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Exploring the influence of ICT on Financial Inclusion and Mobile Money Services in Sub-Saharan Africa

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Abstract

This thesis investigates the influence of two types of Information and Communication Technologies (ICT), internet and mobile phones, on Financial Inclusion (FI) and Mobile Money Mobile Money (MM) adoption in 24 Sub-Saharan African countries in the last decade. A unique feature of this research is the incorporation of an index measuring financial inclusion, developed specifically for this study. It seeks to investigate if ICTs can contribute to advance financial inclusion for the poor, direct or indirect via the channel of mobile money services. Utilizing newly released data on financial inclusion and mobile money usage, this study employs panel regressions with time and country fixed effects and incorporates socioeconomic and demographic control variables. Despite the significant disparities in financial inclusion and mobile money penetration across the studied region, we find that increased internet penetration significantly contributes to the enhancement of financial inclusion and usage of mobile money services. Conversely, mobile phone penetration, socioeconomic and demographic factors, and the quality of governance display negligible effects on financial inclusion and mobile money adoption. These findings shed light on the need for ICT-focused policies and strategies in promoting financial inclusion, thereby addressing poverty and economic inequality issues. The study contributes to the discourse on ICT as a tool for economic empowerment, particularly in regions with historically low access to formal financial systems. The utilization of a custom-developed financial inclusion index enhances the precision and relevancy of the research outcomes.

Keywords: Sub-Saharan Africa, Financial Inclusion, Information and Communication Technology, Internet, Mobile Money

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FE Fixed Effects

FII Financial Inclusion Index

FI Financial Inclusion

ICT Information and Communication Technologies

IMF International Monetary Fund

ITU United Nations International Telecommunications Union

MM Mobile Money

OECD Organisation for Economic Co-operation and Development

OLS Ordinary Least Square

SDG Sustainable Development Goals

SSA Sub-Saharan Africa

UNCTAD United Nations Conference on Trade and Development

1

Introduction

The ongoing global battle on poverty remains a critical issue, particularly in Sub-Saharan Africa (SSA) where the poverty ratio stood at 34.9% in 2019 (World Bank Financial Inclusion, 2023). While there are many ways to reduce poverty, Financial Inclusion (FI), which denotes the provision of affordable and valuable financial products and services to everyone, and utilizes financial intermediaries to benefit both enterprises and consumers, has shown significant influence in spurring economic growth and reducing poverty across various regions and cultures (Gorton & Winton, 2003; Koomson et al., 2020; Kim et al., 2018; Sethi & Acharya, 2018; Lenka & Sharma, 2017; Omar & Inaba, 2020). The International Monetary Fund (IMF) and The World Bank underscore its importance for extending prosperity to developing regions and a crucial tool in achieving seven of the seventeen Sustainable Development Goals (SDG)s.

FI also helps reduce inequality by increasing access to financial services, particularly effective in low-income countries. Yet, as of 2021, 1.7 billion adults worldwide still lack a transaction account due to cost issues, with significant disparities in account ownership between Organisation for Economic Co-operation and Development (OECD) countries with a 97.19% of the adult population owning an account and in comparison, the rate is only at 55.07% in SSA. Despite improvements, SSA remains notably behind in financial access and development.

This thesis analyzes the impact of internet and the penetration of mobile phones on FI, and the related notion of mobile money usage. In the age of ICT – a broad term including internet and mobile connectivity – there has been a rise in mobile money services, a type of financial service that allows for money storage, transfer, and transactions through a mobile device, typically a smartphone. Amid fast-paced Information and Communication Technologies development, internet usage increased from 7% to 60% globally between 2000 and 2020, and has contributed to total factor productivity growth, and by extension, overall economic growth (Lam & Shiu, 2010).

Mobile money, introduced by the mobile operator Safaricom in Kenya in 2007 with the M-PESA service, provides alternative financial services to unbanked individuals. Since then, more companies have joined the revolution and several services have been launched all over SSA operated by both telecommunication operators and banks. M-PESA is a SMS-based money transfer system that enables individuals to deposit, send, and withdraw funds with their mobile phones, offering an alternative for those without traditional banking access (Mas & Morawczynski, 2009). Since then, mobile money services have diversified and some also offers loans and savings solutions. As of 2021, 33% of the adult population in SSA had a mobile money account, the highest proportion globally, indicating progress in bridging the FI gap (World Bank Global Findex, 2021).

Against this background, this paper will try to answer the following question: *Can ICT contribute significantly to FI, direct and indirect via the channel of mobile money?*

This research examines the impact of internet and mobile phone penetration on FI and MM usage. For measuring FI, an index has been developed to capture multiple aspects. Based on panel data obtained from 24 SSA countries over 2014, 2017 and 2021 from the World Bank Findex dataset, this study examines the relationship between ICT and FI and MM penetration. The statistical method accounts for unique characteristics specific to each country and time period using Fixed Effects. To account for potential endogenous effects, control variables for economic growth, rule of law, urbanization and income inequality have been included, enhancing the accuracy of our analysis.

The findings show that that internet penetration had a strong and positive effect on both Financial Inclusion and Mobile Money usage, and were robust with and without including the control variables. However, mobile phone penetration did not show a significant impact on FI or MM adoption, even when controlling for it separately. A plausible explanation is that unreliable telecom connectivity leads to individuals owning multiple subscriptions (Aker & Mbiti, 2010; Rotberg & Aker, 2013). The variable that measures mobile phone penetration might be correlated to the immeasurable variable of scarce mobile connectivity. Unfortunately, this leads to an omitted variable bias that affects the accuracy of our estimation of the true effects of mobile phone penetration.

Surprisingly, urbanization rates had a negative effect on FI, contrary to previous research. Despite including other control variables such as economic growth, rule of law, urbanization, and income inequality in our analysis, the significance of internet penetration remained robust and strongly positive. This implies that the impact of internet usage on both FI and mobile money usage persisted even after accounting for the potential influence of these control variables.

In summary, SSA suffers from poverty and low levels of FI. Researchers and international organizations frequently argue that getting more people financially included can enable prosperity. This thesis argue that the process of getting people financial included in developing areas is heavily reliant on cost-efficient tools that can enable information and transaction exchange, which the ICT infrastructure can provide. Therefore, this study delves into the relationship between technological development, FI, and mobile money penetration, using newly released data for 2021. Further, with a standing point in previous literature the discussion touches on if these tools can bridge the existing financial gap and offer opportunities, prosperity, and FI for those traditionally excluded from the financial system. This thesis extends beyond a general ICT perspective and look into whether specific types of ICTs are more influential in facilitating this transformation.

The remainder of this thesis is organized as follows: Section 2 present an overview of previous literature, followed by section 3 where the theoretical framework is presented, in section 4 the data is presented, 5 examines the econometric method applied, in section 6 results and discussion are presented, lastly section 7 presents conclusions, some limitations, and suggestions on further research.

2

Literature Review

This section aims at summarizing earlier research and literature on FI, ICT infrastructure and MM diffusion. It will contain theories and results on determinants of, and relationships in between the variables. In addition, anchored in the presentation of previous research, it puts forth what contribution to the literature our thesis will provide. To ensure a common understanding of the most important terms, the section will start off by putting forth definitions and descriptions of key concepts.

FI is a multifaceted concept that refers to accessibility and availability of formal financial products and services to a broad spectrum of individuals and businesses. Sarma (2008) contributes a diversified definition of FI and categorizes it into three different dimensions: accessibility, availability, and usage. The argument is that all three need to be covered for inclusiveness to be complete. The World Bank has defined FI as when "individuals and businesses have access to useful and affordable financial products and services that meet their needs – transactions, payments, savings, credit and insurance – delivered in a responsible and sustainable way" (World Bank Financial Inclusion, 2023). We will refer to FI in line with Sarma (2008)) where we focus on how many in the population have access, availability and use financial services.

