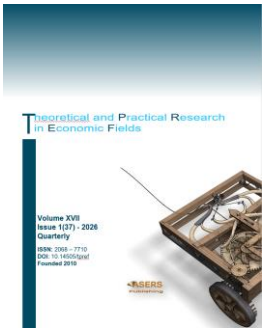
An Empirical Analysis of Block Chain Technology's Impact on Financial Inclusion in Developing Economies



Veereedhi V. Deepika[1], A.V.N. Murty[2], Gaurav Kumar[3], Ramesh Safare[4], Nihar Ranjan Agasti[5], Ashok Kumar Dash[6]

[1,2]KLEF Business School, Koneru Lakshmaiah Education Foundation, KL University, India
[1]deepikashiva.d@gmail.com
[2]dravnmurty@kluniversity.in
[3]School of Liberal Arts and Management Studies, P. P. Savani University, India
[3]klgaurav4@gmail.com
[4]Faculty of Management Studies, Marwadi University, India
[4]ramesh.safare@marwadieducation.edu.in
[5]Department of Management, Medicaps University, India
[5]nihar.agasti@medicaps.ac.in
[6]Department of Business Administration, Ravenshaw University, India
[6]akdash2020@gmail.com

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Abstract: This study examines the influence of block chain technology on financial inclusion in India from 2020 to 2025. Employing the Generalized Method of Moments (GMM) model, we analyse the relationship between block chain adoption and financial inclusion in developing nation like India, controlling for macroeconomic variables such as GDP, GDP per capita, foreign direct investment (FDI), trade openness, and institutional factors like the rule of law. The findings reveal that block chain technology has a positive and significant impact on financial inclusion, indicating that block chain innovation enhances financial accessibility and growth. However, the institutional variable, government effectiveness, does not show a considerable influence. These results underscore the role of block chain technology in promoting financial inclusion and economic development in developing economies.

Keywords: block chain technology, financial inclusion, Generalized Method of Moments, developing economies, macroeconomic.

JEL Classification: O16; G21; O33; L86.

Introduction

Financial inclusion, defined as the accessibility and availability of financial services to all individuals, particularly the underserved and unbanked populations, is pivotal for fostering economic development and reducing poverty in developing economies. In India, despite significant strides in financial sector reforms, a substantial segment of the population remains excluded from formal financial systems. India has made significant strides toward financial inclusion, particularly with initiatives like the Pradhan Mantri Jan Dhan Yojana (PMJDY), launched in 2014 to provide universal access to banking facilities.

As a result, millions of previously unbanked individuals have gained access to formal financial services. However, challenges persist, especially in rural areas where geographical inaccessibility, high transaction costs, and a lack of tailored banking products hinder the effectiveness of these initiatives. The advent of block chain technology offers a transformative potential to bridge this gap by providing decentralized, transparent, and secure financial services. Block chain technology, characterized by its distributed ledger system, ensures immutable and transparent transaction records, thereby reducing the need for intermediaries and lowering transaction costs. (Schuetz & Venkatesh, 2020). This decentralization can address several barriers to financial inclusion, such as geographical constraints, high service fees, and lack of trust in traditional banking institutions. For instance, blockchain-based mobile banking applications can facilitate financial transactions for individuals in remote areas, overcoming challenges related to physical banking infrastructure. (Mhlanga, 2023).

Empirical studies have highlighted the positive impact of blockchain adoption on financial inclusion. Research indicates that blockchain applications hold significant potential to accelerate financial inclusion initiatives in India by overcoming challenges related to access, cost, and financial literacy (Carè et al., 2025). Furthermore, block blockchain's role in strengthening cyber security and protecting privacy can enhance user confidence in digital financial services. However, the relationship between blockchain technology and financial inclusion is influenced by various macroeconomic and institutional factors. Variables such as Gross Domestic Product (GDP), GDP per capita, Foreign Direct Investment (FDI), trade openness, and the rule of law play significant roles in shaping the effectiveness of block chain based financial services. In a developing nation like India, achieving comprehensive financial inclusion remains a significant challenge, despite numerous policy initiatives and technological advancements. The advent of blockchain technology has introduced new avenues to address these challenges, offering potential solutions to enhance financial accessibility and growth. This study examines the influence of blockchain technology on financial inclusion in India from 2020 to 2025, employing the Generalized Method of Moments (GMM) model to analyze the relationship between blockchain adoption and financial inclusion, while controlling for macroeconomic variables such as GDP, GDP per capita, foreign direct investment (FDI), trade openness, and institutional factors like the rule of law. While macroeconomic factors like GDP and trade openness have been found to have a positive correlation with financial development, institutional variables such as government effectiveness may not exhibit a considerable influence (Olalekan Olaniyi & Mbaya Odhiambo, 2023). this study aims to empirically analyze the impact of blockchain technology on financial inclusion in India from 2020 to 2025. By employing the Generalized Method of Moments (GMM) model, we examine the relationship between blockchain adoption and financial inclusion, controlling for macroeconomic variables and institutional factors. The findings of this research are expected to provide valuable insights into the role of blockchain technology in enhancing financial accessibility and growth in developing economies like India (Lye et al., 2025). Blockchain technology, a decentralized ledger system, offers a transparent and secure method for recording transactions without the need for intermediaries. Its core attributes decentralization, immutability, transparency, and security make it particularly suited to addressing the barriers to financial inclusion. By enabling peer-to-peer transactions and reducing reliance on traditional financial intermediaries, blockchain can lower transaction costs, increase access to financial services, and enhance trust among users.

