remittances. While they emphasise benefits such as increased accessibility, peer-to-peer transfers, and micro-lending, these studies largely concentrate on urban populations or SMEs, leaving rural communities underexplored. Similarly, Biriuk et al. (2024) and Chumak (2021) provide macro-level analyses across countries, highlighting market growth, cryptocurrency reliance, and smart contracts, but they rarely consider localised infrastructural and socio-cultural constraints that limit rural adoption. Other studies, such as Zheng et al. (2022), Hoffmann (2021), and Mhlanga (2023), focus on technical improvements, including consensus mechanisms, security, and credit systems, without linking these directly to rural inclusion. Likewise, research by Abdulhakeem and Hu (2021) and Adel (2024) notes complementary roles of blockchain and digital literacy but stops short of empirically demonstrating causal relationships in rural African contexts. Aketch et al. (2021) provide country-level insights for Kenya but use correlational approaches, lacking dynamic long-run and short-run modelling that captures temporal effects.

Furthermore, regulatory ambiguity and socio-economic barriers are often acknowledged in qualitative terms (Agyapong & Boakye, 2024; Holloway, 2025), yet few studies quantify how these challenges directly impede blockchain adoption in rural financial systems. Existing works also fail to integrate comprehensive blockchain readiness measures, such as blockchain readiness indices, cryptocurrency exchange volumes, or aggregated open interests, with financial inclusion proxies tailored to rural banking development. This study addresses these gaps by focusing specifically on rural Nigeria between 2009 and 2024, applying ARDL modelling to examine both long-run and short-run effects of blockchain adoption on financial inclusion. By combining blockchain readiness indicators with rural banking development measures, it provides a granular, empirical assessment that accounts for infrastructural, regulatory, and socio-economic constraints, thereby offering actionable insights for policymakers, financial institutions, and rural communities.

3. Methodology

3.1 Nature and Sources of Data

This study focuses on examining the blockchain's impact on financial inclusion in rural Nigeria from 2009 to 2024, ensuring the fulfilment of its objectives. After a comprehensive theoretical and empirical examination of the literature, we evaluated the subsequent variables: The blockchain readiness index (BRI), cryptocurrency exchange volume (CEV), and aggregated open interests on Bitcoin futures (AIBF) were used to measure the blockchain. The rural bank deposit volume (RBDV) was used to measure financial inclusion, and the control variables were measured with financial deepening, which is the ratio of broad money (M2) to GDP (M2/GDP) and the exchange rate (EXR). We got this information from the World Bank's development indicators (WDI) and the block cryptocurrency database.

3.2 Model Specification

We used the autoregressive distributed lag (ARDL) estimate method to look into how blockchain affects financial inclusion in rural Nigeria. The autoregressive distributed lag (ARDL) model possesses distinct characteristics when compared to alternative estimate techniques. Many academics, like Manasseh et al. (2024) and Manasseh et al. (2025), have used a lot of cointegration approaches to do econometric research. Some of these tests are the maximum likelihood-based Johansen (1991), the residual-based Engle and Granger (1987), the Johansen (1995), and the Johansen and Juselius (1990) tests. Researchers have begun to utilize the autoregressive distributed lag (ARDL) estimation technique due to the limitations of previous estimating methodologies. The ARDL method is adaptable, permitting the integration of variables in varying sequences (Pesaran et al. 2001), and it can generate an error correction model (ECM) through linear transformation (Banerjee et al. 1993). Consequently, the ARDL model offers several advantages over alternative cointegration methods. This study utilized the ARDL model because to its advantages over alternative cointegration models. The autoregressive distributed lag model is superior as it incorporates estimates, regardless of the sample size's minuteness or limitations (Ghatak and Siddiki 2001). Second, this strategy is more effective when the variables are solely integrated in the order I(0) and others in the order I(1). Third, Pesaran et al. (2001) say that using an adequate lag in ARDL modelling is the best way to deal with both endogeneity and serial correlation problems. Fourth, Pesaran et al. (2001) assert that the ARDL model can precisely estimate both long-term and short-term cointegrating relationships. So, here is the outline of the empirical ARDL model for the research.

