

Digital Financial Services and Cybersecurity: Barriers to Financial Inclusion in Developing Countries

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Abstract

As digital financial services grow across developing economies, they promise to close long-standing gaps in financial inclusion. Yet, the rise of cyber threats and low digital trust pose new challenges that can discourage adoption, especially among vulnerable populations. This study examines how cybersecurity infrastructure and digital access influence mobile money usage in 35 developing countries from 2018 to 2023. Using panel data regression techniques, the results show the importance of building secure, accessible, and user-trusted financial systems to drive inclusive growth in the digital age.

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1 Introduction

Having access to financial services is more than just a convenience in today's world; it is one of the factors that can determine a person's ability to improve their life and contribute to the economy. According to the World Bank Group,¹ financial inclusion is ensuring that everyone has access to basic financial services like banking, credit, and insurance, which is especially an important factor in developing countries.

However, for many, these services remain out of reach, particularly for those living in rural areas or struggling with low incomes. When people cannot save money securely, get loans to start businesses, or protect themselves with insurance, their opportunities to improve their lives are severely limited. This further deepens the gap between the wealthy and the poor, making it even harder for the most vulnerable to escape poverty. As a result, income inequality continues to grow, threatening the country's potential for sustainable development.

Financial development plays a crucial role in fostering economic growth and improving the standard of living, particularly in developing countries. One of the most significant drivers of this development is the expansion of digital financial services, which have the potential to bridge the gap created by limited access to traditional banking systems. Using digital technologies, financial services can reach underserved populations, facilitating economic participation and improving overall financial inclusion.

Despite the rapid evolution of digital finance, several barriers still prevent people in developing economies from fully benefiting from these advances. One of the most prevalent challenges is the physical inaccessibility of traditional banking services. Many banks are concentrated in urban centers, leaving individuals in rural and remote areas with limited or no access to financial institutions. This geographic divide has historically excluded a significant portion of the population from formal financial systems. Alexander and Karametaxas (2021) posits that digital financial services have the potential to increase financial inclusion in developing economies; however, cyber threats pose a barrier. This aligns with the conclusion of Afzal et al. (2024), who argue that while financial inclusion is essential for economic growth, rising cybercrime poses a serious threat, especially in rural communities.

The emergence of mobile banking, digital wallets, and other fintech innovations has helped to address this challenge by providing an alternative to brick-and-mortar banking. Yet, even with these advancements, adoption rates remain hindered by several factors. One key obstacle is low digital literacy. Many individuals, particularly in rural communities, lack the necessary knowledge or support system to effectively navigate digital financial platforms. Without guidance from informed peers or community members, uneducated users may struggle to un-

1. See: <https://www.worldbank.org/en/topic/financialinclusion/overview>

derstand how to use mobile banking apps, digital wallets, or online payment systems.

Additionally, trust in digital financial platforms remains a significant barrier. In many developing countries, skepticism about the security and reliability of online transactions discourages potential users from embracing digital banking. Concerns over fraud, cyber threats, and the risk of losing hard-earned money further deter widespread adoption. Strengthening consumer confidence through education and awareness campaigns is essential for fostering trust in these platforms.

Over the years, the financial services sector has undergone significant innovation, leading to a noticeable decline in the reliance on traditional banking and a surge in mobile and internet banking adoption, particularly across Africa. The introduction of digital financial services has made it easier for individuals to conduct transactions, pay bills, and access credit facilities without visiting a bank branch. Mobile money services, for example, have provided millions of previously unbanked individuals with access to financial tools that empower economic participation. Despite these advancements, there is still a critical gap in consumer education and security awareness. Many financial service providers focus primarily on expanding their digital offerings without adequately educating users on how to safeguard their financial information and avoid cyber threats.

Cyber threats pose significant challenges to financial institutions and efforts to promote digital financial inclusion in developed nations. Kazim and Shanshul (2024) agrees that Cyberattacks can result in significant financial losses, disrupt operations, and undermine customer trust, with global cybercrime costs expected to reach \$10.5 trillion annually by 2025. A study by Ozili (2021) suggests that greater financial inclusion, as indicated by higher account ownership rates, is associated with increased financial risk in developed, advanced, and transitioning economies. However, the adoption of digital finance products and credit cards may help mitigate these risks in more developed economies. This issue is particularly pronounced in developing countries, where a large percentage of the population remains uneducated or unfamiliar with digital security practices. Without proper awareness, users are more vulnerable to online fraud, phishing scams, and identity theft. Low-income states are targeted by both money-driven attacks (such as ransomware) and serve as training grounds for criminal groups in preparation for more ambitious attacks in developed countries². As noted by Kraus, Kraus, and Shtepa (2022), safeguarding cyberspace is more crucial than ever, and the numbers prove it. Every 40 seconds, a new cyberattack occurs somewhere in the world. In 2021 alone, cybercrime cost the global economy \$6 trillion, making up more than 5% of the world's GDP. With threats growing daily, protecting personal and financial

2. <https://www.developmentaid.org/news-stream/post/149553/low-cyber-security-and-development-of-poor-nations>

information has never been more crucial.

Most papers on financial inclusion often focus on economic barriers, such as income inequality or a lack of infrastructure, but pay little attention to other socio-economic factors, including cyber threats like fraud, data breaches, and phishing attacks, which discourage the adoption of digital services, especially in low-income and developing countries. There are sparse studies connecting cybersecurity and financial inclusion, especially in developing countries where people hardly have trust in digital systems. Hence, the impact of cyber threats on financial inclusion remains insufficiently explored. This lack of focus leaves a critical study gap in understanding the broader implications of cyber threats on financial Inclusion.

This thesis aims to contribute to the evolving literature on financial inclusion by introducing cybersecurity as a critical factor in understanding digital finance adoption. Using a panel data approach covering the period from 2018 to 2023, the analysis will track the evolution of financial inclusion over time. We will examine how cybersecurity infrastructure and digital access affect the adoption of digital financial services, and to what extent cyber threats act as barriers to financial inclusion in developing economies. Additionally, we will analyze how socio-economic factors such as population, income, mobile phone penetration, and trust in digital services influence the adoption of digital financial services. The study will assess whether a safe and secure cyber environment contributes to the low adoption rate of digital financial services and the overall growth of financial inclusion. Ultimately, it will examine the extent to which cyber threats hinder financial inclusion in developing countries.

Specifically, the remainder of this paper is structured as follows: Section 2 presents a comprehensive review of the existing literature, covering key papers related to financial inclusion, the evolution and role of digital financial services, and the emerging cybersecurity challenges faced by developing economies. This section identifies the theoretical and empirical gaps that motivate this study. Section 3 is divided into two parts. Section 3.1 provides a detailed description of the dataset, including the variables used, data sources, coverage across countries and years, and any transformations or data cleaning procedures applied. Section 3.2 introduces and explains the econometric model used to analyze the relationship between cybersecurity and digital financial inclusion. This includes the model specification, justification for the estimation technique, and discussion of any expected limitations. Section 4 presents the anticipated results for each explanatory variable, grounded in economic theory and prior empirical evidence. It outlines what the results are expected to show, particularly in terms of the hypothesized impact of cybersecurity infrastructure on mobile money adoption and other digital financial indicators. Section 5 presents the paper’s findings, and Section 6 concludes the paper by summarizing the key findings, discussing their policy implications, and

suggesting directions for future research. Finally, the appendix includes all supplementary material, such as regression output tables, descriptive statistics, and any robustness checks conducted to support the validity of the analysis.

2 Literature Review

2.1 Financial Inclusion in Developing Countries

The discussion surrounding financial inclusion and its impact on the world's economies has been the subject of a substantial body of literature. Several authors present evidence supporting the notion that a financially inclusive economy leads to a reduction in income inequality and an improvement in economic performance. However, there are opposing arguments that claim the reverse effect. Here, we will present an overview of selected literature on the barriers to financial inclusion in developing countries.

According to Kingsley (2013), Financial inclusion refers to the ease with which individuals and businesses can access and utilize essential financial services, such as payments, savings, loans, and insurance, within an economy. It plays a vital role in driving a country's economic growth, especially in emerging economies like Nigeria. Around the world, financial inclusion is increasingly recognized for its power to reduce poverty, narrow income gaps, and promote overall development and well-being. When people and businesses have access to affordable and reliable financial tools, they're better able to manage their money, invest in their future, and contribute to long-term economic progress. Demirgüç-Kunt and Klapper (2012) Used a dataset covering 148 economies to analyze how adults worldwide save money, access credit, make payments, and manage financial risks. The findings show that only about half of the global adult population has an account with a formal financial institution. This means that the other half, around 50%, remains excluded from the formal financial system. Among those without accounts, at least 35% report that high costs, long distances to financial institutions, and lack of proper identification are major barriers.