ICT infrastructure refers to the physical and virtual assets that help deliver and manage information and messages and thus connect people, regardless of their location. It takes shape in hardware, for example computers, servers or storage devices and software, for example operator systems or computer programs. Lee and Brahmasrene (2014) refers to United Nations International Telecommunications Union (ITU), OECD and United Nations Conference on Trade and Development (UNCTAD) and put forth a meticulous framework for ICT measurement where supply and usage are distinguished from each other. ICT infrastructure is defined as the first stage in a chain of development, referring to telecommunication services supplied and to what degree they are accessible. In a second stage, adding connectivity and internet traffic to the measurement, both supply and usage is covered. We will define Information and Communication Technology as internet penetration and mobile phone penetration and assume that it covers both supply and use.

At its core, MM refers to financial services that are facilitated through a mobile phone, enabling individuals and businesses to make peer-to-peer transactions, pay bills, store funds, access loans and access other financial products without the need for a traditional bank account (GSMA, 2018). In this thesis MM adoption will be used as a term referring to the extent to which individuals use MM services.

2.1 Determinants of Financial Inclusion

As mentioned, financial inclusiveness is a major key for purposes of fostering development and prosperity. According to Koomson et al. (2020), people who are included in the financial system and participate in consuming its services are less likely to remain poor. As with poverty in general, FI is a substantial concern in SSA. The participation of households and enterprises is among the world's lowest (Mlachila et al., 2013). With regards to this, a great number of researchers have dedicated time to examine what determines FI, both on a societal level and an individual level.

Allen et al. (2016) finds in their study that lower banking costs and proximity to financial institutions have a positive impact on FI. Political stability and strong legal rights were also shown to be crucial factors for inclusiveness. Drawing attention to Africa, Allen et al. (2014) finds population density to be more important for bank-branch penetration, where African countries with large fractions of the population living in rural areas appear to have less developed banking-systems. Furthermore, as will be presented in more detail below, countries where internet connectivity increases have more people financially included (Sanderson et al., 2018; Lenka & Barik, 2018). Hence, the literature agrees on that countries with high rates of FI are attributed with a more enabling environment for financial service accessibility.

Looking at demographic features, there is relative agreement on what determines FI. Being male, older, more educated, literate, employed, having a higher income, and living in urban areas is associated with consuming financial services to a higher extent (Soumaré et al., 2016; Abunga Akudugu, 2013; Zins & Weill, 2016). These indicators are related to being dependent on financial services and hence incentivised to become financially more literate. In addition, Sanderson et al. (2018) , and Abunga Akudugu (2013), by analysing Zimbabwe respectively Ghana, find distance to facilities that provide financial service to be negatively correlated with utilising such products. This suggests that financial accessibility is a function of distance to financial service providers.

Self-reported perception of major barriers for excluded individuals are costs of opening accounts and a low penetration of financial service providers. Further, absence of money and documentation, seem to be a concerning barrier for participation in financial services (Allen et al., 2016). Analyzing Central and West Africa, the regions of lowest levels of financial inclusiveness, Soumaré et al. (2016) puts forth lack of money to be the dominant barrier to inclusion. As easily identified, those perceptions are closely correlated with the features found to predict inclusiveness.

2.2 ICT infrastructure and financial inclusion

The available research that delves into the nexus between ICT and inclusion does, however, indicate a positive correlation. Studies suggest a considerable enhancement in various macro-level indicators of FI, such as the distribution of bank accounts, number of accounts opened, deposits made and loans taken can be attained by expanding ICT infrastructure (Sanderson et al., 2018; Lenka & Barik, 2018; Andrianaivo & Kpodar, 2011; Chatterjee, 2020; Kouladoum et al., 2022). Interestingly, Evans (2018) finds the causal relationship that mobile phones and internet usage have on FI to be significantly uni directional.

The literature on the impact of ICT infrastructures on FI in the SSAn contexts is scarce. However, the studies made are aligned with the results found in literature on other regions in the world. Kouladoum et al. (2022) find digital technology indicators to have a significantly positive relationship with FI. Their results illustrate the effectiveness of increased usage of digital technology in giving regions where the majority of people have been excluded from the financial system a higher consumer rate with regards to financial services. Andrianaivo and Kpodar (2011) relationship between mobile usage and FI in Africa with regards to growth and found similar results. In a further discussion on the underlying mechanisms, they argue that higher mobile penetration makes access to deposits and loans easier, reduces the size of distance and time obstacles and paves way for improved information flows that simplifies information acquisition for both agents and principals.

2.3 Mobile Money Adoption and Effects

Mobile device deployment along with internet services are fundamental necessities in enabling MM diffusion (Della Peruta, 2018; Ozili, 2018). As much as the abundance of such resources could be regarded as valuable assets, the scarcity of them could be regarded as an absolute obstacle for MM adoption. Tobbin (2011), by looking at Ghanian examples, finds perceived ease of use and usefulness of the services to be the most crucial behavioral determinants of MM adoption. It is clear that sufficiently well-functioning infrastructure is the first need that has to be satisfied in order to be able to evaluate those terms. Ironically, with regards to the purpose of MM as an alternative to formal banking, a large fraction of the unbanked population, often living in remote areas, lack the access to well-functioning ICT infrastructure (Ozili, 2018; Salemink et al., 2017).

MM adoption rates cannot solely be explained by the existence of a user-friendly system. Other determinants pointed at in previous literature are trust in the service (Okello Candiya Bongomin & Ntayi, 2020), network externalities (Lepoutre & Oguntoye, 2018) and regulatory environment that is supportive of the service (Lashitew et al., 2019). Further, there have been findings that show that MM adoption is expected to be most palpable where access to banking services are low and where labor participation is high, giving an unsaturated need for transaction and payments services (Della Peruta, 2018). However, in countries with the lowest accessibility to banking services, MM operators do not get the required support and the population is too financially illiterate, obstructing adoption. More encouraging is that the same study finds promising indications on decreasing dependency of MM service on the banking system.

Despite not having been able to reach out to each corner of every region, the success of MM providers in helping excluded individuals and households with financial issues is a fact. Apart from broadly being referred to as an important factor in improving FI in general (Evans, 2018; Demirgüç-Kunt et al., 2015; Coulibaly, 2021; Maurer, 2012), examples on how adopting MM helps remote households are relatively well-documented. Studies made in Kenya and Uganda for example, show that MM usage makes people receive remittances more frequently and at a higher value (Munyegera & Matsumoto, 2016). This results in higher incomes (Kikulwe et al., 2014) and higher levels of consumption after negative shocks (Jack & Suri, 2014). According to Kikulwe et al. (2014), farmers become more financially active when using MM by applying more inputs. Ky et al. (2018) show that in Burkina Faso, people are more likely to save for unpredictable life events if using MM.

Finally, previous literature have been limited in the data available for 2021, that is necessary for investigating these relationships considering the recent advancements in MM and ICT. In March 2023, the World Bank FI Database released a new Findex dataset covering data on FI and MM for additional countries for the year 2021. To our best knowledge, this data has not been utilized before and there is a noticeable dearth of research addressing these years. Identifying this as an interesting gap in the existing literature, our research aims to bridge that gap.

3

Theory

This study explores the effect of the ICTs on FI and MM penetration in SSA. Though we will empirically examine the impact of the two specific ICT metrics, the following theoretical constructs provide important economic reasoning for the relationship under study. Previous literature has identified the most commonly self-perceived barriers that preclude FI. These barriers encompass the prohibitive costs associated with account opening, limited penetration of financial service providers, lack of funds and collateral, and absence of required documentation (Allen et al., 2016; Soumaré et al., 2016). Additionally, according to Allen et al. (2014), not only direct banking costs but also transaction costs, and in particular travel costs to financial institutions, are crucial barriers for FI. Furthermore, and not surprisingly, areas with low population density tend to have a less developed banking system.

We argue that reasonably, cost dynamics play a pivotal role in shaping the relationship between ICT and FI and MM penetration. Investigating these dynamics provides valuable insights into how we can effectively leverage ICT to enhance FI and drive economic development.

3.1 The role of transaction costs for the consumers

Our theory takes its starting point in conventional microeconomic rational choice theory, where people maximize utility, reflecting their preferences, subject to a resource constraint. We will consider the latter in broad terms, where exogenous resources equal the sum of prices times quantities of various goods, and where the prices do not only include monetary prices, but also transaction costs. According to

Perloff (2018, p.78), transaction costs can be defined as: "The expenses, over and above price of the product, of finding a trading partner and making a trade for the product. These costs include the time and money spent gathering information about the product's quality and finding someone with whom to trade. Other transaction costs include the costs of writing and enforcing a contract."