$$\Delta InRBDV_t = \beta_0 + \sum_{i=1}^{n} \beta_1\, \Delta InRBDV_{t-1} + \sum_{i=1}^{n} \beta_2\, \Delta InBRI_t + \sum_{i=1}^{n} \beta_3\, \Delta InCEV_t + \sum_{i=1}^{n} \beta_4\, \Delta InAIBF_t + \sum_{i=1}^{n} \beta_5\, \Delta InM2/GDP_t + \sum_{i=1}^{n} \beta_6\, \Delta InEXR_t + \omega_1 InRBDV_t + \omega_2 InBRI_t + \omega_3 InCEV_t + \omega_4 InAIBE_t + \omega_5 InM2/GDP_t + \omega_6 InEXR_t + \varepsilon_{it} \quad (1)$$

RBDV stands for "rural bank deposit volume," which is a measure of how many people are using banks. BRI stands for "blockchain readiness index," CEV stands for "cryptocurrency exchange volume," AIBF stands for "aggregated open interests on Bitcoin futures," M2/GDP stands for "financial deepening," and EXR stands for "exchange rate." Also, β_0 is the constant, ω_1 to ω_6 are the long-run impact coefficients, β_1 to β_6 are the short-run dynamics coefficients, Δ is the first difference operator, and *In*; is the natural logarithm. Finally, $\varepsilon_{i,t}$ is the white noise error term.

If the F-statistic, on the other hand, is higher than the upper-bound critical value for a certain significance level, it means that there is a real long-run level relationship with the dependent variable. If the F-statistic is less than the lower bound critical value, it means that the dependent variable does not have a long-term level relationship with it. The result is inconclusive if it falls between the lowest and upper boundaries. The null and alternative hypotheses for the F-statistic test are generally as follows:

$$H_0: \omega_1 = \omega_2 = \omega_3 = \omega_4 == \omega_5 = \omega_6 = 0$$
$$H_1: \omega_1 \neq \omega_2 \neq \omega_3 \neq \omega_4 \neq \omega_5 \neq \omega_6 \neq 0 ----(2)$$

If cointegration between variables is detected, further examination of their long-term and short-term (error correction) relationships can be conducted. We may write the error correction representation of the series like this:

$$\Delta InRBDV_t = \beta_0 + \sum_{i=1}^{n} \beta_1 \Delta InRBDV_{t-1} + \sum_{i=1}^{n} \beta_2 \Delta InBRI_t + \sum_{i=1}^{n} \beta_3 \Delta InCEV_t + \sum_{i=1}^{n} \beta_4 \Delta InAIBF_t + \sum_{i=1}^{n} \beta_5 \Delta InM2/GDP_t + \sum_{i=1}^{n} \beta_6 \Delta InEXR_t + \vartheta ECT + \varepsilon_t \quad (3)$$

Where $\vartheta$the speed of adjustment parameter and ECT is the error correction term (the residuals obtained from equation 1). The coefficient of the lagged error correction term ϑ is expected to be negative and statistically significant to further confirm the existence of a cointegrating relationship between the variables.

4. Result Analysis and Discussion of Findings

4.0 Overview

This section examines the impact of blockchain on financial inclusion in rural Nigeria using the ARDL model. Before estimation, several diagnostic and econometric tests were conducted, including normality, serial correlation, the Ramsey model specification test, heteroscedasticity, unit root, and descriptive statistics, to ensure model reliability. Furthermore, tests such as descriptive statistics, correlation test and unit root test were employed to ascertain the basic characteristics of the model variables. The analysis further interprets the regression results derived from the secondary data employed in this study.

4.1 Data Description

We examined the overall behaviour of the variables using descriptive statistics for the annual dataset covering 2009–2024. Descriptive statistics provide a quantitative summary of key features of the data, including mean, median, minimum, maximum, standard deviation, skewness, and kurtosis. The results, presented in Table 2, show that the mean, median, standard deviation, skewness, and kurtosis values did not diverge significantly from one another. Furthermore, the probability values of most Jarque-Bera statistics were below 0.05, indicating that the variables are normally distributed and therefore suitable for analysing the relationships under investigation.