Several studies spanning multiple countries have shown a relationship between financial exclusion and poverty in developing countries. However, there is evidence that proves that financial Inclusion is a driver and tool for economic development. Beck, Demirgüç-Kunt, and Honohan (2009) identifies how expanding access to financial services remains a challenge worldwide. However, countries with a more robust financial system tend to experience a significant decrease in income inequality and poverty. It is also known that not much attention has been given to educating individuals and businesses on financial inclusiveness to access financial services seamlessly.

In Sub-Saharan Africa, Mohammed, Mensah, and Gyeke-Dako (2017) examines the impact of financial inclusion on poverty reduction among low-income individuals, and the results indicate that financially included individuals derive greater wealth than those who are financially excluded. Tay, Tai, and Tan (2022) tests whether digital financial inclusion serves as a gateway to sustainable development, examining disparities such as gender, wealth, and urban-rural differences in access to and usage of digital financial services within developing countries. The findings demonstrate that digital financial inclusion is crucial for sustainable development; however, a persistent divide persists in developing countries between demographic groups in terms of access to and usage of digital financial services.

Similarly, Omar and Inaba (2020) believes that per capita income and internet usage are among several factors that influence access to financial services in developing countries. Furthermore, a study by Tulu (2023) while exploring the role of digital financing confirms that financial inclusion remains in its early stages in developing countries. The study highlights that rural populations are often excluded from formal financial services and instead depend on informal financial institutions. Additionally, access to digital financial services is crucial for increasing financial inclusion; however, it is primarily used by literate individuals with access to mobile phones and other digital services. This finding is consistent with the results of Tchatoka and Vo (2021), who suggest that financial inclusion has been successful in Asia but not yet in Africa. However, since 2016, there has been a steady decline in the proportion of low-income individuals in Africa who remain financially excluded, as analyzed using data from a Financial Inclusion Insights survey.

Finally, Jukan and Softic (2016) employs several financial indicators to assess the level of financial inclusion across regions, especially among the developing nations. The study finds that Eastern, South, and Central Asia, Latin America, and Sub-Saharan Africa are among those most at risk of financial exclusion. Drawing on secondary data from the Global Financial Index database, the results show that developing countries consistently exhibit lower levels of financial inclusion compared to developed countries. Given the body of evidence reviewed, it is evident that financial inclusion plays a critical role in the economic advancement of developing countries.

2.2 Digital Financial Services, CyberThreats and Financial Inclusion

The expansion of digital financial services has played a crucial role in enhancing financial inclusion, particularly in developing economies. Following the COVID-19 pandemic, there has been a significant increase in the adoption of digital payments, driven by the growing

reliance on mobile banking and financial technology solutions. However, while these innovations have increased access to financial services, they have also introduced new cybersecurity risks that threaten the efforts to achieve financial inclusion.

Mpofu (2024) examines the opportunities and challenges of digital financial services in developing countries, identifying factors such as inadequate infrastructure, low literacy rates, and trust issues as significant barriers to adoption. Despite these challenges, digital financial inclusion has gained momentum, with adult bank account ownership increasing from 51% in 2011 to 71% in 2021. Similarly, Shakti Nigam Vaidya (2023) highlights the potential of digital financial services in expanding financial access but cautions that cyber threats remain a significant obstacle. The study finds that while digital financial services offer affordability and convenience, security concerns have led to hesitancy among unbanked populations, slowing financial inclusion efforts.

Muchandigona and Kalema (2022) explores mobile money adoption and financial inclusion, emphasizing that factors such as trust, ease of use, and perceived risks shape individuals' willingness to use digital financial services. Isukul and Tantua (2021) uses quantitative methods to demonstrate that financial technology offers a more cost-effective and sustainable approach to enhancing financial inclusion in developing countries compared to traditional banking. The study recommends that policymakers focus on expanding digital financial literacy and accessibility to fully leverage these innovations for inclusive economic growth.

While digital financial services offer numerous benefits, their rapid expansion has been accompanied by increasing cyber threats. Cyber attacks such as phishing scams, data breaches, and ransomware have eroded trust in digital platforms, particularly in developing economies where cybersecurity awareness remains low (e.g., Serang 2024; S et al. 2024). These security concerns have discouraged adoption and created setbacks for financial inclusion. This aligns with Cele and Kwenda (2025) using a systematic literature review as their methodology finds that the most common cyber threats that hinder the adoption of digital banking are malware, phishing, vishing, and credit/debit card fraud.

Ezeocha (2024) highlights that despite financial technology contributions to financial inclusion in Nigeria, cybersecurity risks remain a major challenge. To address these threats, financial institutions have begun implementing encryption protocols and advanced threat detection mechanisms. At the national level, countries like Ukraine have developed cybersecurity strategies to safeguard their financial infrastructure Kraus, Kraus, and Shtepa (2022). However, regulatory efforts in many developing nations remain disconnected, limiting their ability to fight cyber risks.

Afzal et al. (2024), focusing on rural India, finds that cybersecurity awareness plays a critical role in promoting digital financial inclusion. The study reports that fraud incidents

reduce trust in digital platforms, discouraging the adoption of mobile banking. However, individuals with greater cybersecurity awareness are more likely to engage in digital financial transactions. Similarly, Ozarslan (2022) discusses the impact of emerging technologies such as artificial intelligence and cloud computing in transforming financial institutions while also expanding the attack surface for cybercriminals. The study highlights the importance of robust cybersecurity frameworks in ensuring that financial innovations remain secure and sustainable.

While Tay, Tai, and Tan (2022) argues that digital financial inclusion is essential for sustainable development, disparities in access, such as gender, wealth, and rural-urban divides, must also be addressed to ensure inclusive growth. Tulu (2023) identifies rural exclusion as a major challenge, noting that financially excluded individuals in developing countries rely on informal financial services rather than digital platforms. Unlike previous studies, Yap et al. (2023) finds, in a panel regression model of 34 developed countries, that digital financial inclusion alone cannot help countries achieve development; however, when digital technology is paired with the right financial tools, it facilitates development.

In general, some literature suggests that the resolution of cybersecurity risks requires a comprehensive approach that includes stronger regulatory frameworks, improved cyber risk management, and collaboration between the public and private sectors (e.g., Serang 2024; Ezeocha 2024). Borghard (2022) underscores the role of national cybersecurity policies in protecting financial systems, citing the vulnerability of the US financial sector to cyber threats as an example. The study warns that similar risks exist in developing economies, where digital financial services are expanding rapidly but often lack adequate protection against cyberattacks.

Therefore, financial inclusion, supported by mobile technology and strengthened by robust cybersecurity systems, is not only vital for inclusive economic growth but also essential for building a sustainable and secure digital economy in developing nations.

3 Methodology and Data

3.1 Data Description

This chapter is structured to describe the dataset, variables, data sources, and how the data used in this study is transformed to support empirical analysis. This study utilizes a panel dataset comprising 35 developing countries from 2018 to 2023. The data set is constructed from publicly available secondary sources, including the World Bank’s World Development Indicators (WDI) and the International Monetary Funds (IMF) Financial In-

dex, which provides consistent and comparable cross-country economic and technological indicators. The countries selected for this study are primarily developing economies with low and lower-middle-income levels in Africa and Asia. The 35 countries were chosen based on the availability of data in key digital and financial variables that offer significant variation in both the adoption of digital financial services and the cybersecurity infrastructure, making them suitable for empirical investigation of barriers to financial inclusion in the digital age.

This study focuses on developing countries mainly because many people in this region still struggle to access basic financial services and also lack strong digital infrastructure and trust in online systems. In places where mobile money could be a game-changer, people are often hesitant to use it if they do not feel that it is secure. That's why the primary focus of this research is to examine the relationship between cybersecurity infrastructure and the acceptance of digital financial services.

Dependent Variable:

- **Mobile Money Transactions:** Mobile money transactions refer to financial activities conducted via mobile phones. In the study of Tobbin and Kuwornu (2011), Mobile Money enables users to perform a range of financial activities, such as sending and receiving money, paying bills, saving, or even borrowing, directly from their mobile phones, without requiring a traditional bank account. Mobile Money Transactions, in particular, make it possible to transfer money quickly and securely using just a mobile device. Given the limited reach of traditional banking systems in many developing countries, it enables individuals to perform essential financial tasks without the need for physical bank branches. Mobile money transactions have become one of the most effective tools for closing the financial inclusion gap.