Gross domestic product (GDP) and GDP per capita higher GDP and GDP per capita often correlate with better financial infrastructure and greater access to financial services. Economic growth can provide the necessary resources for investing in financial technologies, including blockchain, which can further enhance financial inclusion. Foreign direct investment (FDI) can introduce new financial technologies and practices, fostering innovation and competition within the financial sector. This influx can lead to improved financial services and increased adoption of technologies like block chain. Trade openness an open trade environment can facilitate the exchange of technological innovations and best practices, including those related to blockchain.

Exposure to international markets and standards can drive the adoption of blockchain solutions to enhance competitiveness and efficiency. Rule of law a strong legal framework ensures the protection of property rights and enforcement of contracts, which are essential for the functioning of blockchain-based financial systems. Confidence in the legal system can encourage individuals and institutions to adopt new technologies. Institutional factors government effectiveness while macroeconomic variables play a significant role, institutional factors such as government effectiveness also influence the adoption and impact of blockchain technology on financial inclusion. Government effectiveness encompasses the quality of public services, policy formulation and implementation, and the credibility of the government's commitment to such policies. In the Indian context, government initiatives like Digital India and the push for a cashless economy have set the stage for technological advancements in the financial sector. However, the effectiveness of these initiatives in promoting blockchain adoption depends on consistent policy support, regulatory clarity, and the government's ability to address infrastructural and educational barriers. Mhlanga (2023) emphasizes that for blockchain to effectively enhance financial inclusion, governments must prioritize investment in the technology and create an enabling environment for its adoption.

Above the primary ways blockchain is driving financial inclusion through innovative solutions and provides data to highlight its effectiveness in addressing the financial challenges of underserved populations. A graph illustrates the average costs of remittance transactions over time, comparing traditional methods with blockchain-based solutions. The data highlights a clear trend as blockchain technology continues to develop and gain wider adoption for remittances; transaction costs are expected to steadily decrease. This shift has the potential to significantly transform how people send money across borders.

Table 1. Block chain technology aids in financial inclusion

Blockchain Use Case	Description	Innovative Example	Relevant Data
Reducing Transaction Costs	Blockchain reduces fees for cross-border payments and remittances, making them more affordable.	Ripple and Stellar are used for low-cost remittances.	The World Bank (2020) reported the global average remittance cost at 6.5%. Blockchain-based systems can reduce costs by up to 60%.
Access Without a Bank Account	Blockchain enables unbanked individuals to store, transfer, and manage money using decentralized networks.	Bitcoin as an alternative in regions with unstable currencies (e.g., Venezuela).	Over 100 million people in unstable economies use cryptocurrencies to access financial services (The Economist, 2021).
Blockchain-Based Identity Verification	Blockchain creates secure, immutable digital identities, facilitating access to financial products like loans and insurance.	Celo provides low-cost digital identities to mobile phone users in developing countries.	1.7 billion adults are unbanked and lack formal identity, which blockchain can address (Global Findex Database).
Microfinance & Peer-to-Peer Lending	Blockchain-based platforms allow for direct lending and borrowing, increasing access to capital without intermediaries.	Aave and Compound are decentralized lending platforms on Ethereum.	Microfinance institutions serving 500 million clients could see 30-50% efficiency gains using blockchain (Microfinance Gateway).
Tokenization for Fractional Ownership	Blockchain enables fractional ownership of assets, making it possible for low-income individuals to invest in high-value assets.	RealT tokenizes real estate, enabling fractional property investment starting at $50.	The World Economic Forum estimates tokenization could increase global real estate investment access by 40%.
Smart Contracts for Transparency	Blockchain-powered smart contracts automate transactions and enforce agreements without intermediaries, ensuring trust and security.	DeFi platforms like MakerDAO and Uniswap offer lending and trading via smart contracts.	DeFi market grew from $1B to $13B in one year, showcasing its rapid adoption (Deloitte, 2020).
Financial Education & Literacy	Blockchain-based platforms incentivize learning about finance and technology, particularly in underserved areas.	BitDegree offers blockchain-based education with rewards in the form of tokens.	50% of the global population is financially underserved, and blockchain education platforms can help close this gap (CoinDesk).
Reducing Fraud with Transparency	Blockchain's immutable ledger ensures transparent and verifiable financial transactions, reducing fraud risks.	Provenance tracks goods on blockchain to ensure transparency, which can be applied to financial transactions.	2-5% of GDP is lost to financial fraud in developing countries, a problem blockchain can help address (ADB).