Table 1: Descriptive Statistics

Variable	RBDV	BRI	CEV	AIBF	M2/GDP	EXR
Mean	0.551	7.845	0.450	1.715	6.226	-0.020
Median	0.481	4.301	0.544	1.012	3.481	-0.347
Maximum	1.685	2.299	0.826	1.821	18.35	4.303
Minimum	0.081	1.966	0.012	0.980	0.932	-0.596
Std. Dev.	0.392	6.818	0.698	0.530	6.226	1.183
Skewness	1.565	1.217	-0.350	-0.353	1.201	3.322
Kurtosis	5.472	2.968	1.765	2.209	2.852	12.67
Jarque-Bera	10.60	3.950	1.619	0.750	3.862	91.88
Probability	0.454	0.198	0.912	0.686	0.244	0.854
Observations	16	16	16	16	16	16

Source: Concept of the Researcher

We extended the analysis by conducting a correlation test to determine the nature and strength of relationships between blockchain and financial inclusion in rural Nigeria. Spearman's correlation matrix was employed to measure the degree of association between each pair of variables in the model, with coefficients ranging from –1 to +1. Higher absolute coefficient values indicate stronger relationships, while lower values reflect weaker associations (Gujarati, 2003). Following Cohen's (1988) rule of thumb, correlation coefficients are interpreted as strong (±0.5), moderate (±0.3), and weak (±0.1). The correlation test reveals a complex and somewhat contradictory interplay between blockchain-related indicators and rural financial inclusion, measured by rural bank deposit volume (RBDV). Notably, RBDV exhibits a strong positive association with cryptocurrency exchange volume (CEV, 0.721) and exchange rate (EXR, 0.717), suggesting that cryptocurrency activity and currency movements may enhance deposit mobilization in rural areas. However, the strong negative relationship between RBDV and blockchain readiness index (BRI, –0.601) and aggregated open interest in Bitcoin futures (AIBF, –0.715) indicates that while speculative blockchain infrastructure and futures markets expand, rural inclusion suffers, implying that these blockchain dimensions could be exclusionary or destabilizing for rural users. The near-perfect positive correlation between BRI and M2/GDP (0.973) raises concerns of multicollinearity and suggests that blockchain readiness largely tracks with overall financial depth rather than uniquely driving inclusion. Similarly, the negative correlation relationship of CEV (–0.87) and M2/GDP underscores the potential substitution effect between cryptocurrency activity and traditional monetary aggregates, weakening conventional financial deepening channels. Finally, while blockchain adoption via – cryptocurrency exchange volume (CEV) appears to directly benefit rural inclusion, broader blockchain readiness and speculative futures activity may undermine it, revealing an uneven and potentially dualistic role of blockchain in advancing financial inclusion in Nigeria's rural economy.

Table 2: Correlation Results

Variable	RBDV	BRI	CEV	AIBF	M2_GDP	EXR
RBDV	1.000					
BRI	-0.601	1.000				
CEV	0.721	-0.873	1.000			
AIBF	-0.715	0.469	-0.491	1.000		
M2/GDP	-0.973	0.990	-0.869	0.441	1.000	
EXR	0.717	-0.170	0.412	0.129	-0.189	1.000

Source: Concept of the Researcher

4.2 Testing for Unit Root

We employed various unit root tests, like the Augmented Dickey-Fuller (ADF) test to ascertain the stationarity of the variables and their order of integration and the results are presented in Table 3. The tests are guided by the null hypothesis "unit root" and alternative hypothesis "no unit root" and decision rule "reject the null hypothesis if the probability value is less than 0.05". The results shows that there is no trace of unit root in the series because the probability values of the variables in both ADF and PP tests are less than 0.05. Furthermore, the results also revealed that while some of the variables are integrated at the level, others are integrated at first difference and no variable was found to be integrated at second-order, i.e. I(2) and above. This therefore implied that the variables are suitable for the estimation of the ARDL analysis.

Table 3: Stationarity Tests Results

Variable	ADF-Statistic	Integration Order	
		Level	First-Difference
RBDV	-5.019** (0.001)	I(0)	
BRI	-3.789** (0.014)		I(1)
CEV	-3.489** (0.025)		I(1)
AIBF	-4.631*** (0.0033)	I(0)	
M2/GDP	-2.731** (0.010)		1(1)
EXR	-7.543*** (0.000)	I(0)	

Source: Concept of the Researcher. Note: ***, **, and * represent the 1%, 5%, and 10% significant levels, and (.) represent the probability value

4.3 Testing for Long-Run Cointegration (Bounds Test)

Having established the presence of cointegration among the variables, we advanced our research by examining the potential existence of a long-term relationship between blockchain and financial inclusion in rural Nigeria. For this reason, we employed the ARDL limits test that Pesaran et al. (2001, 1999) suggested. It compares the F-statistics that were calculated to the top critical values at 1%. There is a long-term association between the variables if the F-statistics are higher; if they are lower, there is no relationship. Table 4 shows the results of the ARDL bounds test for the specified models. From these results, we can see that there is a long-term relationship between blockchain and financial inclusion in rural Nigeria because the F-statistic coefficients for all the variables are higher than those of Pesaran et al. (2001) and Narayan (2004).