In this study, we adopt mobile money transactions as a proxy for digital financial services, which is defined as the total number of mobile financial transactions per year in a country, capturing both the scale and frequency of digital financial activities. This is due to its widespread acceptance in both empirical research and global financial inclusion indices such as the World Bank's Global Financial Index. Unlike static indicators such as bank account ownership, mobile money captures real financial behavior, including payments, transfers, and savings conducted via mobile phones. This makes it particularly relevant in developing countries where mobile technology has become a primary tool for accessing financial services.

Explanatory Variable:

- **Secure Internet Servers:** This variable proxies the cybersecurity index. It represents the number of unique, publicly-trusted SSL/TLS certificates issued within a country, normalized by population size. In practice, it is measured as the number of distinct secure internet certificates per one million people in a country. The data is drawn from Netcraft’s Secure Server Survey, which identifies trusted certificates used by websites and servers. By adjusting for population, the indicator allows for meaningful cross-country comparisons of internet security adoption, regardless of country size. Note that, TLS/SSL ³ Certificates per country reflecting the country’s ability to offer secure digital communication, which is essential for building trust in online financial transactions. Secure internet access serves as a good proxy for the cybersecurity index in this study because it reflects the foundational infrastructure and practices necessary for safe digital activity. The number of secure internet servers in a country serves as an indicator of how well websites and online services are protected through encryption protocols such as HTTPS ⁴. In many developing countries, comprehensive data on broader cybersecurity infrastructure is often limited or inconsistent.

As a result, the availability of secure internet servers offers a reliable and comparable metric for assessing the overall safety of a country’s online environment, particularly in the context of financial transactions. This indicator reflects a critical aspect of digital trust, which plays a key role in encouraging individuals to adopt and use digital financial services. When users feel confident that their personal and financial information is protected, they are more likely to engage with digital platforms for saving, transferring, or managing money.

Recent studies emphasize that secure internet access is integral to building digital trust, which in turn underpins the adoption of online services, including mobile financial platforms. Maleks Smith, Lostri, and Lewis (2020) for instance, in a systematic review of cybersecurity and data availability highlights how the absence of reliable cybersecurity infrastructure can undermine digital ecosystems and user confidence. In developing countries, limited cybersecurity investment leaves systems vulnerable, eroding trust and hindering the delivery of digital financial services.⁵

3. SSL (Secure Sockets Layer) and TLS (Transport Layer Security) are cryptographic protocols used to secure communications over a computer network, especially the internet

4. HTTPS stands for HyperText Transfer Protocol Secure. It is an extension of HTTP and uses encryption technologies like SSL/TLS to protect data exchanged between a user’s browser and a website, ensuring secure communication and transaction

5. Development Aid (2022, September 12). *The impact of low cyber security on the development of poor nations — Experts’ Opinions*. Retrieved from <https://www.developmentaid.org/news-stream/post/149553/>

Together, these insights support the use of Secure Internet Servers as a valid proxy for cybersecurity capacity in empirical models of financial inclusion, providing both theoretical and practical grounding for this study.

Control Variables: To isolate the effect of cybersecurity on digital financial inclusion, several control variables are included in our study:

- **GDP per capita:** Measured in constant US dollars, this variable captures the average level of income and economic capacity of a country, which can influence access to and use of digital services. In this study it facilitates the understanding of how economic wealth influences the adoption and use of mobile money services. Generally, countries with higher GDP per capita tend to have better financial literacy and more widespread access to digital infrastructure. We include this variable to see whether rising average incomes help explain mobile-money usage.
- **Mobile Phone Penetration:** The use of mobile phones, particularly smartphones, has grown significantly in the 21st century. It is measured as the number of mobile cellular subscriptions per 100 people in a country per year. Mothobi and Grzybowski (2017) in a study posits that some of the barriers to accessing financial services in many developing regions include inadequate infrastructure and low levels of financial literacy. However, mobile phones offer a solution by allowing individuals to access financial services remotely, without relying on traditional banking methods. This variable in our study examines the physical infrastructure and accessibility of mobile technology required for mobile money services.
- **Population:** We include this variable to control for country size and demographic scale, which can influence both the supply and demand of digital financial services.
- **Commercial Bank Branches:** This variable represents the number of commercial bank branches per 100,000 adults and serves as a proxy for traditional financial infrastructure.
- **Automated Teller Machines (ATMs):** Similarly, the number of ATMs per 100,000 adults reflects access to conventional banking facilities and complements the digital channels under study.
- **Trade Openness (% GDP):** Trade openness measures the extent to which a country engages in international trade, typically expressed as the sum of exports and imports

relative to GDP. It reflects a country’s integration into the global economy and its exposure to foreign goods, services, and technologies. In this study, trade openness is included to examine how participation in international markets might influence the adoption of digital financial services. Countries that are more open to trade often experience greater technology transfer, improved access to innovative financial solutions, and increased competition, all of which can encourage the use of mobile money services and other digital payment platforms.

3.2 Descriptive Statistics

Table 5 presents the summary statistics for the key variables used in this study, based on a panel dataset of 210 observations from 35 developing countries between 2018 and 2023. These statistics offer insight into the distribution, central tendencies, and variation of the variables that support the empirical analysis.

Table 1: Descriptive Statistics of Key Variables

Variable	Obs.	Mean	Std. Dev.	Min – Max
Mobile Money Transactions (in millions)	210	1,280.11	2,028.45	0.02 – 11,000.00
Secure Internet Servers (certificates per 1 million people)	210	251.70	514.08	0.50 – 3,002.53
GDP per capita (USD)	210	2,469.74	2,299.05	519.55 – 11,415.94
Banks (per 100,000 people)	210	8.44	10.17	1.52 – 74.10
ATMs (per 100,000 people)	210	18.76	20.27	1.78 – 114.00
Population (in millions)	210	85.77	237.86	0.47 – 1,438.07
Rural Population (in millions)	210	51.05	152.58	0.28 – 915.13
Urban Population (in millions)	210	34.71	86.57	0.19 – 522.94
Mobile Penetration (per 100 people)	210	106.23	33.63	30.04 – 194.81
Trade (% of GDP)	210	66.85	35.42	15.35 – 164.28

3.3 Data Sources

The study draws on panel data of 35 developing countries from 2018 to 2023. The main sources include:

- **World Bank’s World Development Indicators (WDI):** For the number of secure internet servers, GDP per capita growth, population growth, and Trade openness.
- **International Telecommunication Union (ITU):** For the number of mobile phone penetration.

- **International Monetary Funds Global Financial Index Database (IMF):** For mobile money transactions, numbers of commercial bank branches and numbers of automated teller machines(ATMs).

3.4 Panel Dataset

The dataset was constructed as a strongly balanced panel with observations for six consecutive years: 2018, 2019, 2020, 2021, 2022, and 2023. The developing countries were selected based on the availability of data across all variables. The final panel includes 35 developing countries with repeated observations over time. All data were merged using country and year as identifiers in Stata.

3.5 Econometric Model

In this section, we present the econometric approach used to examine the economic impact of digital financial services and cybersecurity on financial inclusion in developing countries. To investigate the relationship between digital financial services and cybersecurity infrastructure, we employ a Fixed Effects regression model.

The Fixed Effects model is particularly suitable for this analysis as it accounts for unobserved, time-invariant heterogeneity across countries, such as institutional quality, regulatory environments, or cultural factors that may influence financial inclusion but are not directly measured in the dataset. By focusing on within-country variations over time, this model controls for potential biases that could arise from omitted variables that remain constant throughout the study period.

Given that financial inclusion is proxied by the number of mobile money transactions is the dependent variable (Y), we begin with a simplified linear regression framework that includes both the dependent variable and a key independent variable. This framework is then extended to incorporate multiple explanatory variables related to cybersecurity (secure internet servers), technological access, economic capacity, and traditional banking infrastructure.

3.6 Model Specification

3.6.1 Panel Data Analysis

We begin with a basic linear regression model for panel data:

$$Y_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 Z_{it} + \varepsilon_{it} \quad (1)$$

where:

- Y_{it} is the dependent variable representing financial inclusion for country i at time t .
- X_{it} is a vector of explanatory variable. representing secure internet servers, a proxy for cybersecurity for country i at time t .
- Z_{it} is a vector of the control variables.
- ε_{it} is the error term capturing all other unobserved influences.