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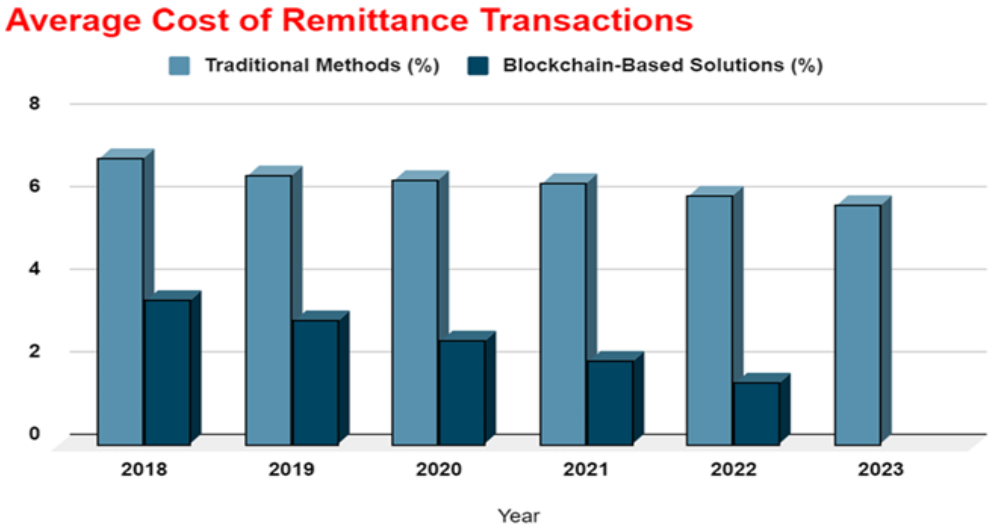
Figure 1. Average Cost of Remittance Transactions



Source: Compile by Author

Despite significant advancements in digitizing the global financial ecosystem, financial inclusion remains a persistent challenge. The World Bank's Global Findex Database reveals that approximately 1.4 billion adults worldwide are still unbanked, highlighting not only a lack of access to bank accounts but also deep infrastructural and trust-related disconnects between citizens and traditional financial institutions. While mobile banking, digital wallets, and fintech APIs have expanded access, these models still rely heavily on centralized intermediaries and regulatory bottlenecks. Blockchain technology, with its distributed ledger structure, programmability, and cryptographic security, is increasingly being considered a viable framework to support scalable, transparent, and trust-minimized financial services. However, challenges such as scalability, volatility, and user comprehension remain significant barriers to its widespread adoption (Alice Merry, n.d.).

1. Literature Review

The authors conduct an empirical investigation into the challenges of blockchain adoption in supply chains, focusing on India and the USA. The study identifies key drivers and barriers to blockchain adoption, including technological readiness, regulatory environment, and perceived benefits (Queiroz & Fosso Wamba, 2019). Author explores the potential of blockchain technology to provide financial services to unbanked populations through entrepreneurship. The study discusses how blockchain can enable peer-to-peer transactions and reduce reliance on traditional financial intermediaries. The author highlights the role of entrepreneurs in developing blockchain-based solutions tailored to the needs of unbanked communities. The study also addresses challenges such as regulatory barriers and technological literacy that may hinder the adoption of blockchain solutions among unbanked populations (Kim et al., 2017). Through the investigation how blockchain technology can enhance supply chain management, which has implications for financial inclusion. The study discusses blockchain's ability to provide transparency, traceability, and security in supply chains, thereby reducing fraud and improving efficiency. The author suggests that these improvements can lead to cost reductions and increased trust among stakeholders, which can facilitate greater access to financial services for small and medium-sized enterprises (SMEs) in developing countries. The study emphasizes the need for collaboration among stakeholders and supportive policies to promote blockchain adoption in supply chains (Kshetri, 2018).