In our context, the costs that potential customers face are not only directly linked to the financial services such as collateral or service fees, but also transaction costs related to the time and money spent on participating in the institutional financial system. Since large parts of the populations in the Sub-Saharan African region live in rural areas, or in areas with a low level of bank penetration, it appears likely that the travel costs would be particularly high.

This theory proposes that digital banking services, and digital information and communication exchange, reduce the geographical barriers to financial institution, thus reduces travel costs for remote residents. Additionally, MM services provides flexibility by detaching banking activities from conventional banking hours. This allows individuals to participate without disrupting their work schedules, leading to time savings and consequently, reduced transaction costs. These platforms also allow cost comparison between financial services, fostering informed decision-making and potential cost savings for consumers.

Overall, assuming that FI is a normal good, reducing transaction costs by increased internet and mobile phone penetration would then imply the following hypothesis:

H1: Increased ICT penetration should cause increased FI (measured in the Financial Inclusion Index FII).

Moreover, we would for the same reasons expect the following hypothesis to hold:

H2: Increased ICT penetration should cause increased Mobile Money (MM) penetration, and thereby FI.

Increased penetration of Information and Communication technology would then contribute to FI both directly (H1) and indirectly through MM (H2) since accessibility is measured as if an individual has an account, where MM accounts is included. Theoretically, hypotheses 1 and 2 are stated in causal terms. It is however important to recognize the challenge of establishing causality, particularly in this situation where we are constrained by data limitations and the lack of a natural experiment. Despite these holdbacks, we attempt to approximate causality as close as we can by applying fixed effects models and using control variables.

3.2 The role of transaction costs for the financial institutions

Reduced transaction costs do not only affect the customers, but also the financial institutions, which maximize profits subject to cost constraints. Indeed, the financial institutions face a set of costs that directly impact the level and reach of the banking system. These costs include operational costs and risk-associated costs. The operational costs like the costs of establishing and maintaining physical branches and service points, can in low-income and rural areas be significantly higher due to lack of infrastructure, logistical challenges, and low population density.

The risk-associated costs are likely to be particularly large in low-income markets, due to low levels of financial literacy, deficiencies in formal identification systems, and inadequate credit history. These factors can amplify information asymmetry, and to handle this problem, financial firms must invest in screening and monitoring mechanisms, such as credit assessments, due diligence, and continuous loan monitoring. These processes, while crucial for risk management, significantly increase costs, transaction costs, and administrative overhead, affecting the profitability of lending operators.

Further in low-income and rural areas, official identification and personal information is often insufficient. According to Gelb and Clark (2013), almost half of the Sub-Saharan African population have not registered their births at an official institution. Having an official personal registration number or any sort of official documentation is crucial in the process for accessing institutional bank services.

There are two main channels through which ICT development and MM Innovations can change the dynamics of the financial market. First, the development of Information and Communication technologies will lead to a lower cost of information gathering for the banks. Second, most of the MM innovations offer a simpler and more agile solution that does not require bank branches and the same amount of documentation. Instead of visiting a bank branch to apply to open an account, one can instead attain a MM account by visiting the supermarket or a gas station and connecting their Subscriber Identity Mobile (SIM) card and phone number, which does not require an official personal registration number or other types of due diligence information.

In summary, digital operations and MM applications can enable streamlined processes that reduce the need for physical infrastructure. Internet and mobile technologies can automate routine tasks in traditional institutional financial services such as account management, transaction processing and customer identification, which lowers labor costs. Further, digital technologies can enable collection of data for analytics which can improve risk assessment and decision-making.

3.3 Network externalities

Finally, together with the mechanisms described above, it is reasonable to think that network externalities could have significant effects on the willingness to financial participation for both consumers and suppliers. This is not something that we will measure in our model, it is mechanisms that we believe will impact the relationship of interest.

Network externalities can be described as when the benefit or impact that consumers receive from a product or service tends to enhance further as the number of users, auxiliary products, or services expands (Katz & Shapiro, 1985).

One example of a network effect is the telephone network. The telephone network is a two-way network where individuals can interact with each other, then, each component can potentially form a unique pair with every other component, adding value to the system. Here we see it as the utility for agents increases as more individuals join the networks of internet, mobile phones and/or MM services. These effects, in turn, could potentially influence the state of FI in the Sub-Saharan African region. Prior studies have demonstrated that network externalities positively influence user experience and allegiance to social networking platforms, as well as contribute to enhanced consumer utility, perceptions, and adoption of internet-connected devices (Chiu et al., 2013; Hsu Lin, 2016). Moreover, network externalities have been identified as the primary catalyst in the acceptance of MM systems (Qasim Abu-Shanab, 2016). In summary, network externalities positively influence a user's intention to accept and utilize mobile telephone and internet networks.

In summary, the emergence of direct network externalities will, inter alia, lead to cost reduction and increased profit for firms as adoption increases because of economies of scale. In this thesis, we incorporate both mobile telephone networks and internet networks as integral components of the ICT-infrastructure and posit that network externalities will manifest within both of these networks and the utility will increase as more users join. The more ICT penetration increases, banks can reach more customers via communication on digital platforms without additional infrastructure costs, thus spreading fixed costs over an increased number of customers. Assuming that the direct network externalities result in a reduction of costs, it is plausible to posit that this condition paves the way for H1 (Increased ICT penetration, should cause increased FI.).

4

Data

In the following section, we present the data employed in his study, the general trend for our main variables and variation between countries, and an explanation of the data sources with a presentation of all the included indicators. We further justify the selection of our dependent variables measured in FII and MM, independent, control-and interaction variables and present descriptive statistics.

4.1 Data description

Data on the included components for the FII, and MM have been compiled from the Global Findex (2021), by The World Bank (Demirgüç-Kunt et al., 2021). The Global Findex 2021 database features FI and MM metrics generated from survey data that encompasses approximately 145,000 participants from 139 economies for 2014, 2017 and 2021. The data collection has been undertaken by Gallup, Inc., as a part of their Gallup World Poll. The Global Findex data collection has been based on face-to-face interviews, even if the Covid-19 pandemic led to a pivot towards phone interviews in some areas; this did not impact the countries involved in our study. Data on the penetration of mobile phone and internet, which we use to measure ICT penetration has been collected from the World Development Indicators from the World Bank.

To incorporate the quality of governance, we used data on the Rule of Law from the World Bank's Worldwide Governance Dataset. This resource provides governance aggregates for over 200 countries and territories, with a historical scope extending from 1996 to 2021. To gain further insight into rural and urban population dynamics, and income levels, we relied on estimates from the World Bank's World

Development Indicators Dataset.

Table 4.1: Variable list with data sources

Variable name (unit)	Proxy for	Type of variable	Source
Accounts (% among the population aged 15+)	FI	Dependent variable (part of FII) in model 1	Findex Database[1]
Made or received a digital payment (% among the population aged 15+)	FI	Dependent variable (part of FII) in model 1	Findex Database
Saved any money (% among the population aged 15+)	FI	Dependent variable (part of FII) in model 1	Findex Database
Borrowed any money (% among the population aged 15+)	FI	Dependent variable (part of FII) in model 1	Findex Database
Mobile money account (% among the population aged 15+)	Mobile money penetration	Dependent variable in model 2	Findex Database
Individuals using the internet (% of population)	Internet penetration	Main explanatory variable	World Development Indicators[2]
Mobile cellular subscriptions (per 100 people)	Mobile penetration	Main explanatory variable	World Development Indicators
GDP per capita, PPP (fixed $)	Income	Control variable	World Development Indicators
Rule of Law	Quality of governance	Control variable	Worldwide Governance Indicators[3]
Urban population (% of total population)	Urban population	Control variable	World Development indicators
Gini Coefficient	Economic inequality	Control variable	World Inequality Database[4]

[1] Demirgüç-Kunt, Asli, Leora Klapper, Dorothe, Singer, Saniya Ansar. 2022. The Global Findex Database 2021: FI, Digital Payments, and Resilience in the Age of COVID-19. Washington, DC: World Bank..