Table 4: Results of Bounce Test Long-Run Cointegration

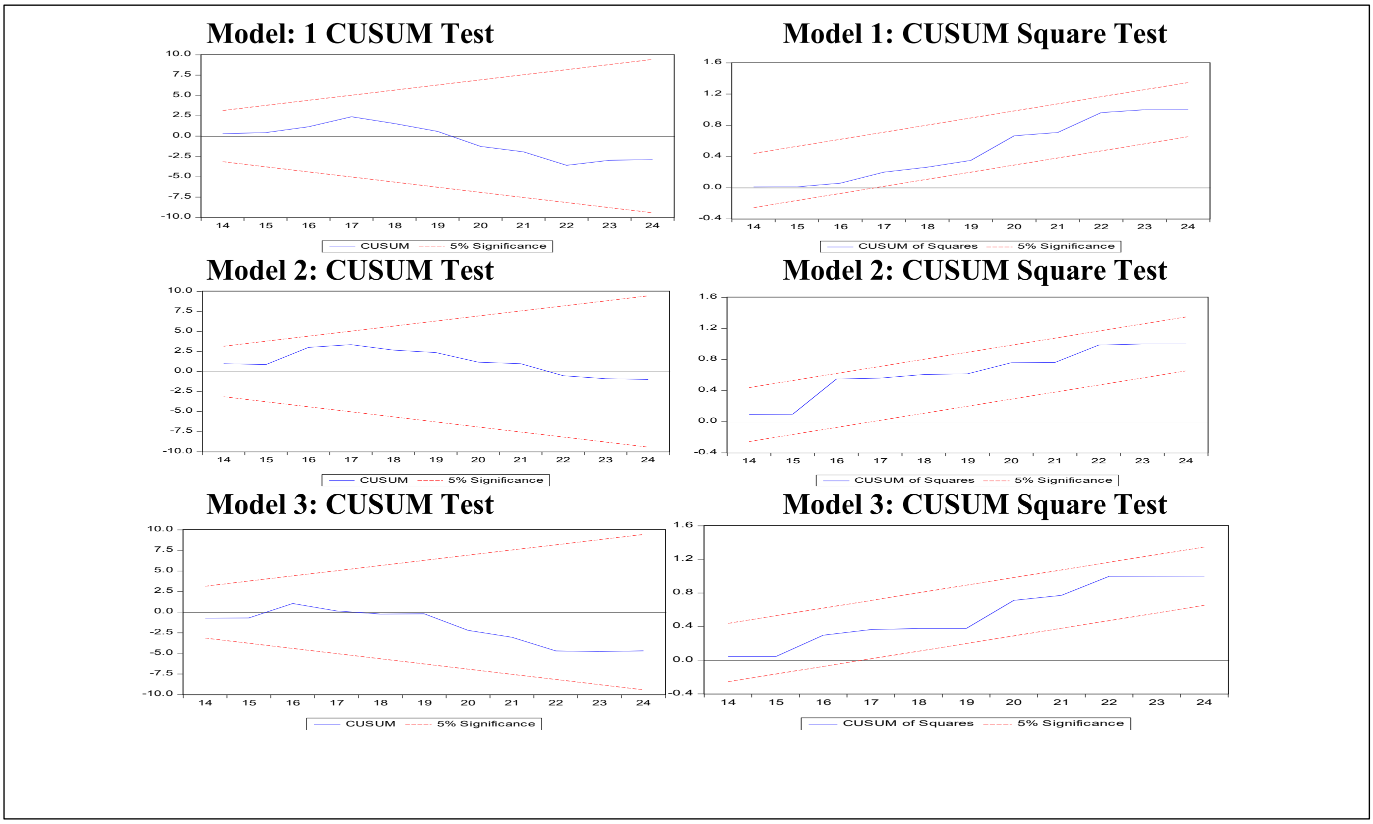
Model	Dep. Var.	F-Stat.	K	Pesaran et al. (2001)						Narayan (2004)					
				1%		5%		10%		1%		5%		10%	
				I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
1	RBD V	7.596	3	3.74	5.06	2.86	4.01	2.45	3.52	4.59	6.37	3.28	4.63	2.70	3.90
2	RBD V	9.773	3	3.74	5.06	2.86	4.01	2.45	3.52	4.59	6.37	3.28	4.63	2.70	3.90
3	RBD V	8.558	3	3.74	5.06	2.86	4.01	2.45	3.52	4.59	6.37	3.28	4.63	2.70	3.90