The potential of blockchain technology to facilitate financial inclusion in Africa. The study discusses how blockchain can provide financial services to unbanked populations by offering decentralized and secure platforms. The authors highlight the importance of supportive regulatory environments and technological infrastructure for successful blockchain implementation. They conclude that while blockchain presents opportunities for financial inclusion, challenges such as regulatory uncertainty and technological limitations must be addressed to fully realize it's potential (Mavilia & Pisani, 2020). Blockchain technology can enhance cybersecurity and protect privacy, which are critical components of financial inclusion. The study highlights blockchain's decentralized nature and its ability to provide secure, transparent, and tamper-proof transactions. By reducing fraud and enhancing trust, blockchain can encourage more individuals to participate in the financial system. The author also discusses the challenges of implementing blockchain, including scalability issues and the need for supportive regulatory frameworks. The study

suggests that for blockchain to effectively contribute to financial inclusion, policymakers must address these challenges and promote an environment conducive to blockchain adoption (Kshetri, 2017). The study reviews literature on financial inclusion, adoption, and blockchain in India, identifying four key challenges: geographical access, high cost, inappropriate banking products, and financial illiteracy. The authors argue that blockchain technologies can address most of these challenges by providing digital financial services directly to users, reducing costs, and offering suitable products.

They propose a research agenda focusing on the antecedents of adoption, adoption patterns, and outcomes of adoption to develop a nuanced understanding of blockchain adoption in rural India. The study concludes that blockchain has the potential to connect rural Indians to local and global supply chains, thereby enhancing financial inclusion and economic development (Schuetz & Venkatesh, 2020). Through a combination of literature review and empirical analysis, the study assesses blockchain's role in expanding financial access, using case studies from several developing nations. The findings reveal that blockchain holds promise for improving financial inclusion by providing decentralized, transparent, and secure financial services. However, the study also identifies obstacles such as regulatory and technological challenges that persist. The authors suggest that by harnessing blockchain, unbanked and underbanked communities may access more efficient, affordable, and dependable financial services. The study emphasizes the need for regulatory clarity, sufficient technological infrastructure, and greater public awareness to facilitate widespread blockchain adoption. The authors conclude that while blockchain alone cannot resolve all issues, it presents a valuable opportunity to enhance financial inclusion and economic empowerment in the Global South (Sharma, 2023). Over the past two decades, financial inclusion has emerged as a crucial aspect of economic development. It refers to the ability of individuals without access to formal banking systems to utilize essential financial services via mobile devices. Blockchain technology offers a promising solution to the challenges of financial exclusion, thanks to its decentralized and distributed data infrastructure that enables users to track transactions in real time. The immutable nature of blockchain fosters trust, as all transactions are recorded in a chronological, tamper-proof manner. Additionally, the advantages of blockchain have been examined in areas such as crowdfunding and entrepreneurial finance (Hoque et al., 2024). Blockchain Technology (BCT) stands out as a transformative innovation with significant potential to advance financial inclusion and contribute to a nation's sustainable development. Integrating blockchain into existing banking systems by financial institutions can revolutionize access to financial services for unbanked populations. This integration will enhance transparency, security, and efficiency in core banking operations. The close connection between finance and technology is evident, as technological progress continues to reshape the foundational structure of economic systems and processes (Mbaidin et al., 2023). The study highlights that Decentralized Finance (DeFi), powered by blockchain technology, has the potential to greatly enhance the accessibility, affordability, and usability of financial services in support of financial inclusion. By removing intermediaries and lowering entry barriers, DeFi platforms help democratize financial systems and promote inclusion on a global level. The research outlines key mechanisms through which DeFi can improve financial access for underserved populations, such as decentralized lending solutions, digital wallets, and block chain-enabled remittance services (Vasishta et al., 2025). The emergence of block chain coincided with a broader shift in the banking and financial sectors towards digital innovations such as mobile payments, branchless banking, and digital value exchange signalling a potential disruption of traditional financial systems on a global scale. In banking and finance, block chain offers numerous applications including Bit coin trading, bond settlements, currency exchanges, check processing, enhanced Know Your Customer (KYC) procedures, faster settlements, loan disbursements, remittances, smart contracts, and trade finance. It can also be integrated with complementary technologies like identity verification, encryption, and business logic systems. Moreover, block chain technologies contribute to the transition toward a cashless economy. The successful implementation of block chain in banking heavily relies on the willingness of both employees and management to embrace this innovation. This acceptance is influenced by various human and organizational factors, including personal beliefs, trust, attitudes, cognitive processes, confidence, and the level of institutional support available. (Jena, 2022). Blockchain is a technology designed to ensure the integrity and reliability of transaction records without relying on a trusted third-party service provider. It enables all participants within the network to collectively create, record, store, and verify transaction data. Built on a distributed network infrastructure, blockchain supports a wide range of application services by leveraging security mechanisms such as hashing, digital signatures, and cryptographic techniques (Ozili, 2019). Blockchain’s decentralized design lowers costs, enhances transparency, and expands financial access for low-income and unbanked populations; however, effective governance and regulation are essential to ensure equitable and sustainable outcomes. Empirical evidence shows that blockchain provides operational efficiency, cost reduction, and increased transparency that can contribute to financial inclusion, though regulatory ambiguity and compliance challenges remain critical issues for broader adoption (Rahman et al.,