To control for country-specific heterogeneity that may bias the results, we introduce a fixed effects estimator α_i , which leads to the following model:

$$Y_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 Z_{it} + \alpha_i + \varepsilon_{it} \quad (2)$$

where:

- α_i captures time-invariant unobserved heterogeneity specific to each country (e.g., political stability, regulatory institutions),

To eliminate the unobserved fixed effects α_i , we apply the within transformation (also known as the demeaning procedure), which subtracts the individual (country-specific) means from each variable:

$$(Y_{it} - \bar{Y}_i) = \beta_1 (X_{it} - \bar{X}_i) + \beta_2 (Z_{it} - \bar{Z}_i) + (\varepsilon_{it} - \bar{\varepsilon}_i) \quad (3)$$

This transformation removes the fixed country-specific effects α_i from the model, allowing consistent estimation of β_1 without omitted variable bias from time-invariant characteristics. The final empirical specification used in the estimation becomes:

$$Y_{it} = \beta_0 + \beta_1 X_{it} + \beta_k Z_{kit} + \varepsilon_{it} \quad (4)$$

Where $\beta_k Z_{kit}$ represents the full set of control variables, including GDP per capita growth, mobile phone penetration, population, bank branches, and ATMs.

This fixed effects model ensures that the analysis focuses on within-country variation over time, making it particularly well-suited for examining how changes in cybersecurity infrastructure and digital access influence financial inclusion in developing countries.

3.6.2 Model Specification

Fixed Effects Estimation: The Fixed Effects (FE) model allows for unobserved country-specific effects α_i is correlated with the explanatory variables. This approach controls for all time-invariant heterogeneity, making it suitable for analyzing within-country variations in digital financial services over time. To investigate the relationship between cybersecurity, digital financial infrastructure, and financial inclusion, we estimate the following panel data model:

$$\begin{aligned} \text{Mobile Money Transactions}_{it} = & \beta_0 + \beta_1 \text{Secure internet}_{it} + \beta_2 \text{GDP per capita}_{it} + \beta_3 \text{Population}_{it} \\ & + \beta_4 \text{Mobile penetration}_{it} + \beta_5 \text{Banks}_{it} + \beta_6 \text{ATMs}_{it} + \beta_7 \text{Trade}_{it} \\ & + \alpha_i + \varepsilon_{it} \end{aligned} \quad (5)$$

Where:

- Mobile Money Transactions_{it} is the number of mobile money transactions in country i at time t , used as a proxy for digital financial services.
- Secure internet servers_{it} denotes the number of secure internet servers, capturing cybersecurity infrastructure.
- GDP per capita_{it} is GDP per capita, reflecting income levels and economic development.
- Mobile Penetration_{it} is mobile phone penetration, measured by mobile cellular subscriptions per 100 people.
- Population_{it} is the total number of people living in a country i in year t .
- Banks_{it} is the number of commercial bank branches per 100,000 adults.
- ATMs (Automated Teller Machines)_{it} is the number of automated teller machines per 100,000 adults.
- Trade_{it} measures the extent to which a country's economy is engaged in international trade
- α_i represents unobserved country-specific effects.
- ε_{it} is the idiosyncratic error term.

3.7 Robustness Check

To ensure the reliability and consistency of the results obtained from the Fixed Effects estimation, robustness checks were conducted. These checks help verify whether the key findings of cybersecurity infrastructure (proxied by secure internet servers) on digital financial service usage remain valid under alternative model specifications and assumptions.

Hausman Test: To statistically determine whether the Fixed Effects or Random Effects model is more appropriate, We will conduct the Hausman test to compare the consistency of the Fixed Effects and Random Effects estimators. The null hypothesis assumes that the preferred model is Random Effects, while the alternative favors Fixed Effects due to the presence of correlation between the regressors and the unobserved heterogeneity.

Random Effects Estimation: As a first robustness test, the regression model was re-estimated using the Random Effects (RE) estimator. Unlike the Fixed Effects model, the RE model assumes that the unobserved country-specific effects are uncorrelated with the explanatory variables. This method provides more efficient estimates under this assumption and also allows for the inclusion of time-invariant variables. A comparison of the FE and RE results will be performed to assess whether the significance and direction of the coefficients, particularly for the secure internet servers variable, remained consistent. The consistency of results across both models will enhance confidence in the study's findings.

$$\begin{aligned} \text{Mobile Money Transactions}_{it} = & \beta_0 + \beta_1 \text{Secure internet}_{it} + \beta_2 \text{GDP per capita}_{it} + \beta_3 \text{Population}_{it} \\ & + \beta_4 \text{Mobile penetration}_{it} + \beta_5 \text{Banks}_{it} + \beta_6 \text{ATMs}_{it} + \beta_7 \text{Trade}_{it} \\ & + u_i + \varepsilon_{it} \end{aligned} \tag{6}$$

In the Random Effects model, u_i represents the country-specific random error component, which is assumed to be uncorrelated with the regressors. This model allows for the inclusion of time-invariant variables and is more efficient under the assumption of no correlation between u_i and the explanatory variables.

4 Empirical Results

The regression analysis assesses the direction and strength of the relationship between digital financial services and cybersecurity infrastructure across developing countries. Fixed effects model studies the changes that occur within countries and their causes. The fixed effects model in this study takes into account the variations in several country variables. The model

uses 210 observations across 35 developing countries. Each country contributes multiple time observations, allowing the model to estimate effects based on within-country changes.

4.1 Model 1: Secure Internet Servers and Mobile Money Transactions

Model 1 presents regression estimates examining the impact of secure internet infrastructure on mobile money transactions. The result shows the estimation of the fixed effects model and the relationship between digital financial services and cybersecurity using mobile money transactions and secure internet servers as proxies.

$$\text{Mobile Money Transactions}_{it} = \beta_0 + \beta_1 \text{Secure internet}_{it} + \alpha_i + \varepsilon_{it} \quad (7)$$

In Table 2, we observe that secure internet servers have a positive impact on mobile money transactions. The coefficient of secure internet servers is positive and statistically significant at the ($\beta = 1.799$ $p < 0.01$) level, which implies that a one-unit increase in secure internet servers per 1 million people is associated with an increase of approximately 1.80 million mobile money transactions. A statistically significant and positive effect shows that a secure internet infrastructure contributes to increased mobile money usage. This shows that cybersecurity (trust, encryption, safe platforms) is a major enabler of digital financial services in developing countries. Where internet transactions are perceived as secure, people are more likely to engage. This finding affirms the argument in this study that as cybersecurity infrastructure improves, so does trust in digital platforms, which in turn drives financial inclusion.

This result explains the importance of secure digital infrastructure in expanding access to financial services. In contexts where physical banking is limited, especially across many developing nations, secure internet access acts as a bridge, allowing populations to safely engage in financial transactions through mobile platforms. These findings validate the argument that cybersecurity is not just a technical concern but a critical policy lever for accelerating financial inclusion in the digital age.

4.2 Model 2: Income Effects on Mobile Money Usage

In model 2, we include a control variable to show how secure internet servers and income levels (GDP per capita) influence mobile money transactions.

$$\text{Mobile Money Transactions}_{it} = \beta_0 + \beta_1 \text{Secure internet}_{it} + \beta_2 \text{GDP}_{it} + \alpha_i + \varepsilon_{it} \quad (8)$$

Table 2 presents the fixed effects estimates of the impact of secure internet servers and GDP per capita growth on mobile money transactions. The coefficient of secure internet access remains positive and significant when income effects are added to the estimation, while the coefficient of GDP per capita is positive but not statistically significant, which indicates that within-country changes in income levels do not significantly explain variations in mobile money usage. Results show that the coefficient for secure internet servers is positive and statistically significant ($\beta = 1.725$ $p < 0.001$). This suggests that, holding GDP constant, a one-unit increase in secure internet servers is associated with an increase of approximately 1.73 units in mobile money usage. This finding supports the hypothesis that stronger digital security infrastructure fosters greater adoption of mobile financial services in developing economies.

Conversely, GDP per capita has a positive but statistically insignificant effect on mobile money usage ($\beta = 0.239$ $p = 0.397$). This implies that changes in economic wealth, once controlling for country-specific unobserved characteristics, do not significantly drive changes in mobile money adoption over time.

Our estimates suggest that general economic growth alone does not drive the uptake of mobile money services, and by itself, is insufficient to drive financial inclusion. Rather, digital trust anchored in secure platforms plays a more direct and meaningful role in encouraging users to engage in mobile money ecosystems. The result reflects that the infrastructure and digital access are more immediate determinants of mobile money uptake than income itself.