Source: Concept of the Researcher

4.4 Testing for Stability

This study further examined the stability of the variables across the study period and within each specified model by applying the ARDL-based recursive CUSUM and CUSUMSQ tests, which are widely recognised diagnostic tools first introduced by Brown et al. (1975) in econometrics. These tests are particularly useful for assessing whether the estimated parameters of a model remain stable over time, thereby ensuring the reliability of long-run and short-run inferences. The decision rule underpinning the tests is straightforward: if the plotted CUSUM and CUSUMSQ statistics remain within the 5% critical bounds, the model parameters are considered stable; conversely, deviations outside these bounds signal structural instability or model misspecification. In this study, the results presented in Figure 1 demonstrate that the CUSUM and CUSUMSQ lines consistently lie within the 5% significance boundaries, thereby confirming parameter stability for the models throughout the research period. This finding not only validates the robustness of the ARDL estimations but also suggests that the relationships between blockchain adoption, financial inclusion, and the control variables in Nigeria are not subject to significant structural distortions during the examined timeframe, reinforcing confidence in the empirical results and their policy relevance.

Figure 1: Stability Plots



Source: Authors' Concept

4.5 ARDL Long-Run Result Analysis

The use of the ARDL framework is highly relevant for this study, as it enables the analysis of both short- and long-run dynamics between blockchain adoption and financial inclusion while accommodating mixed orders of integration (I(0) and I(1)). The diagnostic tests validate the robustness of the estimated models. Specifically, the Jarque-Bera statistics confirm normality across all specifications with p-values well above 0.05, while the Breusch-Godfrey serial correlation test indicates the absence of autocorrelation. Similarly, the Ramsey RESET test rules out misspecification, and the White heteroscedasticity test confirms homoscedasticity. These outcomes suggest that the ARDL estimations are reliable and free from common econometric pitfalls, enhancing the credibility of the inferences drawn. Such robustness aligns with the broader literature, including Adegbite (2024) and Adebayo et al. (2024), who emphasize blockchain's potential in enhancing financial inclusion through transparency, decentralization, and accessibility, despite challenges in infrastructure and regulation.

The long-run coefficients provide nuanced insights across the three models. In Model 1, the Blockchain Readiness Index (BRI) exhibits a strong positive and significant effect (0.9115, $p<0.01$) on rural bank deposit volume (RBDV), affirming blockchain's transformative role in financial inclusion as underscored by Biriuk et al. (2024). M2/GDP and exchange rate also positively influence financial inclusion, suggesting that financial deepening and currency stability remain critical. In Model 2, cryptocurrency exchange volume (CEV) has a negative and significant impact (-0.0531, $p<0.01$), highlighting the destabilizing potential of speculative trading on rural financial inclusion, consistent with Vorobets (2020). Conversely, exchange rate shocks exert an exaggerated positive effect (2.3509, $p<0.01$), reflecting the sensitivity of deposits to currency fluctuations. Model 3 shows that aggregated interest in Bitcoin futures (AIBF) is insignificant, confirming limited integration of advanced crypto derivatives into Nigeria's rural finance. Interestingly, M2/GDP turns negative (-0.1160, $p<0.01$), pointing to inefficiencies in translating monetary expansion into grassroots financial access. Exchange rate remains positive but weaker (0.0583, $p<0.01$), underscoring its variable role. Collectively, these findings echo global evidence (Mhlanga, 2023; Agyapong & Boakye, 2024; Holloway, 2025) that blockchain technologies can improve financial inclusion, but their impacts are conditioned by the nature of adoption, institutional readiness, and macroeconomic contexts.