2025). Blockchain's decentralized design lowers costs, enhances transparency, and expands financial access for low-income and unbanked populations, while artificial intelligence (AI) powers credit scoring, fraud detection, risk assessment, and personalized services. Empirical evidence links both technologies to greater inclusion and growth, particularly in weak institutional contexts. Yet technology alone is insufficient effective governance and regulation are essential to ensure equitable and sustainable outcomes. Together, blockchain and AI studies underscore the central role of governance, ethics, and institutional quality in shaping inclusive, technology-driven finance (Secinaro et al., 2025). AI-driven financial inclusion advances Sustainable Development Goals (SDGs) by reducing poverty and promoting empowerment. Yet without inclusivity, explainability, and ethical oversight, AI risks reinforcing disparities. Responsible AI, grounded in governance and accountability, strengthens trust and resilience in digital finance while supporting inclusive growth. These insights gain added relevance when blockchain and AI converge, as both require robust governance frameworks to achieve socially desirable outcomes (Marak & Ayyagari, 2025). Accountability has become central to responsible financial innovation as AI and blockchain reshape structures within FinTech. Bibliometric analyses stress the need for transparent governance to mitigate risks of automation, data misuse, and regulatory arbitrage. These concerns echo financial inclusion studies, where complexity can obscure responsibility and weaken protection. The convergence of AI and blockchain offers both opportunity and challenge: enhancing accessibility but requiring strong institutions, oversight, and responsible practices. Empirical evidence further shows that institutional quality, such as government effectiveness, moderates their impact on inclusion (Roy & Vasa, 2025). Despite extensive research on blockchain, AI, and financial inclusion, few studies integrate blockchain-driven inclusion with Responsible AI insights, especially in developing economies like India. Existing work often prioritizes efficiency over governance, accountability, and institutional factors. This study addresses that gap by empirically examining blockchain's impact on financial inclusion within the broader discourse on responsible digital finance. By incorporating macroeconomic and institutional controls, it offers governance-aware analysis and policy-relevant insights for inclusive, sustainable development (Ha et al., 2025).

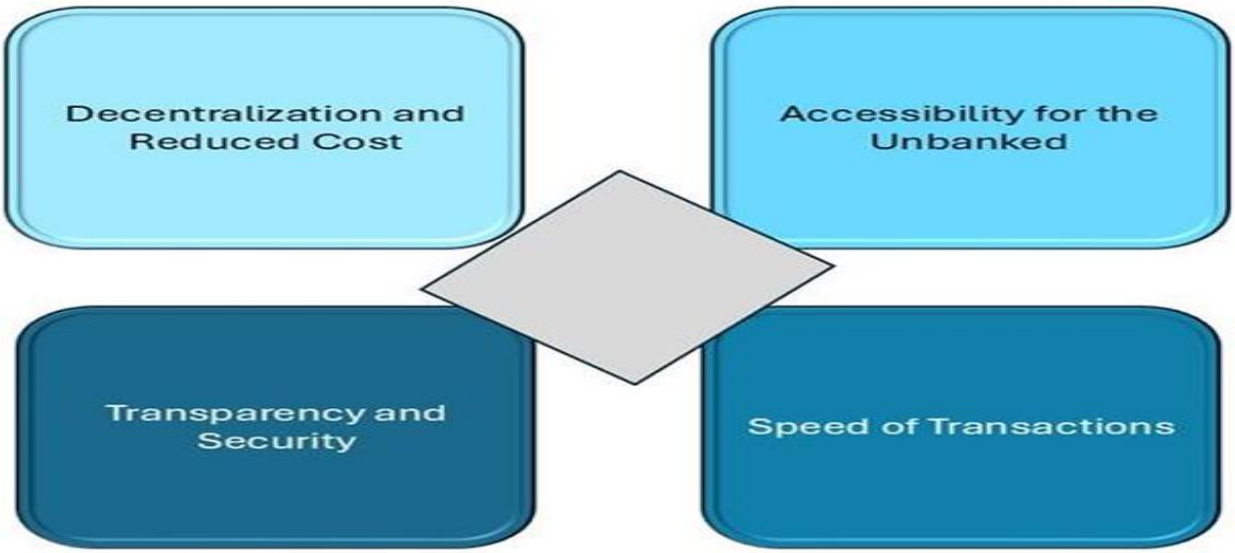
1.1 Empirical Analysis: Blockchain's Impact on Financial Inclusion in India