[2] World Bank. (2021). World Development Indicators. Retrieved from (https://datatopics.worldbank.org/world-development-indicators/)

[3] Worldwide Governance Indicators, https://databank.worldbank.org/source/worldwide-governance-indicators, last retrieved 2023-05-04

[4] https://wid.world/

* *Accounts (% aged 15+)* refer to the percentage of the population having an account at a financial institution or a MM account.

* *Made or received a digital payment (% aged 15+)* refers to the percentage of the population that report usage of a card, mobile or internet to make or receive a payment in the past year.

* The *Saved any money (% aged 15+) and Borrowed any money (% aged 15+)* variables refer to percentage of people that have done so by themselves or together with others from any source in the past year.

* *Mobile money accounts (% aged 15+)* refer to the percentage of the population that reports having used a MM account in the past year.

* *Individuals using the internet (per 100 people)* refers to individuals that have connected to the internet using a fixed or mobile network over the last three months.

* *Mobile cellular subscriptions (per 100 people)* refer to the number of people that report subscribing to a mobile telephone service that provides access to a public mobile network.

* Moving on to the control variables. We use *GDP per capita,* measured in dollars and adjusted for today's price levels.

* The *rule of law* variable captures each country's confidence in abiding the societal rules, including for example property rights, quality of courts and the likelihood of criminal activity.

* *Urban*, refers to the fraction of the population living in urban areas and the *Gini-coefficient* is a well-established income inequality measurement, ranging from 0 to 1, for which 0 is absolute equality and 1 is absolute inequality.

4.2 Dependent and independent variables

In model 1, the dependent variable of interest is FI. For measure it for each country, we constructed a Financial Inclusion Index FII. The FII generates a number between 0 and 1 where 0 is absolute exclusion and 1 is absolute inclusion. Our choice of indicators and method is inspired by Sarma (2008). The intention is to capture information on different dimensions to reduce risk of fall short on features that should be accounted for with respect to how FI is defined. The indicators examined are accessibility, noted $I_{a,i}$, and usage, noted $I_{u,i}$.

Accessibility is represented by the proxy *Accounts*. Having an account serves as the foundation for numerous financial transactions, enhancing the ease and security of managing and storing money. In line with Demirgüç-Kunt et al. (2015), we have used account ownership as our measurement for financial accessibility. This measure has been employed in previous scholarly work (Evans, 2018), thereby providing a robust and globally recognized indicator for FI. Further, *Usage* is represented by weighted average of the proxies *Made and received a digital payment, Borrowed any money, and Saved any money.* Due to lack of data, Sarma's availability dimension is not directly covered in the FII but indirectly through the other indicators. In line with Sarma (2008) we first compute an indicator index using the formula:

$$I_i = \frac{A_i - m_i}{M_i - m_i} \tag{4.1}$$

A_i represents the actual value, m_i represents the observed minimum value for the indicator and M_i represents the observed maximum value for the indicator.

Aiming at having an indicator for *usage* that covers different services that all are relevant to account for, we compute an index for all three of the proxies for *usage*. The average is given by the formula:

$$I_{u,i} = \frac{I_m + I_b + I_s}{3} \tag{4.2}$$

I_m is the proxy *Made and received a digital payment.*
I_b is the proxy *Borrowed any money.*
I_s is the proxy *Saved any money.*

The FII in our main analysis equally combines these two components: the accessibility and usage of financial services. To enhance the reliability of our findings and ensure that the results are not contingent upon the construction of the FII, we subjected our primary results to a robustness check.

As a component of this robustness check, we devised two alternative versions of the FII. The first version exclusively encompasses the *"accessibility"* dimension, attributing to it a full weight of 100%, while disregarding the *"usage"* dimension by weighting it 0%. The second version is composed solely of the *"usage"* dimension weighted 100%, and *"accessibility"* dimension is entirely omitted at 0% weight. These versions aim to scrutinize whether the observed associations in our primary analysis are sensitive to changes in the computation on the FII. The results will be presented later in results (chapter 6) and can be found in Appendix. Based on the tests, the choice was made to weight the two components equally.

The final formula for FII is:

$$FII_i = 1 - \frac{\sqrt{(1 - I_{a,i})^2 + (1 - I_{u,i})^2}}{\sqrt{2}} \tag{4.3}$$

Looking at the second component in the formula above, the numerator is the Euclidean distance of the indicators to their corresponding ideal ($I_i = 1$). The denominator is normalizing the distance and the subtraction makes it an inverse version. By normalizing it is made sure that the index is a number between 0 and 1 and the inverse distance makes the index correspond positively to FI.

4.3 Control variables

In our evaluation, we consider indicators that are likely to exhibit variation across the countries and have shifted within the considered timeline. This consideration aids us in developing a more robust understanding of potential causality. In line with previous literature (Allen et al., 2016), we believe that neglecting these macroeconomic, demographic, and socioeconomic variables, puts the analysis at a potential risk of bias. To circumvent this bias, our model aligns with existing literature by incorporating a set of these variables as control variables.

For capturing economic development, which could influence the level of FI through activity dynamics, *GDP per capita* has been included as a proxy. According to Sethi and Acharya (2018), the relationship between real per capita GDP and FI works in a uni-direction. Suggesting that economic growth can drive FI. Moreover, Allen et al. (2016) finds legal rights and political stability to be positively correlated with FI. Thus, we add *rule of law* as a control variable, controlling for quality of governance. The positive relationship between urbanization and FI referred to in the literature review is controlled for by the *urban* variable. Further, we find it interesting to control income inequality and include the Gini-coefficient.

By controlling these variables, we believe our model to better isolate the effect of ICT development and MM services on FI. This allows for a more accurate understanding of these relationships and provides more precise insights for conclusions.

4.4 Variable dispersion

Our analysis incorporates balanced cross section time series panel data from 24 SSA countries, covering the years 2014, 2017 and 2021. Given that the expansion of ICT and MM services in SSA predominantly transpired in recent years, data preceding previous years would be inadequate for the purposes of this study and likely contain numerous missing values. To the best of our knowledge, this is the initial application of this data, given that the information pertaining to 2021[1] has only recently been made available.

In the following figures we examine the development of the two ICT components included in this analysis - internet and mobile phones penetration. Additionally, we show the progression of MM penetration and FI. These box plots capture the degree of variation in these parameters across the examined countries and time. (See appendix section A.1 for explanation of box-plot calculations).

[1]Data for Botswana, Chad, Congo, Dem. Rep, Ethiopia, Mauritiana have not been included in previous datasets