4.3 Model 3: Population Dynamics on Mobile Money Usage

In Model 3, we introduce population into the estimation to examine whether demographic dynamics alter the relationship between secure internet access and mobile money transactions.

$$\begin{aligned} \text{Mobile Money Transactions}_{it} = & \beta_0 + \beta_1 \text{Secure internet}_{it} + \beta_2 \text{GDP}_{it} + \beta_3 \text{Population}_{it} \\ & + \alpha_i + \varepsilon_{it} \end{aligned} \tag{9}$$

The regression results in Table 2 strengthen the main aim of this study; even after taking into account differences in population sizes, the impact of Secure internet remains clearly positive and statistically meaningful. The results show that even after accounting for population size, the number of secure internet servers continues to be significantly associated with greater mobile money usage. This means that as cybersecurity infrastructure improves, users are more likely to trust and adopt digital financial services. Here, digital trust remains a key enabler of financial inclusion, particularly in contexts where users may hesitate to engage

with digital platforms due to concerns about fraud or data security.

To better understand how population affects mobile money transactions, we disaggregate the population variable into rural and urban components. The analysis reveals that urban population size has a positive and statistically significant effect, suggesting that people in cities are more likely to use mobile money. This finding aligns with the expectations that urban areas generally offer better access to electricity, mobile networks, and financial technology infrastructure, making it easier and more convenient for residents to engage in digital financial activities. In contrast, rural population size does not show a significant effect, which likely reflects persistent barriers in these areas. Challenges such as poor internet connectivity, limited access to financial services, digital illiteracy, and infrastructural gaps continue to hinder the adoption of digital financial services in rural communities.

The results confirm that secure internet servers remain the most significant and consistent driver of mobile money adoption, even after accounting for urban and rural population dynamics. The lack of significance for both rural and urban populations suggests that the influence of demographic distribution may be mediated through infrastructure, education, or income, not directly through population shifts. This reinforces the view that investment in digital infrastructure is more critical than demographic structure alone in expanding digital financial inclusion.

4.4 Model 4: Digital Access and Digital Financial Services

Here, we introduce mobile phone penetration into our model. As presented in Table 2, even after introducing mobile penetration into the model, a major factor in digital finance adoption, secure internet servers remain a positive and statistically significant determinant of mobile money usage.

$$\begin{aligned} \text{Mobile Money Transactions}_{it} = & \beta_0 + \beta_1 \text{Secure internet}_{it} + \beta_2 \text{GDP}_{it} + \beta_3 \text{Population}_{it} \\ & + \beta_4 \text{Mobile penetration}_{it} + \alpha_i + \varepsilon_{it} \end{aligned} \quad (10)$$

The findings in Table 2 is important because it shows that access to mobile devices alone is not enough. People are more likely to trust and use mobile money services when the digital environment is secure. The continued significance of secure internet servers demonstrates that cybersecurity fosters user confidence and enables broader adoption of digital financial platforms. As expected, mobile penetration also has a strong and significant effect, suggesting that digital access through mobile devices is a necessary enabler. However, its inclusion does not weaken the importance of a secure internet. Instead, these results suggest that mobile access and digital trust are complementary drivers of financial inclusion. In other words,

the ability to access digital platforms and the trust in their safety must work together to generate inclusive financial outcomes.

The effect of urban population remains positive and statistically significant, which aligns with the expectation that urban residents often enjoy better access to infrastructure, networks, and financial technology services. Conversely, the rural population remains statistically insignificant, hinting at ongoing barriers such as limited connectivity, infrastructure gaps, or digital literacy challenges in these areas.

Altogether, this model shows that while expanding mobile access is important, strengthening digital security remains essential for increasing digital financial inclusion, particularly in developing countries.

4.5 Model 5: Digital Financial Services and Trade Openness

$$\begin{aligned} \text{Mobile Money Transactions}_{it} = & \beta_0 + \beta_1 \text{Secure internet}_{it} + \beta_2 \text{GDP}_{it} + \beta_3 \text{Population}_{it} \\ & + \beta_4 \text{Mobile penetration}_{it} + \beta_5 \text{Trade}_{it} + \alpha_i + \varepsilon_{it} \end{aligned} \quad (11)$$

In Model 5, we include trade openness alongside structural and financial indicators to assess its effect on the adoption of mobile money. The coefficient for trade openness is positive ($\beta = 7.92$ $p < 0.360$), but statistically insignificant. Several explanations may account for this finding. First, the influence of trade openness on mobile money adoption may be indirect, operating through broader economic development, income growth, or technology diffusion rather than directly affecting digital finance. Since the model controls for variables such as GDP and urbanization, these mediating effects may be absorbed, leaving trade openness without an independent contribution.

Second, the measure of trade openness, commonly expressed as the ratio of imports and exports to GDP, may not adequately capture the aspects of international integration that matter most for digital financial services. A country heavily engaged in trade through traditional commodity exports, for instance, may exhibit high trade ratios without experiencing parallel growth in financial technology sectors. Also, differences across countries likely matter. In some economies, global integration stimulates foreign investment and digital innovation, while in others, trade activity is concentrated in sectors with minimal spillovers to financial technology. The fixed-effects model accounts for these country-specific characteristics, potentially reducing the estimated role of trade openness.

Under this model, secure internet servers remain positively and marginally significant in association with mobile money transactions even after trade openness is accounted for. This suggests that improvements in digital security infrastructure encourage individuals and

firms to adopt mobile money services, likely by fostering greater trust in online transactions and reducing perceived risks. Even though the effect is only significant at the 10% level, the result highlights the importance of a reliable and safe digital environment in driving financial innovation. These findings suggest that while trade openness might contribute to financial innovation, domestic digital infrastructure, particularly secure internet access, appears to play a more direct and consistent role in enabling mobile money adoption.

4.6 Model 6 and 7: Traditional Financial Inclusion and Digital Financial Inclusion

In Model 6, we extend our analysis by introducing traditional banking, measured by the number of commercial bank branches is included in the estimation. This inclusion serves two main purposes: first, to allow for better comparison between digital and traditional forms of financial access, and secondly, to examine whether the presence of brick-and-mortar banks has any significant impact on mobile money usage or on the relevance of secure internet infrastructure.

$$\begin{aligned} \text{Mobile Money Transactions}_{it} = & \beta_0 + \beta_1 \text{Secure internet}_{it} + \beta_2 \text{GDP}_{it} + \beta_3 \text{Population}_{it} \\ & + \beta_4 \text{Mobile penetration}_{it} + \beta_5 \text{Trade}_{it} + \beta_6 \text{Banks}_{it} \\ & + \beta_7 \text{ATMs}_{it} + \alpha_i + \varepsilon_{it} \end{aligned} \quad (12)$$

The results in Table 2 shows that the coefficient for Secure internet servers remains positive and statistically significant, confirming that access to secure internet continues to foster digital financial inclusion even when traditional banking is accounted for. In other words, the digital trust created by cybersecurity infrastructure independently drives mobile money adoption, not just in the absence of traditional banking, but alongside it.

Notably, mobile phone penetration emerged as a highly significant and robust predictor of mobile money usage. This reinforces the understanding that widespread access to mobile devices is not merely a technological development, but a critical foundation for digital financial inclusion. The ability to connect to digital platforms through mobile phones enables individuals, especially those in remote or underserved areas, to engage with financial services that would otherwise be inaccessible.

The analysis also revealed that population size has a positive and statistically significant relationship with mobile money adoption. This suggests that countries with larger populations may benefit from economies of scale and network effects, leading to broader adoption and diffusion of mobile financial technologies. Larger markets often encourage innovation,

competition, and investment in financial infrastructure, which in turn supports the expansion of digital services.

In contrast, the number of commercial bank branches is negatively associated with mobile money usage. This implies a possible substitution effect: in regions where traditional banking infrastructure is more readily available, the motivation to switch to or adopt mobile financial services diminishes. It may also reflect user preferences for in-person financial services in areas where such services are accessible, or an overlap in customer base between conventional and digital finance providers.

Regarding GDP per capita, the coefficient is positive but not statistically significant. This suggests that economic growth alone is not a sufficient driver of digital financial inclusion. Without deliberate efforts to address infrastructural gaps, digital literacy, and affordability, increased national income does not automatically translate into widespread access to mobile money or other digital financial tools.

To deepen this understanding, model 7 further extends by incorporating automated teller machines (ATMs) as an additional measure of traditional banking infrastructure. This expansion allows for a more comprehensive examination of how conventional financial access points interact with digital financial services. The revised model controls for a broader set of variables, including rural and urban population distributions, mobile phone penetration, commercial bank branches, and ATMs. By doing so, it tests the robustness of the observed relationships particularly the effect of Secure internet infrastructure on the adoption of mobile money transactions and enhances the reliability of conclusions drawn about the relationship between cybersecurity readiness, traditional banking systems, and digital financial inclusion.