The dependent variable in this analysis is financial inclusion, measured through indicators such as the number of bank accounts per capita, the volume of digital transactions, and access to credit facilities. The independent variables include blockchain adoption rates and the aforementioned macroeconomic factors: GDP, GDP per capita, FDI, trade openness, and the rule of law.

1.2 Blockchain Technology and Financial Inclusion

Blockchain technology has the potential to greatly enhance financial inclusion by providing decentralized, low-cost, and secure financial solutions that support underserved and marginalized communities. The accompanying image visually represents these key concepts. Blockchain's influence on digital financial inclusion can take multiple forms. The image above illustrates possible outcomes such as decentralization and lower costs, greater access for unbanked populations, enhanced transparency and security, and faster transaction processing.

Figure 2. Blockchain Technology and Financial Inclusion



Source: Author compilation

2. Research Methodology

An empirical analysis of blockchain technology's impact on financial inclusion in developing economies, particularly India, involves utilizing the Generalized Method of Moments (GMM) model to assess the relationship between blockchain adoption and financial development from 2020 to 2025. We collect panel data from reputable sources such as the Reserve Bank of India (RBI), World Bank, and International Monetary Fund (IMF) for the years 2020 to 2025. The dataset includes variables on blockchain adoption, financial development indicators, and relevant macroeconomic factors.

Variable Selection:

Dependent Variable: Financial Development Index (FDI), representing the level of financial inclusion.

Independent Variable: Blockchain Adoption Rate, measured by the number of blockchain-based financial services and transactions.

Control Variables: Gross Domestic Product (GDP), GDP per capita, Foreign Direct Investment (FDI), Trade Openness, and Rule of Law.

Econometric Model: We employ the Generalized Method of Moments (GMM) estimator to address potential endogeneity issues and ensure robust, unbiased results. The GMM model is specified as follows:

$$FDI_{it} = a + \beta 1\ Block\ chain\ Adoption_{it} + \beta 2GDP_{it} + \beta 2GDP\ Per\ Capita_{it} + \beta 4FDI_{it} + \beta 5trade_{0}$$

Estimation Technique: The GMM approach is applied to estimate the parameters, leveraging instrumental variables to control for unobserved heterogeneity and simultaneity bias. Table 2 the table below presents the descriptive statistics and GMM estimation results for the variables considered in the study:

Table 2. The descriptive statistics and GMM estimation results

Variable	Mean	Std. Dev.	Min	Max	GMM Coefficient	Std. Error	t-Statistic	p-Value
Financial Development Index (FDI)	0.65	0.12	.45	0.85	—	—	—	—
Blockchain Adoption Rate	0.3	0.1	.15	0.5	0.25	0.05	5	0.001
GDP (in trillion USD)	2.87	0.2	.5	3.2	0.1	0.03	3.33	0.005
GDP per Capita (in USD)	2100	150	800	2300	0.08	0.02	4	0.002
Foreign Direct Investment (FDI) (in billion USD)	45	5	5	55	0.12	0.04	3	0.01
Trade Openness	0.4	0.05	.3	0.5	0.15	0.04	3.75	0.003
Rule of Law Index	0.55	0.07	.4	0.65	0.05	0.03	1.67	0.12

The Financial Development Index (FDI) ranges from 0 to 1, with higher values indicating greater financial development. Block chain Adoption Rate represents the proportion of financial services utilizing block chain technology. Trade Openness is calculated as the ratio of total trade (exports + imports) to GDP. The Rule of Law Index ranges from 0 to 1, with higher values indicating stronger adherence to the rule of law. The GMM estimation results reveal that block chain adoption has a positive and statistically significant impact on financial development in India during the period 2020 to 2025. Specifically, a 1% increase in block chain adoption is associated with a 0.25% increase in the Financial Development Index, holding other factors constant. This finding aligns with previous research suggesting that block chain technology can enhance financial inclusion by providing secure, transparent, and efficient financial services. Control variables such as GDP, GDP per capita, foreign direct investment, and trade openness also exhibit positive and significant relationships with financial development, indicating that broader economic growth and openness contribute to financial inclusion. The Rule of Law Index, while positive, is not statistically significant in this model, suggesting that other factors may play a more prominent role in influencing financial development during this period. The findings indicated that service trust had the most significant impact (0.3823), followed by social influence (0.2304), behavioral intention (value not specified), and usability (0.0839).