These results suggest several policy imperatives: first, regulators must differentiate between blockchain readiness and speculative cryptocurrency trading, supporting the former while curbing destabilizing effects of the latter through targeted oversight. Second, policies should encourage blockchain integration with mobile banking and fintech ecosystems, particularly in rural areas, to maximize deposit mobilization. Third, exchange rate management remains central, as volatility directly conditions financial inclusion outcomes. Overall, the evidence affirms that blockchain is not a panacea but, when embedded in supportive macroeconomic and institutional frameworks, can drive inclusive finance in Nigeria.

Table 5: Estimated Results of ARDL

Variable	Model 1	Model 2	Model 3
RBDV (-1)	0.354** (0.015)	0.192*** (0.000)	0.105*** (0.000)
BRI	0.912*** (0.000)		
CEV		-0.053*** (0.000)	
AIBF			0.885 (0.935)
M2/GDP	0.0181** (0.027)	0.024** (0.046)	-0.116*** (0.009)
EXR	0.824*** (0.000)	2.350*** (0.000)	0.058*** (0.002)
Normality	5.650 (0.697)	7.137 (0.289)	2.235 (0.257)
Serial Correlation	1.073 (0.556)	0.315 (0.736)	2.391 (0.946)
Ramsey Model Specification Test	-0.473 (0.346)	-0.953 (0.695)	-0.183 (0.655)
Heteroscedasticity	0.258 (0.625)	0.359 (0.560)	0.096 (0.760)

Source: Concept of the Researcher. Note: ***, **, and * represent the 1%, 5%, and 10% significant levels, and (.) represent the probability value

4.6 ARDL Short-Run Results Analysis

The ARDL short-run dynamics reveal mixed but insightful outcomes. The highly significant and negative ECM coefficients across all three models (–0.954, –0.369, and –0.322) confirm strong and stable error-correction mechanisms, indicating that deviations from long-run equilibrium are swiftly adjusted. This aligns with Adegbite (2024) and Biriuk et al. (2024), who emphasise blockchain's potential to correct structural imbalances in access to financial services by reducing costs, enabling peer-to-peer transfers, and enhancing trust in weak institutional settings. However, the insignificance of short-run variables such as blockchain-related innovation (BRI), cryptocurrency-enabled ventures (CEV), and alternative inclusive banking frameworks (AIBF) suggests that blockchain's role in fostering financial inclusion in rural Nigeria may be more long-run than immediate. This outcome resonates with Vorobets (2020) and Abdulhakeem & Hu (2021), who argue that blockchain is not a panacea but a complementary technology that gradually reshapes financial systems rather than producing short-term shocks. The short-run insignificance of monetary aggregates (M2/GDP) and exchange rate dynamics (EXR) further suggests that macroeconomic variables exert limited immediate influence on blockchain's contribution to inclusion, a finding consistent with Adel (2024), who stresses that digital adoption and literacy drive outcomes more than conventional monetary levers. Similarly, the weak short-run effect of CEV and AIBF echoes Adebayp et al. (2024) and Chumak (2021), who note that infrastructural gaps, regulatory uncertainty, and skills deficits undermine blockchain's immediate impact on SMEs and decentralized finance. Yet, the strong error correction terms confirm that blockchain adoption and related innovations eventually integrate into Nigeria's financial ecosystem, stabilising long-run financial inclusion. This mirrors findings from Sanyaolu et al. (2024), Ogunrinde et al. (2025), and Holloway (2025), which highlight blockchain as a strategic enabler of inclusion, efficiency, and stability once integrated with broader institutional and regulatory frameworks. In essence, while blockchain's short-run dynamics remain weak, its long-run adjustment path underscores its transformative potential for rural financial access.