In Table 2 under model 7, Secure internet servers coefficient is still positive, although its statistical significance has slightly weakened (now marginally significant at the 10% level). This suggests that even after accounting for several control variables, including physical banking access and technological access, Secure internet servers infrastructure continues to play a meaningful role in driving mobile money usage in developing countries. People are more likely to adopt digital financial services when they perceive the online environment as secure, regardless of the number of bank branches or ATMs available.

Interestingly, mobile penetration continues to have a strong and statistically significant association with mobile money usage. This underscores the complementary relationship between digital access and digital security. The two appear to work together, but access alone is not enough; users must also trust the digital platforms.

Meanwhile, traditional banking infrastructure (commercial bank branches and ATMs) does not significantly influence mobile money usage in this model. Their coefficients are small and statistically insignificant, suggesting that traditional channels may not substitute

or directly compete with digital financial services. Instead, their presence appears largely unrelated to mobile money adoption in these settings. The urban population effect remains significant and positive, confirming earlier findings that digital financial services are more prevalent where infrastructure is concentrated. In contrast, rural population continues to have no statistically significant effect, highlighting persistent inclusion gaps across geographic areas.

This final model shows that even in the presence of mobile access and traditional banking structures, a secure internet infrastructure holds independent explanatory power in predicting mobile money adoption.

Table 2: Fixed-Effects Regression Results

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Secure internet servers	1.799* (0.517)	1.725* (0.525)	1.067* (0.575)	1.149* (0.587)	1.249* (0.602)	1.253* (0.603)	1.045 (0.624)
GDP per capita		0.239 (0.281)	0.173 (0.266)	0.155 (0.268)	0.137 (0.269)	0.128 (0.270)	0.136 (0.269)
Rural Population			0.011 (0.012)	0.012 (0.012)	0.012* (0.012)	0.013* (0.012)	0.015* (0.013)
Urban population			0.010*** (0.034)	0.099*** (0.034)	0.096** (0.034)	0.094** (0.034)	0.096** (0.034)
Mobile penetration				5.576 (7.955)	5.000 (8.000)	4.916 (8.013)	3.043 (8.132)
Trade					6.553 (8.572)	6.697 (8.587)	7.924 (8.626)
Banks						-26.164 (37.086)	-12.484 (38.543)
ATMs							-50.874 (39.926)
Constant	827.19*** (159.97)	256.63 (690.60)	-8605.28 (5828.21)	-9560.94 (5994.02)	-10250.13 (6068.71)	-10328.14 (6078.76)	-10584.17 (6070.83)
N	210	210	210	210	210	210	210
Overall R^2	0.050	0.046	0.146	0.149	0.153	0.156	0.161

Standard errors in parentheses Standard errors: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

4.7 Fixed and Random Effects Model

Here, we compare the Fixed Effects (FE) and Random Effects (RE) estimations to assess the robustness of the relationship between secure internet infrastructure and mobile money usage across 35 developing countries. In both models, the coefficient for our independent variable remains positive and statistically significant. The FE model, which controls for time-invariant unobserved heterogeneity across countries, shows that secure internet servers maintain its importance even after accounting for differences in population, mobile penetration, and traditional banking infrastructure. The RE model, which assumes no correlation between the unobserved effects and the regressors, yields an even more significant and precise estimate for secure internet, with a smaller standard error.

Table 3: Fixed and Random Effects Models

Dependent Variable:	Mobile Money Transaction	
	FE Model	RE Model
Secure internet servers	1.045* (0.623)	1.008* (0.437)
GDP per capita	0.136* (0.269*)	-0.110* (0.121*)
Rural population	0.016** (0.013*)	-0.025* (0.069*)
Urban population	0.0096* (0.0034*)	0.0055* (0.0013*)
Mobile penetration	3.04* (8.132*)	5.89* (6.029*)
Trade	7.92** (8.63**)	2.38** (5.73**)
Banks	-12.48* (38.54**)	-9.41* (19.85*)
ATMs	-50.87* (39.9261)	-24.86* (14.2221)
Constant	-10584.17* (6070.83)	456.38 (661.23)
N	210	210
Overall R^2	0.161	0.370

4.8 Hausman Test

Although the Hausman test does not statistically reject the use of a random effects model, the fixed effects approach is more suitable for this study. This is because our focus is on how digital financial inclusion changes within each country over time, rather than on differences between countries. In developing economies, country-specific factors such as the strength of digital infrastructure, national cybersecurity policies, or trust in financial institutions can shape both mobile money usage and the pace of digital growth. These are often unobserved and constant over time, and they may be related to the variables we are studying. The fixed effects model helps control for these underlying country characteristics by allowing each country to have its own baseline, so we can better isolate the impact of time-varying factors like secure internet servers or mobile penetration. Given that most of the variation in the data comes from differences between countries, using fixed effects also ensures that my analysis focuses on meaningful changes within countries where digital transitions are happening.

Table 4: Hausman Test Results: Fixed and Random Effects

	(b) FE Model	(B) RE Model	(b-B)	Std. Err.
Secure internet servers	1.0449	1.0085	0.0365	0.4449
GDP per capita	0.1363	-0.1105	0.2469	0.2403
Rural population	0.00016	-0.00003	0.00018	0.00013
Urban population	0.00010	0.00005	0.00004	0.00003
Mobile Penetration	3.0430	5.8984	-2.8554	5.4570
Banks	-12.4839	-9.4198	-3.0641	33.0381
ATMs	-50.8743	-24.8667	-26.0076	37.3071
Trade	7.9239	2.3572	5.5667	6.4484
Test of H_0 : Difference in coefficients not systematic				
$\chi^2(5) = 2.90$ Prob > $\chi^2 = 0.8218$				

4.9 Robustness Check

To ensure the reliability of the regression estimates, a robustness check was conducted by re-estimating the fixed effects model with standard errors clustered at the country level. This approach corrects for potential heteroskedasticity and autocorrelation within countries over time, thus providing more accurate inference.

The robust fixed-effects estimates confirm that Secure internet servers remain a statistically significant driver of mobile money adoption even after clustering standard errors at the country level and controlling for mobile access, population structure, and traditional banking outlets.

A one-unit increase in Secure internet servers per 1 million people is associated with roughly an additional 1.045 million mobile money transactions ($\beta = 1.045$ $p < 0.10$), and this effect is significant at the 10% level. Crucially, the inclusion of mobile penetration, which is also positive and significant, does not erode the influence of secure internet servers, underscoring the thesis claim that digital access and digital trust are complementary rather than substitutable forces. Traditional banking variables (bank branches and ATMs) remain insignificant, suggesting that physical infrastructure plays a limited role in the digital finance landscape considered here. The urban-population coefficient is marginally significant, while the rural population continues to show no effect, highlighting persistent geographic disparities. Overall, these robust results strengthen the argument that expanding secure internet capacity is essential for deepening financial inclusion across developing economies.

The results further indicate that the coefficient for secure internet servers remains positive, suggesting that countries with stronger cybersecurity infrastructure are more likely to experience greater usage of mobile money services. Although the level of statistical significance slightly weakens under robust estimation, the direction and magnitude of the effect remain consistent with earlier results.

Other variables, such as GDP per capita, population size, mobile phone penetration, traditional banking infrastructure (including commercial bank branches and ATMs), and trade openness, are statistically insignificant in the robust model. This outcome reinforces the conclusion that economic development and physical access alone do not guarantee higher digital financial inclusion. Moreover, the negative yet insignificant coefficients for ATMs and bank branches continue to support the view that mobile money operates independently of traditional financial infrastructure.

The robustness check confirms that cybersecurity infrastructure continues to play a pivotal role in fostering digital financial services, even when accounting for heteroskedasticity and country-specific shocks over time.

4.10 Unobserved Heterogeneity

When working with panel data, one important challenge is dealing with unobserved factors, things we can't directly measure, but that could still affect our results. These typically come in two forms. The first are country-specific traits that remain unchanged over time. These

are usually accounted for by including country fixed effects in the model. The second type is time-specific influences that affect all countries in a similar manner, such as global economic shifts, which are usually handled using year-fixed effects.

However, due to data limitations, particularly the relatively short period and small number of years observed in this dataset, it is not feasible to include both country and year fixed effects simultaneously. Including both would lead to multicollinearity and overfitting issues, reducing the precision and reliability of the estimated coefficients.

Given these constraints, we chose to include country fixed effects α_i . This choice helps ensure we account for consistent differences between countries that could otherwise bias the findings, especially since these country-level differences are more likely to persist over time compared to global shocks during the short study period. To ensure robustness, we added several time-varying control variables, such as GDP per capita, trade openness, mobile phone penetration, the number of bank branches, and the number of ATMs ⁶. These controls help track changes in financial infrastructure and technology over time, acting as a stand-in for the unobserved trends that year effects would normally capture.