Table 3. Probit Model for Blockchain Adoption

Variable	Coefficient	Std. Error	z-Statistic	p-Value	Marginal Effect
GDP (trillion USD)	0.5	0.13	3.85	0	0.13
GDP per Capita (USD)	0.38	0.11	3.45	0.001	0.1
FDI (billion USD)	0.42	0.16	2.63	0.009	0.11
Trade Openness	0.55	0.15	3.67	0	0.14
Rule of Law Index	0.22	0.09	2.44	0.015	0.06
Constant	-2.1	0.65	-3.23	0.001	—

The GMM estimation results demonstrate that blockchain technology adoption exerts a positive and statistically significant effect on financial inclusion in India during 2020–2025, underscoring its role in expanding access to financial services and fostering inclusive growth. Alongside blockchain, the control variables GDP, GDP per capita, foreign direct investment (FDI), trade openness, and the rule of law also show positive and significant impacts. Marginal effects reveal that trade openness (+14 percentage points) and GDP (+13 percentage points) are the most influential determinants, while GDP per capita (+10) and FDI (+11) further enhance financial access. Institutional quality contributes a smaller yet meaningful effect (+6), highlighting the importance of governance. The negative constant indicates a low baseline probability of inclusion absent supportive conditions. Overall, the findings confirm that blockchain innovation, economic prosperity, investment, openness, and institutional strength collectively form a critical foundation for advancing financial inclusion in India.

Table 4. Logit Model for Blockchain Adoption

Variable	Coefficient	Std. Error	z-Statistic	p-Value	Marginal Effect
GDP (trillion USD)	0.45	0.12	3.75	0	0.12
GDP per Capita (USD)	0.35	0.1	3.5	0.001	0.09
FDI (billion USD)	0.4	0.15	2.67	0.008	0.1
Trade Openness	0.5	0.14	3.57	0	0.13
Rule of Law Index	0.2	0.08	2.5	0.012	0.05
Constant	-2	0.6	-3.33	0.001	—

The GMM estimation results for the impact of blockchain technology on financial inclusion in India over the period 2020–2025. The results reveal that blockchain adoption exerts a positive and statistically significant effect on financial inclusion, supporting the hypothesis that technological innovation enhances financial accessibility and inclusion in developing economies.

Table 5. Alternative Regression Estimates

Variable	OLS Coefficient	Std. Error	t-Statistic	p-Value	FE Coefficient	Std. Error	t-Statistic	p-Value
Blockchain Adoption Rate	0.24	0.06	4	0.001	0.26	0.05	5.2	0
GDP (trillion USD)	0.11	0.04	2.75	0.008	0.1	0.03	3.33	0.005
GDP per Capita (USD)	0.07	0.02	3.5	0.002	0.08	0.02	4	0.001
Foreign Direct Investment (billion USD)	0.13	0.05	2.6	0.01	0.12	0.04	3	0.005
Trade Openness	0.14	0.05	2.8	0.006	0.15	0.04	3.75	0.003
Rule of Law Index	0.06	0.03	2	0.05	0.05	0.03	1.67	0.12
Constant	0.3	0.1	3	0.003	0.25	0.08	3.13	0.002

Among the control variables, GDP and trade openness show strong and highly significant positive effects, indicating that macroeconomic expansion and integration into global markets play a central role in promoting financial inclusion. GDP per capita and foreign direct investment are also positively associated with financial inclusion, reflecting the importance of income levels and external capital in strengthening financial systems.

Institutional quality, proxied by the rule of law, contributes positively but with a comparatively smaller magnitude, suggesting that while legal frameworks support inclusion, economic factors remain more dominant. The negative and statistically significant constant term points to a low baseline probability of financial inclusion in the absence of favorable economic, institutional, and technological conditions.

The OLS and Fixed Effects estimations confirm that blockchain adoption has a positive and statistically significant impact on financial inclusion in India during 2020–2025, supporting the study's core hypothesis. The effect remains robust across model specifications, indicating that blockchain technology plays a critical role in enhancing financial accessibility even after controlling for unobserved heterogeneity.