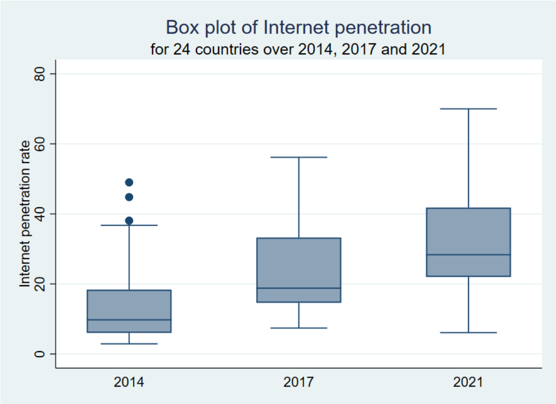

Figure 4.1: Internet penetration

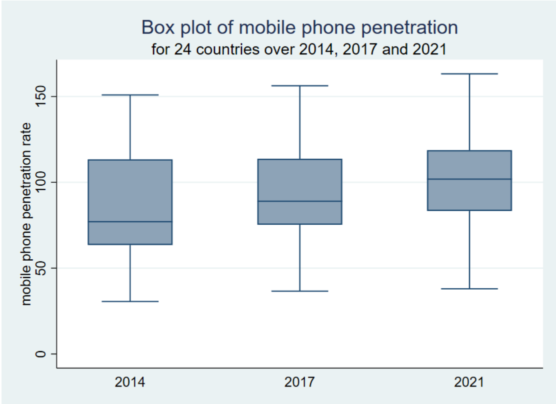

Figure 4.2: Mobile phone penetration

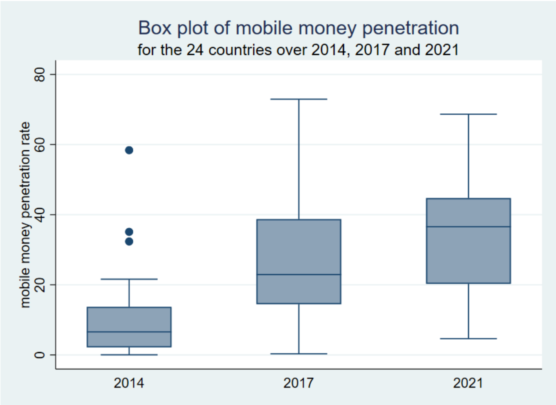

Figure 4.3: Mobile money penetration

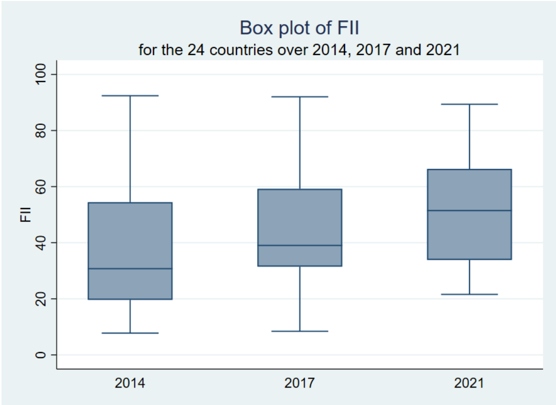

Figure 4.4: FII

The box plot statistics for internet penetration (Figure 4.1) across 2014, 2017 and 2021 illustrates considerable progress across the observed countries. In 2014, the median value was 9.75%, suggesting that countries on average in the region had limited access to internet services. By 2017, there was a rise to 18.8% reflecting improvement. By 2021, the median value had increased to 28.34%, showing continued development. Between 2014 and 2017 there was an increase in IQR, from 12.33% to 18.63%, implying some countries posing good development of internet penetration while others not seeing the same development. Between 2017 and 2021 the increase of IQR was not as substantial, changing from 18.63% to 19.8%. The top and bottom whiskers depicts the countries with lowest and highest internet penetration. From 2014 to 2021, the lower whisker rose slightly from 3% to 6%, showing development in countries that were lagging. The upper extreme, however, sharply increased from 37% to 70%, suggesting fast development in some countries. The large difference between the top and bottom whisker over all of the years indicates a high inequality in internet penetration among the countries.

The statistics for mobile phone penetration, (Figure 4.2) paints a different picture staying quite stable over the years, with some notable developments. In 2014 the median penetration rate was already quite high at 77.04%, and the rate changed going into 2017 at 88.97%. In 2021 the rate increased to 101.74%, indicating that on average, there was slightly more than one mobile connection per person across these countries. Between 2014 and 2017 the IQR decreased sharply from 49.89% to 37.73%, indicating an increase in mobile phone penetration equality. The IQR was only slightly decreased between 2017 and 2021 to 35.4%. Notable is that already in 2014 the 3rd quartile exceeded 100%, indicating that in at least 25% of the countries, people had more than one mobile phone, or in strict terms, more than one cellular subscription. As mentioned, we believe this to be explained by unreliable connectivity leading to people owning multiple subscriptions in order to avoid being out of reach in the event of no connection. The extreme values that the whiskers tell about stays stable over the years, where the lower ranges from 31% to 38% and the upper from 151% to 163%. This Confirms the continued rise in mobile phone penetration across the countries, including those with the highest and lowest rates, and a high variation.

MM penetration rates from 2014, 2017 and 2021 (Figure 4.3) shows a positive trend with increased penetration. The trend, however, indicates not just growth in penetration rates but also a shift in the dynamics of MM penetration across countries. The low median of 2014 was at a relatively nascent stage at only 6.56%. Continuing on-wards to 2017 a robust increase in the usage of MM to 22.91% was observed and in 2021 the median penetration rate had further increased to 36.56% showing that MM services had become more widespread. Like in the case of internet penetration, there was a sharp increase in IQR between 2014 and 2017 from 11.56% to 24.3%, reflecting the differing stages of MM uptakes across the countries. Between 2017 and 2021 the increase of IQR was not as substantial, changing from 24.3% to 24.46%. Looking at the whiskers, a broad spectrum of the distribution reflects the differing stages of MM uptakes across the countries, with the lower whisker standing at 0.1% and and the upper 22% respectively in 2014. In 2017 the least served countries showed a continued low level at 0.3%. At the same time, in some nations, the adoption rates were more noticeable, pushing the upper whisker to 73%. In 2021 the lower extreme had risen sharply to 4.6%, indicating a substantial growth in MM services even in the countries that were initially lagging. Interestingly, the lower whisker dipped slightly to 68.5%, suggesting possible slowdown in the countries that were early adopters.

The box plot statistics for the FII (Figure 4.4) across 2014, 2017 and 2021 illustrate considerable progress in FI across the observed countries. In 2014, the median index value was 30.74, suggesting that countries on average in the region had limited access to financial services. By 2017, this had risen to 39.03 reflecting some improvement. By 2021, the median value had increased to 51.46, showing continued progress. In 2014, the IQR was 34.83 reflecting a considerable variation in FI among the SSA countries. By 2017, the IQR narrowed to 27.74, and in 2021, it increased further to 32.46, indicating increasing diversification in FI rates. The extremes depict the most and least financially inclusive countries. From 2014 to 2021, the lower extreme rose from 8 to 22, showing development in countries that were lagging. The upper extreme, however, slightly decreased from 92 to 89, suggesting potential saturation in the most inclusive countries.

The data on our main variables, shown in the box plots, examines the variance in the FII, internet penetration, mobile phone penetration, and MM usage across the 24 included countries over the years 2014, 2017 and 2021. We argue that this data is a good fit for our analysis. The substantial variation in these datasets allows for the exploration of potential patterns, correlations, and trends. Moreover, the spread of the data examined by the IQR, and extremes shows the diverse range of penetration and inclusion rates across different countries.

4.5 Data preparation

In this setup, we are treating each country as its own unit for the cross-section part of the study, and each year represents a separate time period for the time-series part. For operationalization purposes, the data is arranged in long format[2].

The removal of 25 countries out of a total of 49 SSAn countries, was driven by the presence of inconsistent and limited data. The list of included and excluded countries can be found in table A.3 in the appendix. This decision was made to maintain the integrity, quality, and reliability of the analysis. Including countries with substantial missing or inconsistent data could have introduced bias or error into the study and potentially affected the validity of the findings.

The impact of removing 25 countries on the interpretation of the results should be considered with caution. By excluding these countries, the final analysis may not fully capture the variability or generalizability that would have been more present in the complete dataset of 49 countries. Therefore, the results of this study should be interpreted as being more applicable to the 24 countries included in the analysis, rather than for the entire SSA.

However, by focusing on a subset of countries with more comprehensive and consistent data, the study aims to provide a robust and meaningful analysis of the relationship and patterns under investigation. We still want to stress that the interpretations of the findings of this study, within the context of the 24 countries, should be done cautiously when extrapolating the results to the broader population of SSA.

[2]To utilize stata/SE17.0, data is arranged in long format. Each country and variable are assigned unique numeric identifiers. The dataset layout is such that individual rows represents separate time periods, and specific columns are dedicated to capturing observations for each variable in every year.