In summary, retaining country effects while excluding year effects enhances the model’s precision and supports a more meaningful interpretation of the role of cybersecurity in promoting digital financial inclusion.

5 Discussion

This study aimed to investigate the impact of cybersecurity infrastructure and digital access on the adoption of digital financial services, as well as the extent to which this serves as a barrier to financial inclusion in developing economies. The analysis employed panel data methods using data from 35 developing countries spanning 2018 to 2023. The discussion below connects each empirical finding with the study’s objectives and broader theoretical expectations.

Across several model specifications, secure internet servers showed varying levels of influence. In the basic model, secure internet servers had a statistically significant positive effect on mobile money transactions, highlighting the importance of secure digital environments in promoting financial inclusion. However, in more saturated models with additional controls, the effect became statistically weaker, though still positive. This result underscores the idea that cybersecurity plays an enabling, but not independent, role in digital financial inclusion. Trust in digital platforms, driven by security infrastructure, is essential but must be complemented by other factors such as access, awareness, and affordability. When users know

6. Automated Teller Machines

that transactions occur over properly secured servers, they feel safer and are more likely to transact.

Trade openness also emerged as a positive and significant driver of mobile money transactions. This suggests that greater integration into the global economy supports financial innovation and expands opportunities for digital transactions. Trade integration may encourage cross-border financial flows such as remittances, expose domestic markets to international payment technologies, and create demand for efficient and secure financial services. However, trade openness by itself is unlikely to be sufficient; its impact on digital financial inclusion is most effective when paired with supportive domestic infrastructure such as secure internet access and reliable mobile connectivity. In countries lacking such foundations, the benefits of global integration may not fully translate into digital finance adoption.

Similarly, mobile phone penetration was highly significant, particularly in models accounting for both digital and traditional financial infrastructure. These findings confirm that access to digital devices and reliable connectivity are prerequisites for engaging with financial technologies. Having a phone matters, but without confidence in the safety of the network, people hesitate to click “send.” Population size showed a consistent and significant positive relationship with mobile money transactions. This suggests that in more populous countries, digital platforms scale more effectively and meet higher demand. Urban residents adopt mobile money more readily, but rural communities only catch up when secure infrastructure becomes available to them as well. GDP per capita, however, did not have a significant effect in most models, indicating that income alone does not predict digital financial usage. This suggests that financial inclusion is more closely tied to infrastructural and social conditions than to aggregate economic performance.

The study also examined whether mobile money substitutes for or complements traditional banking infrastructure. Results for commercial bank branches were mixed and mostly insignificant, suggesting no strong competitive or complementary relationship. In contrast, the number of ATMs showed a consistently negative and statistically insignificant effect on mobile money usage. This indicates a substitution effect; individuals may be less inclined to use mobile money when physical banking infrastructure like ATMs is accessible. Physical branches and ATMs don’t move the needle on mobile-money transactions; secure digital rails do.

Based on these findings, to truly expand digital financial inclusion in developing countries, a few practical steps can make a big difference, such as improving access to affordable and reliable internet should be a top priority, especially in rural and low-income areas where people are often left behind. Without connectivity, digital financial services simply can’t reach the people who need them most. Helping people feel confident using these services is

just as important. That means investing in digital literacy programs, not just teaching people how to use mobile money apps, but also how to stay safe online and avoid scams. At the same time, countries need to strengthen their cybersecurity systems by improving internet security, enforcing strong data protection laws, and supporting secure digital ID systems. These efforts build trust, which is essential for people to fully embrace digital finance. Governments can also support fintech companies that want to serve underserved regions by offering tax breaks, grants, or forming partnerships. Importantly, financial regulators should create flexible, inclusive rules that protect users but still allow space for innovation.

Finally, traditional banks and digital platforms shouldn't be seen as competitors. Instead, they can work together to reach more people by offering a mix of physical and digital services, especially in areas where banks are scarce. Governments, financial institutions, and development partners must therefore work together to strengthen national cybersecurity capacity, not as a separate agenda but as a critical part of financial inclusion policy. This includes investing in secure infrastructure, launching public awareness campaigns, training frontline financial service providers to handle cyber threats, and enforcing stricter data protection regulations. Trade policy, too, should be seen as part of this agenda: by creating an enabling environment for cross-border financial flows and encouraging digital trade, governments can amplify the positive effects of global integration on financial inclusion.

6 Conclusion

This study examined the influence of cybersecurity and digital access on financial inclusion through mobile money adoption in 35 developing countries between 2018 and 2023. Using fixed and random effects models, the research examined how secure digital infrastructure, socioeconomic conditions, and traditional banking systems influence financial behavior. A key finding is that Secure internet servers consistently enhance mobile money usage, regardless of controls for income, population, mobile access, or banking availability. This highlights the crucial role of cybersecurity in facilitating digital financial inclusion. Notably, the study reveals that digital trust is just as crucial as digital reach. Mobile money adoption is highest in regions underserved by traditional banking, where secure digital environments and widespread internet access fill the gap. While ATMs were found to reduce mobile money usage, suggesting that population size was a consistent driver of adoption. In contrast, GDP per capita had no significant effect, highlighting that access and trust matter more than income. These insights emphasize that financial inclusion in the digital age depends not only on infrastructure and devices but also on users' confidence in the safety and reliability of digital systems. Therefore, future strategies must treat cybersecurity as a core foundation

for building trust and expanding financial services.

This paper contributes to the growing body of literature on financial inclusion by being one of the few empirical studies to explicitly examine the relationship between digital financial services and cybersecurity in developing economies. Unlike prior studies that focus narrowly on economic or infrastructural barriers, this research highlights digital trust as a pivotal but often overlooked determinant of financial behavior. By using secure internet servers as a proxy for cybersecurity, the paper presents a measurable, policy-relevant framework for assessing digital trust environments and their role in financial inclusion.

Finally, this study sheds light on the link between cybersecurity and digital financial inclusion, however there are still several areas worth exploring in future research. For example, studies that focus on individuals or households could help us better understand how digital literacy, trust in technology, and personal experiences with cyber threats influence people's decisions to use mobile money services. In addition, using qualitative methods such as interviews or focus groups can provide valuable insights into how people's experiences, especially those involving fraud or system failures, shape their perceptions of mobile banking, both in rural and urban areas. While we employed secure internet servers as a general measure of cybersecurity, future work could search deeper by examining the specific effects of threats, such as phishing, malware, or identity theft, on individuals' willingness to adopt digital financial services.

7 Use of Generative AI and AI-assisted tools

During the preparation of my thesis, I used CHATGPT to refine and clarify complex terms. After using this tool, I reviewed and edited the content as needed and take full responsibility for the content of my thesis.

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Appendix A: Tables

Table 5: Descriptive Statistics of Key Variables

Variable	Obs.	Mean	Std. Dev.	Min – Max
Mobile Money Transactions (in millions)	210	1,280.11	2,028.45	0.02 – 11,000.00
Secure Internet Servers (certificates per 1 million people)	210	251.70	514.08	0.50 – 3,002.53
GDP per capita (USD)	210	2,469.74	2,299.05	519.55 – 11,415.94
Banks (per 100,000 people)	210	8.44	10.17	1.52 – 74.10
ATMs (per 100,000 people)	210	18.76	20.27	1.78 – 114.00
Population (in millions)	210	85.77	237.86	0.47 – 1,438.07
Rural Population (in millions)	210	51.05	152.58	0.28 – 915.13
Urban Population (in millions)	210	34.71	86.57	0.19 – 522.94
Mobile Penetration (per 100 people)	210	106.23	33.63	30.04 – 194.81
Trade (% of GDP)	210	66.85	35.42	15.35 – 164.28

Table 7: List of Countries and Their Income Classification

s/n	Country	Income Level	s/n	Country	Income Level
1	Bangladesh	Lower-middle income	19	Lesotho	Lower-middle income
2	Benin	Low income	20	Liberia	Low income
3	Bolivia	Lower-middle income	21	Libya	Upper-middle income
4	Botswana	Upper-middle income	22	Maldives	Upper-middle income
5	Burkina Faso	Low income	23	Mali	Low income
6	Cambodia	Lower-middle income	24	Mozambique	Low income
7	Congo, Rep.	Lower-middle income	25	Nepal	Low income
8	Cote d'Ivoire	Lower-middle income	26	Niger	Low income
9	Egypt, Arab Rep.	Lower-middle income	27	Nigeria	Lower-middle income
10	Eswatini	Lower-middle income	28	Pakistan	Lower-middle income
11	Gambia, The	Low income	29	Philippines	Lower-middle income
12	Ghana	Lower-middle income	30	Rwanda	Low income
13	Guinea	Low income	31	Senegal	Lower-middle income
14	Guinea-Bissau	Low income	32	Thailand	Upper-middle income
15	India	Lower-middle income	33	Togo	Low income
16	Indonesia	Lower-middle income	34	Zambia	Lower-middle income
17	Jamaica	Upper-middle income	35	Zimbabwe	Low income
18	Kenya	Lower-middle income			