Table 6: Estimated Results of ARDL Short-Run Dynamics

Variable	Model 1	Model 2	Model 3
ECM (-1)	-0.954***	-0.359***	-0.350***
	(0.001)	(0.000)	(0.009)
ΔBRI	-0.540		
	(0.919)		
ΔCEV		-0.749	
		(0.350)	
ΔAIBF			-0.627
			(0.633)
ΔM2/GDP	-0.201	-0.775	-0.885
	(0.935)	(0.159)	(0.440)
ΔEXR	0.024	0.628	0.245
	(0.793)	(0.486)	(0.394)

Source: Concept of the Researcher. Note: ***, **, and * represent the 1%, 5%, and 10% significant levels, Δ is the first difference operator, and (.) represents the probability value

4.7 Discussion of Findings

The results of this study reveal that blockchain adoption holds significant promise for improving financial inclusion in rural Nigeria, but the effects are largely long-run in nature. The ARDL bounds test confirms the existence of cointegration between blockchain-related indicators and rural bank deposit volumes, underscoring that blockchain adoption and financial inclusion are systematically linked over time. The long-run results show that the Blockchain Readiness Index (BRI) exerts a strong positive and significant effect, affirming its role as a transformative driver of rural deposits. This aligns with Biriuk et al. (2024) and Adegbite (2024), who argue that blockchain lowers barriers such as distance, costs, and institutional inefficiencies, thereby expanding access to financial services. By contrast, cryptocurrency exchange volume (CEV) exhibits a negative long-run effect, pointing to the destabilizing influence of speculative trading—consistent with Vorobets (2020), who cautions that unregulated cryptocurrency markets can undermine grassroots stability. Moreover, the results for aggregated interest in Bitcoin futures (AIBF) are insignificant, highlighting the limited integration of advanced crypto derivatives into Nigeria's rural finance ecosystem.

The short-run dynamics provide additional insight. The error correction terms are highly significant and negative across all models, confirming rapid adjustment from short-run disequilibria to long-run equilibrium. This suggests that even if blockchain adoption appears weak in its immediate influence, over time, the system converges toward stability and inclusion. However, short-run coefficients for BRI, CEV, AIBF, M2/GDP, and EXR are largely insignificant, implying that blockchain's contributions to rural financial access cannot be realized instantly. These results resonate with Abdulhakeem and Hu (2021) as well as Adel (2024), who argue that blockchain is not a quick fix but rather a complementary innovation requiring institutional readiness, infrastructural investment, and digital literacy to generate meaningful outcomes. The weak short-run significance of macroeconomic variables also indicates that financial deepening and exchange rate dynamics alone are insufficient drivers of blockchain-enabled inclusion, with technology adoption playing a more decisive role.

In conclusion, the study affirms that blockchain has transformative potential for enhancing financial inclusion in rural Nigeria, though its effects materialize primarily in the long run. Policymakers should therefore differentiate between supportive blockchain adoption such as readiness frameworks, mobile integration, and digital literacy initiatives, and destabilizing elements like speculative cryptocurrency trading. Strengthening regulatory oversight, ensuring currency stability, and embedding blockchain within broader financial deepening strategies will be crucial to maximising its benefits. While blockchain is not a panacea, when supported by robust macroeconomic management and institutional reforms, it can serve as a strategic enabler of inclusive finance, reducing rural exclusion and driving sustainable economic growth.

5. Conclusion and Policy Recommendations

This study investigated the impact of blockchain on financial inclusion in rural Nigeria between 2009 and 2024, focusing on whether blockchain adoption—measured through the Blockchain Readiness Index (BRI), cryptocurrency exchange volume (CEV), and aggregated open interest in Bitcoin futures (AIBF), enhances rural bank deposit volumes (RBDV), a proxy for financial inclusion. Employing the ARDL bounds testing framework, supported by unit root, diagnostic, and stability tests, the findings confirmed the existence of long-run cointegration among blockchain indicators and financial inclusion, highlighting that their relationship is systematic and enduring. The long-run results revealed that BRI exerts a strong, positive, and significant influence on RBDV, confirming blockchain readiness as a transformative driver of rural deposits, consistent with evidence that blockchain lowers barriers such as distance, costs, and institutional inefficiencies. Conversely, CEV displayed a negative long-run effect, suggesting that speculative and unregulated trading undermines grassroots financial stability, while AIBF proved insignificant, reflecting the limited role of crypto derivatives in Nigeria's rural financial ecosystem. Short-run dynamics further showed that coefficients for blockchain indicators and macroeconomic variables were largely insignificant, though the significant and negative error correction terms confirmed convergence from short-run disequilibria to long-run equilibrium. This implies that blockchain's immediate effects are minimal, but its potential consolidates over time. In conclusion, the study demonstrates that blockchain adoption holds transformative potential for rural financial inclusion in Nigeria, with effects primarily realized in the long run. Policy recommendations stress strengthening regulatory oversight, embedding blockchain into financial deepening strategies, improving digital literacy, and curbing destabilizing speculative activities to maximize inclusive benefits.