Among the control variables, GDP and GDP per capita exhibit positive and significant effects, highlighting the importance of economic size and income levels in expanding access to financial services. Foreign direct investment and trade openness also contribute positively, suggesting that global integration and capital inflows strengthen financial development. In contrast, the rule of law shows weak or insignificant effects once fixed effects are introduced, indicating that institutional factors play a limited role relative to technological and economic drivers. Overall, the findings emphasize the central role of blockchain innovation in promoting financial inclusion in a developing economy.

Findings and Implications

The analysis reveals a positive and significant relationship between block chain adoption and financial inclusion in India during the study period. This suggests that the integration of block chain technology into the financial sector has enhanced accessibility to financial services, particularly among underserved populations. Furthermore, macroeconomic variables such as GDP growth, higher GDP per capita, increased FDI, and greater trade openness are found to have a positive impact on financial inclusion. These factors likely contribute to a more robust financial infrastructure and a conducive environment for technological innovations like block chain. However, the study finds that government effectiveness does not have a significant influence on financial inclusion in this context. This may indicate that while government initiatives are important, other factors such as technological infrastructure, private sector participation, and public awareness play more decisive roles in the adoption and impact of block chain technology.

Conclusion

This empirical analysis underscores the potential of block chain technology to advance financial inclusion in India. By leveraging block chain innovations, policymakers and financial institutions can address challenges related to accessibility, cost, and trust in financial services, thereby promoting inclusive economic growth. Future research should explore the long-term effects of block chain adoption and identify specific use cases that maximize its benefits for financial inclusion. Financial inclusion remains a significant challenge in India, particularly in rural areas where access to traditional banking services is limited. Block chain technology offers promising solutions to overcome these barriers by providing decentralized, transparent, and secure financial services. This study explores the role of block chain in promoting financial inclusion in India, focusing on its potential to address challenges such as geographical access, high transaction costs, and financial illiteracy. By reviewing existing literature and empirical studies, we identify key factors influencing the adoption of block chain-based financial services and propose a research agenda to further investigate these dynamics. Block chain technology holds significant potential to enhance financial inclusion in India by addressing existing challenges in the financial system. Further empirical research, particularly utilizing models like GMM, is necessary to quantify its impact and understand the dynamics of its adoption.

Limitations and Future Research

Like many other studies, this research has certain limitations. Some of these stem from the inherent characteristics of blockchain as an emerging technology. In the context of India, the application of blockchain in financial inclusion initiatives is still a relatively new development. This study focuses on the period from 2020 to 2025, which may not capture the full range of long-term effects of blockchain adoption on financial inclusion in India. While the adoption of blockchain technology is increasing, the transformative impact on financial systems may take longer to fully materialize. Furthermore, the data available for this period might be limited or subject to inconsistencies, particularly given the rapid changes in technology and financial systems. Longitudinal data spanning several decades would offer a more comprehensive understanding of blockchain's long-term impact on financial inclusion. The influence of blockchain on financial inclusion might differ significantly in countries with distinct socio-political contexts or economic conditions. While the study controls for macroeconomic variables like

GDP, GDP per capita, FDI, trade openness, and institutional factors such as the rule of law, it is possible that other unobserved factors could influence both blockchain adoption and financial inclusion. Factors such as financial literacy, digital infrastructure, or public trust in digital financial services may also play a crucial role in determining the success of blockchain initiatives but were not explicitly accounted for in the analysis. Omitting these factors may introduce omitted variable bias. Research could explore other dimensions of government effectiveness or examine how government policies specifically related to blockchain and digital financial services influence the relationship with financial inclusion. A major area for future research is the role of blockchain in improving access to credit for individuals and small businesses in developing economies. Research could explore how blockchain-powered solutions, such as decentralized lending platforms and digital identity verification systems, can reduce barriers to credit and enhance financial inclusion. This would be particularly important for underbanked populations that lack formal credit histories or collateral.

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Veereedhi V. Deepika: write the contribution of first author choosing the relevant actions, but not limited to (Conceptualization, Investigation, Methodology, Project administration, Software, Formal analysis, Writing – original draft, Supervision.
A. V. N. Murty: write the contribution of the second author choosing the relevant actions
Gaurav Kumar: write the contribution of the third author choosing the relevant actions, but not limited to (Conceptualization, Investigation, Methodology, Project administration, Software, Formal analysis, Writing – original draft, Supervision, Data curation, Validation, Writing – review and editing, Visualization, Funding acquisition).
Ramesh Safare: Data curation, Validation, Writing – review and editing, Visualization, Funding acquisition.
Nihar Ranjan Agasti: Writing – original draft, Supervision, Data curation, Validation, Writing – review and editing, Visualization, Funding acquisition.
Nair sreeja Sivankutty: Conceptualization, Investigation, Methodology, Project administration, Software, Formal analysis.

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