4.6 Descriptive statistics

Table 4.2: Descriptive Statistics

Variable	Obs.	Mean	Std. dev.	Min.	Max.
Accounts (%)	72	44.1765	21.2444	6.96	90.53
Made or received any digital payments (%)	72	37.6571	20.798	5.65	80.81
Borrowed any money (%)	72	51.40778	11.7612	28.62	86.13
Saved any money (%)	72	54.5694	9.98786	26.88	76.06
index_100	72	44.31032	22.19655	7.7643	92.41
mma_100	72	23.97616	18.6725	0.027895	72.93168
indinternet	72	24.73769	17.06689	2.9	70
mobcel	72	93.20971	32.76774	30.56741	163.191
loggdp	72	3.569509	0.353196	2.916145	4.345347
gini_100	72	60.97491	6.417211	49.45793	74.64855
rule_of_law	72	33.70726	20.15383	2.884615	79.32692
urban	72	43.94081	15.7761	18.998	90.092

4.7 Visualization of correlations

Before going into the econometric analysis, to provide an initial visualization of the correlation between our dependent and two independent variables in the two models, scatter plots are used. The purpose of the visualizations is to make a clear visual examination and understanding of the relationship between key variables and their convergence.

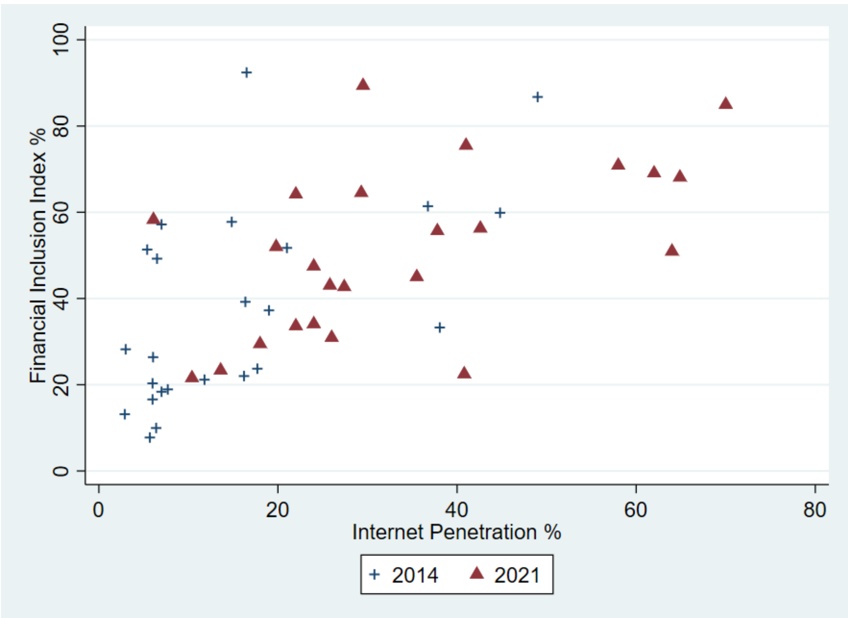

Figure 4.5: Correlation between FI and Internet penetration

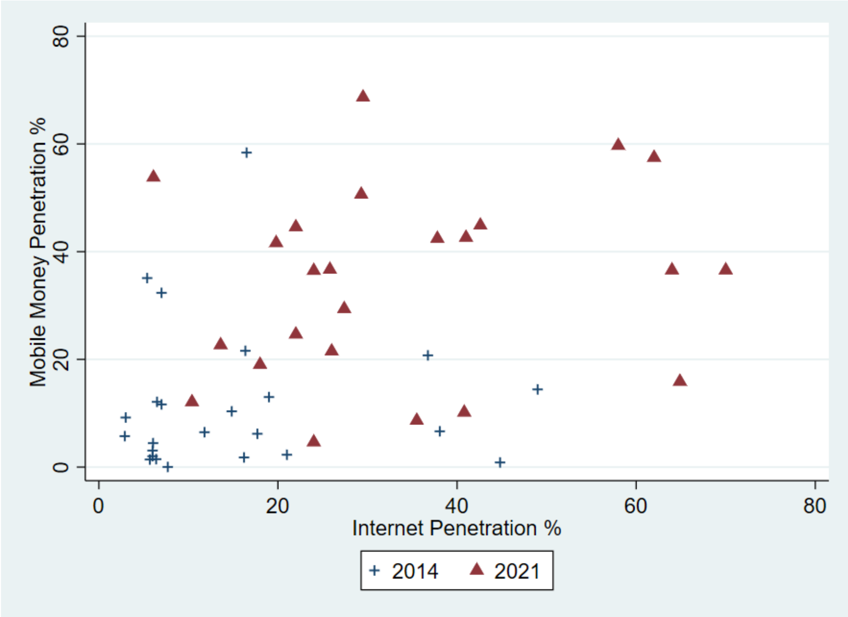

Figure 4.6: Correlation between Mobile Money penetration and Internet penetration

5

Methodology

To address the research question: *"Can ICT contribute significantly to FI, direct and indirect via the channel of mobile money?*, two uni-variate models are introduced. The two estimated models are executed as linear panel Ordinary Least Square (OLS) with time and country fixed effects (FE). The objective of applying the OLS methodology is to reduce the total squared errors, thereby accurately characterizing the relation between the variable of interest and the outcome variable. Using country and time fixed effects, the model enables country and time specific variables that are not included in the model to be controlled for. This makes it possible to do a within country analysis (Wooldridge, 2012, p. 485).

To achieve this level of control, it's essential that the influence of the country related omitted variables does not change over time but can vary between countries (like levels of democratization and geographical features), and the time related omitted variables can change over time but not between countries (global commodity prices, climate change and global technological progress). Therefore, all variables not included due to data scarcity, but still potentially impacting ICT penetration are instead assumed to change equally, or alternatively remain constant over time, in all countries. Examples of such variables are global technological advancements and the cost of expanding financial infrastructure.

For conducting a fixed effect analysis, a fundamentally crucial precondition is that the data must be in panel form and thus have cross-sectional and time dimensions. This is fulfilled when the same entities, here countries, are observed at the same points in time in contrast to an unbalanced dataset where observations are missing for one or more of the entities in one or more time periods (Wooldridge, 2012, p.

10). Data for each variable has been collected for every country in our sample for 2014, 2017 and 2021, which makes it a balanced panel dataset.

Further, to justify the fixed effect approach, the Hausman specification test has been included in order to test the null hypothesis that a random effects model would be preferable. By including the test we aim to control for correlation between the unique errors and the variables. If the p-value is less than 0.05 we will reject the null hypothesis and so the choice of the fixed effect approach is justified (Wooldridge, 2012, p. 496).

Additionally, the Likelihood-ratio-test has been included to determine if the model's predictive capacity improves when time dummy variables are incorporated (Wooldridge, 2012, p. 420). The Likelihood-ratio test will examine if the time periods are jointly significant and determine if the model will better predict the outcome variable when we account for potential changes over time. If the Likelihood-ratio test rejects the null hypothesis (p-value less than 0.05), including the time dummy variables in the model will significantly increase the explanatory power, however if we fail to reject the null hypothesis, the inclusion of time dummies does not significantly improve the model's fit. Although, there can still be theoretical reasons for including time dummies (Ibid p.818).

To account for the potential issue that our model may not meet a crucial assumption of regression analysis - the independence of standard error across observation - we implement Clustered Standard Errors (CSE). This approach, employed in Stata 17.0, also includes the execution of robust standard errors. Since our panel data set includes observation across both time and countries, observations might be correlated because of unobserved underlying factors. We aim to adjust for this correlation by adding CSE, which allows the errors to be clustered or correlated within each group but not between groups. This will help to adjust and prevent underestimation of the standard errors, which could lead to overestimated statistical significance and false positive findings (Cameron & Trivedi, 2005, p. 74).

5.1 Econometric models

In order to investigate our research question represented by H1 and H2:

H1. *Increased ICT penetration should cause increased FI.*

H2. *Increased ICT penetration should cause increased MM penetration, and thereby FI.*

Our analysis is divided into two main specifications with two different dependent variables. The first specification utilizes the FII as its dependent variable, aligning with hypothesis 1. The second specification employs MM penetration as its dependent variable, corresponding to H2. Both models are displayed with standard errors clustered by the variable $_{i,t}$, representing time and country, to control for the risk of errors being correlated between countries of observations and robust standard errors[1].