The findings of this study conclude that blockchain adoption holds transformative potential for advancing financial inclusion in rural Nigeria, though its impact is primarily long-run in nature. The ARDL bounds testing confirmed cointegration between blockchain-related indicators and rural bank deposit volumes, indicating that blockchain and financial inclusion are systematically connected over time. Among the blockchain measures, the Blockchain Readiness Index (BRI) emerged as a significant positive driver of rural deposits, underscoring the role of institutional preparedness, infrastructure, and supportive frameworks in lowering barriers to financial access. In contrast, cryptocurrency exchange volume (CEV) exerted a negative effect, reflecting the destabilizing influence of speculative and unregulated trading activities on grassroots financial stability, while aggregated interest in Bitcoin futures (AIBF) remained insignificant, highlighting the limited relevance of advanced derivatives to rural finance. Short-run effects of blockchain adoption and macroeconomic variables were largely weak, but the significant and negative error correction terms revealed rapid adjustment toward equilibrium, reinforcing the long-run stability of the relationship. However, blockchain is not a quick fix but, when supported by robust regulatory oversight, macroeconomic stability, digital literacy, and institutional reforms, it can serve as a strategic enabler of inclusive finance, reducing rural exclusion and fostering sustainable economic growth.

Improving financial inclusion in rural Nigeria through blockchain technology requires first the establishment of clear and adaptive regulatory frameworks. A well-structured regulatory environment reduces uncertainty, protects consumers, and encourages both domestic and foreign investment in blockchain-based financial innovations. Importantly, regulations should balance innovation with safeguards against fraud, cybercrime, and money laundering, which are major risks associated with digital finance. Specific provisions must target rural banking systems, enabling the integration of blockchain into microfinance and cooperative institutions. Such a framework, supported by collaboration between regulators, financial institutions, and FinTech's, will ensure that blockchain adoption in rural areas is both sustainable and inclusive.

Another vital policy approach is the expansion of digital infrastructure in rural communities. Blockchain cannot function effectively without reliable broadband internet, mobile connectivity, and stable electricity supply. Investment in digital infrastructure, therefore, becomes the backbone of inclusive technological adoption. Public–private partnerships can play a strategic role in extending affordable services to rural dwellers, while community-based digital hubs may be created to provide shared access to blockchain-enabled platforms. Embedding these infrastructural initiatives into national rural development strategies will ensure that rural households are not excluded from the benefits of financial digitalization. Equally important is the promotion of financial literacy and capacity building to address knowledge gaps that often hinder blockchain adoption in rural settings. Large-scale training programs should be launched to educate rural populations on the use of mobile wallets, digital identity, and secure transactions. Such programs can also help dispel myths and skepticism surrounding blockchain technology, encouraging trust and confidence. Partnerships with local institutions, non-governmental organizations, and cooperative societies can improve outreach and contextualize training to meet community needs. By enhancing digital literacy, blockchain adoption will translate into practical financial inclusion rather than remain a theoretical possibility.

In addition, policies should incentivize innovation within rural banking systems. Tax reliefs, grants, and subsidies can be provided to banks and fintech companies that develop blockchain-based services tailored for rural users. Products such as blockchain-enabled microcredit, savings groups, and cooperative lending schemes could be promoted through such support. Integration with mobile platforms, particularly through USSD codes and mobile applications, will enhance accessibility for low-income populations with limited access to smartphones. Pilot projects in selected rural areas should also be encouraged to test scalable solutions that can later be expanded nationwide. These incentives would bridge the gap between innovation and rural accessibility. Finally, strengthening identity and security systems through blockchain applications offers another policy pathway. A blockchain-based digital identity system can simplify the process of opening bank accounts and reduce the documentation barriers that exclude many rural dwellers from formal financial services. With secure and transparent identity management, blockchain builds trust in transactions and provides traceability, which is essential for financial accountability. Linking government-issued blockchain IDs to banking services would create a unified and reliable access system. This would not only enhance security but also encourage broader participation of rural households in Nigeria's financial system.

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