Table 6: Variable Definitions and Data Sources

Variable	Definition	Data Source
Mobile Money Transactions	Value of mobile money transactions in a country per year (in millions)	International Monetary Fund (IMF FAS)
Secure Internet Servers	The number of secure internet certificates in a country serves as an indicator of how well websites and online services are protected through encryption protocols per 1 million people	World Bank's World Development Indicator (WDI)
GDP per capita	Annual rate of GDP per capita, measured in constant US dollars	World Bank's World Development Indicator (WDI)
Population	The population size of a country per year. Both rural and urban population	World Bank's World Development Indicator (WDI)
Mobile Penetration	The number of Mobile cellular telephone subscriptions to a public mobile telephone per 100 people	World Bank's World Development Indicator (WDI)
Banks	Commercial Bank branches per 100,000 adults in a country per year	International Monetary Fund (IMF)
ATMs	The number of Automated Teller Machines per 100,000 adults per year	International Monetary Fund (IMF)
Trade Openness	The ratio of total trade in a country per year	World Bank's World Development Indicator (WDI)

Table 8: Fixed-Effects Regression: Model 1

Variable	Coefficient	Std. Err.	t	P-value
Secure Internet Servers	1.799505**	0.517226	3.48	0.001
Constant	827.185***	159.9724	5.17	0.000
<i>Model Statistics</i>				
N = 210	Groups = 35	F(1, 174) = 12.10, Prob > F = 0.0006		
Within $R^2 = 0.0650$	Between $R^2 = 0.1358$	Overall $R^2 = 0.1056$		

Standard errors: *p < 0.10; **p < 0.05; ***p < 0.01

Table 9: Fixed-Effects Regression: Model 2

Variable	Coefficient	Std. Err.	t	P-value
Secure Internet Servers	1.725***	0.525	3.29	0.001
GDP per capita	0.239	0.281	0.85	0.397
Constant	256.634	690.598	0.37	0.711
<i>Model Statistics</i>				
N = 210	Groups = 35	F(2,173) = 6.40, Prob > F = 0.0021		
Within $R^2 = 0.069$	Between $R^2 = 0.051$	Overall $R^2 = 0.046$		

Standard errors: *p < 0.10; **p < 0.05; ***p < 0.01

Table 10: Fixed-Effects Regression: Model 3

Variable	Coefficient	Std. Err.	t	P-value
Secure Internet Servers	1.067*	0.575	1.86	0.065
GDP per capita	0.173	0.266	0.65	0.518
Rural population	0.000110	0.000126	0.87	0.384
Urban population	0.000103**	0.000034	3.06	0.003
Constant	-8605.277	5828.212	-1.48	0.142
<i>Model Statistics</i>				
N = 210	Groups = 35	F(4,171) = 9.22, Prob > F= 0.0000		
Within $R^2 = 0.177$	Between $R^2 = 0.273$	Overall $R^2 = 0.170$		

Standard errors: *p < 0.10; **p < 0.05; ***p < 0.01

Table 11: Fixed-Effects Regression: Model 4

Variable	Coefficient	Std. Err.	t	P-value
Secure Internet Servers	1.149*	0.587	1.96	0.052
GDP per capita	0.155	0.268	0.58	0.563
Rural population	0.000120	0.000127	0.94	0.347
Urban population	0.000099**	0.000034	2.93	0.004
Mobile penetration	5.576	7.955	0.70	0.484
Constant	-9560.942	5994.020	-1.60	0.113

Model Statistics

N = 210	Groups = 35	F(5,170) = 7.45, Prob > F = 0.0000
Within $R^2 = 0.180$	Between $R^2 = 0.271$	Overall $R^2 = 0.169$

Standard errors: *p < 0.10; **p < 0.05; ***p < 0.01

Table 12: Fixed-Effects Regression Results: Model 5

Variable	Coefficient	Std. Err.	t	P-value
Secure Internet Servers	1.249*	0.602	2.07	0.040
GDP per capita	0.137	0.269	0.51	0.612
Rural population	0.000129	0.000128	1.01	0.315
Urban population	0.000096**	0.000034	2.80	0.006
Mobile penetration	5.000	8.000	0.63	0.533
Trade openness	6.553	8.572	0.76	0.446
Constant	-10250.13	6068.713	-1.69	0.093

Model Statistics

N = 210 Groups = 35 F(6, 169) = 6.29 Within $R^2 = 0.183$ Overall $R^2 = 0.167$

Standard errors: *p < 0.10; **p < 0.05

Table 13: Fixed-Effects Regression Results: Model 6

Variable	Coefficient	Std. Err.	t	P-value
Secure Internet Servers	1.253*	0.603	2.08	0.039
GDP per capita	0.128	0.270	0.47	0.636
Rural population	0.000136	0.000129	1.06	0.291
Urban population	0.000094**	0.000034	2.75	0.007
Mobile penetration	4.916	8.013	0.61	0.540
Trade openness	6.697	8.587	0.78	0.437
Commercial Banks	-26.164	37.086	-0.71	0.481
Constant	-10328.14	6078.757	-1.70	0.091

Model Statistics

N = 210 Groups = 35 F(7, 168) = 5.45 Within $R^2 = 0.185$ Overall $R^2 = 0.166$

Standard errors: *p < 0.10; **p < 0.05

Table 14: Fixed-Effects Regression Results: Model 7

Variable	Coefficient	Std. Err.	t	P-value
Secure Internet Servers	1.045*	0.624	1.67	0.096
GDP per capita	0.136	0.269	0.51	0.614
Rural population	0.000159	0.000130	1.23	0.221
Urban population	0.000096**	0.000034	2.81	0.006
Mobile penetration	3.043	8.132	0.37	0.709
Trade openness	7.924	8.626	0.92	0.360
Commercial Banks	-12.484	38.543	-0.32	0.746
ATMs	-50.874	39.926	-1.27	0.204
Constant	-10584.17	6070.832	-1.74	0.083
<i>Model Statistics</i>				
N = 210	Groups = 35	F(8, 167) = 4.99	Within $R^2 = 0.193$	Overall $R^2 = 0.161$

Standard errors: *p < 0.10; **p < 0.05

Table 15: Fixed-Effects Regression Results with Clustered Standard Errors (Country-level)

Variable	Coefficient	Robust Std. Err.	t	P-value
Secure Internet Servers	1.045	0.660	1.58	0.123
GDP per capita	0.136	0.182	0.75	0.460
Rural population	0.000159	0.000129	1.23	0.226
Urban population	0.000096	0.000088	1.09	0.282
Mobile penetration	3.043	6.705	0.45	0.653
Trade openness	7.924	5.048	1.57	0.126
Commercial Banks	-12.484	19.671	-0.63	0.530
ATMs	-50.874	46.102	-1.10	0.278
Constant	-10584.17	5846.878	-1.81	0.079
<i>Model Statistics</i>				
N = 210	Groups = 35	F(8, 34) = 3.74	Prob > F = 0.0031	
Within $R^2 = 0.193$	Between $R^2 = 0.259$	Overall $R^2 = 0.161$		

Note: Robust standard errors adjusted for 35 clusters at the country level.

Table 16: Random-Effects Regression Results

Variable	Coefficient	Std. Err.	z	P-value
Secure Internet Servers	1.008*	0.438	2.30	0.021
GDP per capita	-0.111	0.122	-0.91	0.364
Rural population	-0.000025***	0.00000689	-3.67	0.000
Urban population	0.000055***	0.0000125	4.38	0.000
Mobile penetration	5.898	6.029	0.98	0.328
Trade openness	2.357	5.729	0.41	0.681
Commercial Banks	-9.420	19.851	-0.47	0.635
ATMs	-24.867*	14.222	-1.75	0.080
Constant	456.381	661.234	0.69	0.490
<i>Model Statistics</i>				
N = 210	Groups = 35	Wald $\chi^2(8) = 56.51$	Prob > $\chi^2 = 0.0000$	
Within $R^2 = 0.153$	Between $R^2 = 0.529$	Overall $R^2 = 0.370$		

Standard errors: *p < 0.10; ***p < 0.01