Model 1:

$$\begin{aligned} \mathrm{Y}_{i,t} = \lambda_i + \eta_t + \beta_1 \mathrm{Internet}_{t,i} + \beta_2 \mathrm{mobcel}_{i,t} + \beta_3 \mathrm{GDP}_{i,t} \\ + \beta_4 \mathrm{Gini}_{i,t} + \beta_5 \mathrm{RuleOfLaw}_{i,t} + \beta_6 \mathrm{Urban}_{i,t} + \epsilon_{i,t} \end{aligned} \tag{5.1}$$

Model 1 represents the final regression for the first model and shows the relationship between the degree of FI, measured in our developed index FII, denoted by FII, in country i at time period t where λ_i is the country specific intercept, η_t is the time specific intercept, β_1 is the parameter for the variable internet penetration named "Internet", β_2 is the parameter for the variable mobile phone penetration named "Mobile", β_3, β_4, β_5 and β_6 is the parameters for our included control variables GDP per capita, Gini coefficient, rule of law and urbanization rate. Last, $\epsilon_{i,t}$ is the clustered error term varying both across countries and time.

Given its inclusion of control variables, GDP, Gini-coefficient, Rule of Law and urbanization rate, that have been statistically significant in past research, Model 1

[1] Using "vce(cluster clustvar) in Stata 17.0, gives the clustered sandwich estimator which enables standard errors that are robust to both heteroskedasticity and within cluster correlation.

is anticipated to decrease a considerable proportion of the fluctuations in FI.

Model 2:

$$\begin{aligned} \text{MMA}_{i,t} = \delta_i + \theta_t + \beta_1 \text{Internet}_{t,i} + \beta_2 \text{mobcel}_{i,t} + \beta_3 \text{GDP}_{i,t} \\ + \beta_4 \text{Gini}_{i,t} + \beta_5 \text{RuleOfLaw}_{i,t} + \beta_6 \text{Urban}_{i,t} + \zeta_{i,t} \end{aligned} \tag{5.2}$$

Applying the same econometric methods, model 2 examines the relationship between the penetration of Mobile Money Accounts in country i at time period t where δ_i is the country specific intercept, the $_t$ term represents the isolated effects specific to each year, and $\zeta_{i,t}$ is the clustered error term. Same steps as in the first model have been applied so that country and time fixed effects have been added in steps, additionally the same control variables are also included since these are expected to have an impact on the penetration of Mobile Money Accounts. Based on the same argumentation as in model 1 including dummy variables and control variables, we aim to offer a more credible estimation of the relationship.

The first model corresponding to H1 aims to ascertain the impact of ICT penetration on FI in the SSA region. Further, the second model related to H2 investigates the effect of ICT penetration on Mobile Money penetration. The reason for the segregation of the two models is due to the fact that *MM accounts* are inherently incorporated within the broader term of FI. The factor *'Accessibility'* that is part of the FII, is too correlated (see appendix table A.4) with *Mobile Money accounts* and therefore, including *Mobile Money Accounts* as an explanatory variable would be statistically infeasible. Instead, MM accounts are part of the broader concept, FI. Previous literature has already found MM services to drive FI, instead this thesis tries to examine how ICT penetration affects this relationship.

Further, in both the first and second model, control variables for socio-economic, demographic, and governance-related factors are included since these are expected to affect the state and degree of FI from findings in previous literature (Allen et al., 2016; Sanderson et al., 2018; Soumaré et al., 2016; Abunga Akudugu, 2013; Zins & Weill, 2016)).

6

Results

6.1 Model 1

Table 6.1 presents the results from the Fixed Effect-regression related to the first hypothesis, H1: *Increased ICT penetration should cause increased FI.* Column 1 in table 6.1 gives the results for using only country Fixed Effects (FE), Column 2 shows the results on the same specification but where in addition time FE are included, and column 3 control variables are added to the country- and time FE.

Table 6.1: Model 1 corresponding to H1 (t-statistics in parenthesis)

FII	**1**	**2**	**3**
Internet	0.828*** (4.51)	0.846*** (3.62)	1.050*** (4.14)
Mobcel	-0.119 (-0.84)	-0.124 (-0.79)	-0.197 (-1.38)
gini_100	-	-	0.922 (1.36)
loggdp	-	-	17.007 (1.70)
rule_of_law	-	-	-0.119 (-0.33)
urban	-	-	-3.616** (-2.12)
2017	-	-1.140 (-0.35)	1.536 (0.43)
2021	-	-0.333 (-0.07)	5.682 (0.86)
Cons	34.933*** (3.26)	35.446** (2.62)	1.214 (0.01)
Observations	72	72	72
R-squared	0.472	0.475	0.544
Contry FE	x	x	x
Time FE		x	x
likelyhood-ratio		Prob > $\chi^2(2) = 0.85$	Prob > $\chi^2(4) = 0.03$
* $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$			

The parameter associated with *Internet* is consistently positive and statistically highly significant (at 1% or better), consistent with H1. Moreover, the parameter values are large. For example, the parameter value 1.050 in column 3 can be interpreted as the percentage points increase in the FII due to a one percentage point increase in the internet penetration, holding all other variables constant. These findings could imply that internet access has the capacity to mitigate financial service costs and reduce transaction costs, thereby facilitating greater financial inclusion among marginalized populations, especially those experiencing poverty. Network externalities could also contribute to the positive relationship as the utility from internet on information exchange increases as more individuals use it. This interpretation and reasoning on cost mechanisms aligns with findings and interpretations from previous literature (Andrianaivo & Kpodar, 2011; Evans, 2018; Okoroafor et al., 2018)

Surprisingly, and contrary to previous research (Andrianaivo & Kpodar, 2011; Evans, 2018) the results are not consistent with the second part of H1 corresponding to the mobile phone penetration, named *mobcel*. Indeed, the effects of mobile cellular subscription on FI are consistently insignificant, and even negative. This may seem counter intuitive, but a plausible interpretation is due to omitted variable bias, where the mechanism is as follows:

Despite the penetration of mobile phones, the ability to use them for financial services can remain limited due to lack of digital literacy, unreliable connections and other challenges related to scarce infrastructure. The lack of infrastructure and unreliable connections can in fact lead to individuals owning multiple cellular subscriptions (Aker & Mbiti, 2010; Rotberg & Aker, 2013). We can not include a variable that captures the effect of scarce mobile connectivity due to lack of data. Unfortunately, we believe this variable to be correlated with the variable *mobcel* which leads to an omitted variable bias. Alternatively, or as a complementary explanation, it is possible that there is a non linear relationship between mobile phone penetration and FI, which our linear regression model does not capture correctly.

As seen in column 2 in table 6.1, the results from adding time dummies for 2017 and 2021 did not align with the expected positive relationship. Instead, both coefficients are negative, indicating a non-monotonic time effect on FI, holding all other variables constant. However, neither of the two time-parameters are statistically significant, and the results do not provide reliable evidence of a negative effect in 2017 or 2021 relative to the baseline year of 2014. Moreover, from the Likelihood-ratio test we cannot reject the more restrictive model in column 1 in favor of the more general model in column 2. The negative sign merely implies that the time patterns was contrary to our expectations, but due to the statistical insignificance, no robust conclusions should be drawn. Several factors could explain the unexpected negative coefficients. It is plausible that unobserved factors that have negatively impacted the dependent variable over time were not fully captured by other covariates in the model. It may also be that the positive effect hypothesized is lagged and might appear in later years.

Further, when adding control variables, as seen in column 3, the coefficients are indeed in line with our initial expectations, in that they are both positive and larger for 2021 than for 2017. These results indicate a positive relationship between FI and time ceteris paribus, i.e., when accounting for the effects of the added controls and the fixed-effects variables. However, caution must still be applied when interpreting these results since they are still not significant, although the t-values have increased compared to the previous model.

When incorporating control variables into our FE regression, the coefficient for internet usage increases slightly and remains statistically highly significant. This supports that internet usage continues to have a robust and positive relationship with FI, even when accounting for other socioeconomic, demographic and institutional factors. The coefficient for mobile phone penetration in column 3 for the H1 model remains negative and statistically insignificant. It seems like controlling additional variables does not significantly change our previous observations regarding mobile phone penetration and FI.

Turning to our control variables, despite the positive correlation between *log(GDP-per-capita)* and FII, thus suggesting that increased GDP per capita contributes positively to financial inclusion, this relationship is not statistically significant within our model (albeit close to 10% level). The *Gini Coefficient*, representing income inequality, shows a positive relationship with FI, which is counter-intuitive, as one might expect a more equal distribution of income to promote FI ceteris paribus. However, this result is also not statistically significant.

The insignificant negative relationship between the level of rule of law and FI is also somewhat surprising and contradicts previous research (Park & Mercado, 2015). However, these studies have not included ICT indicators.

Surprisingly, the percentage of the population living in urban areas has a negative and statistically significant relationship with FI. This suggests that as urbanization rates increase, FI decreases, holding all other variables constant. There are different possible explanations, in addition to non-measured variables that are correlated with urbanization. For example, the negative relationship can be due to the fact that not all urbanization results in prosperity and inclusion, and therefore, not all urbanization fosters FI. While urban areas generally offer greater access to resources and services, including financial services, the reality can be complex. A crucial aspect to consider is that urbanization can lead to disparities within urban populations. While some individuals may experience upward mobility and access, others may find themselves socially excluded and poorly integrated in the urban society, leading to a stark divide in FI.

Moreover, here we can from the Likelihood-ratio test reject the more restrictive model in column 2 in favor of the more general model in column 3 (at 3% level). In conclusion, our expanded model reinforces the positive and significant impact of internet penetration on FI, while the negative but insignificant effect of mobile phone penetration persists.

6.2 Robustness tests on FII

Further, we want to add the results from the robustness tests on the FII. To test the validity of the construction of the two components, *accessibility* and *usage* was weighted 100% exclusively. The model emphasizing *usage* led to results that were in line with our initial findings, that the main independent variables remained significant and their relationship with the FII were consistent with our primary analysis. This suggests that our original findings are robust when considering the *usage* term of FI. The regression results can be found in the appendix in A.1 and A.2.

When emphasizing *accessibility*, the the corresponding parameter was slightly insignificant with a p-value of 0.065. While this is above the conventional threshold for statistical significance ($p < 0.05$), it is close enough to suggest a trend in the same direction as our initial findings. The minor deviation in p-value might be due to the change in weighting, emphasizing that our results depend somewhat on how we measure FI. These findings suggest that the influence of our main variables of FI is more robust when *usage* is emphasized. While *accessibility*-weighted model did show enough significance, the near-significant p-value indicates a similar trend. Hence, the robustness of the indicators make it reasonable to include them both in the FII.

6.3 Model 2

Moving on to model 2, in table 6.2 the results from the FE-regression related to the second hypothesis, H2: *Increased ICT penetration should cause increased MM penetration, and thereby FI*, is presented.

Column 4 gives the results on the main specification for H2 using only country FE. Column 5 shows the results on the same specification but where in addition time FE are included. In column 6 control variables are added to the country- and time FE

Table 6.2: Model 2 corresponding to H2(T-statistics in parenthesis)

MM penetration	**4**	**5**	**6**
Internet	1.191***	0.815***	0.867***
	(6.75)	(3.17)	(3.47)
Mobcel	-0.077	-0.127	-0.113
	(-0.57)	(-0.92)	(-0.93)
gini_100	-	-	0.402
			(0.48)
loggdp	-	-	-12.620
			(-1.21)
rule_of_law	-	-	-0.408
			(-1.37)
urban	-	-	-1.759
			(-1.22)
2017	-	7.210**	9.830***
		(2.75)	(2.95)
2021	-	9.043*	13.800**
		(1.96)	(2.19)
Cons	1.688	10.293	175.446
	(0.16)	(0.85)	(1.35)
Observations	72	72	72
R-squared	0.730	0.761	0.794
Contry FE	x	x	x
Time FE		x	x
likelyhood-ratio		Prob > $\chi^2(2) = 0.01$	Prob > $\chi^2(4) = 0.03$
* p < 0.1			
** p < 0.05			
*** p < 0.01			

In examining the effect of internet penetration on MM penetration, we find a robust and positive correlation that is statistically significant, even at the stringent 1% level in all columns. These findings are in harmony with H2 and previous research (Mothobi & Grzybowski, 2017). Furthermore, the magnitude of these coefficients is strong and non-trivial. As expected, the coefficient value of 1.19 in the model corresponding to column 4 signifies that for every one percentage point increase in the penetration of ICT infrastructure, the MM penetration is predicted to grow by 1.19 percentage points, ceteris paribus. This indicates that the internet plays a crucial role, significantly influencing the outcomes of both H1 and H2 in our economic model.

Our analysis posits that the mechanisms elucidated in H1 could extend to H2, with internet penetration influencing MM penetration. Further, online platforms, relying on the internet, streamline the process of MM transactions, making them faster and more efficient. They eliminate the need for physical infrastructure, thereby cutting overhead costs which makes them more affordable and thereby accessible, especially to individuals in lower income brackets. This outcome aligns with the existing literature that underscores the significant role of the internet in promoting MM usage, (Mothobi & Grzybowski, 2017), particular in areas with scarce accessibility to institutional financial services. Reliable and qualitative internet can then further strengthen the mobile based participation and therefore further reinforce FI through MM participation, as we expected in H2.

Once again, the results for mobile phone penetration are not in line with our expectations or previous findings on the relationship (Asongu, 2015). The implications of mobile cellular subscriptions on MM penetration exhibits a negative trend. This inverse correlation, akin to the one observed in H1, appears counter intuitive. However, we find the same mechanisms proposed in model 1, related to unreliable connectivity, could potentially explain this paradoxical outcome.

When introducing control variables as presented in Table 6, the coefficients related to the time-dummies align well with our initial prediction. They are both positive and exhibit larger values for 2021 as compared to 2017, even surpassing those in H1. These results signify a positive correlation between FI and time, ceteris paribus, that is, when controlling for the effects of the introduced controls and fixed effects variables. Unlike in H1, the time dummy variables are significant for both 2017 and 2021, with or without control variables. This underlines a positive time trend.

When we introduce control variables into our fixed effects regression, the coefficient for internet usage exhibits a slight decrease yet maintains a high level of statistical significance. This underscores the robust and positive correlation between internet usage and FI, even when adjusting for other socioeconomic and institutional determinants. Moreover, here we can from the Likelihood-ratio test reject the more restrictive model in column 4 in favor of the more general model in column 5 (at 1% level) and reject model in column 5 in favor of the model in column 6 (at a 1% level).

The socioeconomic and institutional control variables included in column 6, including log GDP per capita, Gini coefficient, rule of law and urbanization rate, all exhibit no statistical significance. Interestingly, the coefficient for the Gini index is somewhat less positive compared to H1. Moreover, the correlation between log-GDP per capita and MM is in H2 negative compared to the positive outcome in H1. The parameters for rule of law and urbanization continue to hold negative values as observed in Hypothesis 1. However, the insignificance of all these variables implies they do not exert a statistically significant influence on MM penetration.

Finally, our enhanced model further validates the strong, positive relationship between internet usage and MM adoption and at the same time a weak, insignificant negative effect of mobile phone penetration.
Our only consistently significant variable, internet penetration, has, as we expected, a considerable positive effect on both FI as well as MM penetration. This result stresses the importance of lowering information exchange costs for both traditional financial services but also for mobile banking.

6.4 Heterogeneity analysis with an interaction approach

Finally, we want to further justify our analysis by addressing the possible heterogeneity. The varying development in terms of ICT penetration rates, MM and FII, as examined in section 4.4, in SSA over the time period makes it plausible to think that the impact of the ICT development on our dependent variables might not be uniform across all countries. To capture this potential heterogeneity, we conducted an interaction analysis in our regression model. In this analysis, countries are categorized into two groups based on their level of ICT penetration: “high penetration” and “low penetration”, where high penetration defined as any penetration level above the mean.

In our interaction models, only one result stands out as statistically significant: the positive effect of high internet penetration on FI, showed in table 6.3. This suggests that, compared to countries with lower level of internet penetration, countries with high internet penetration have higher FI levels, on average, ceteris paribus. The interaction terms in all models were not statistically significant. This indicates that the effect of MM and internet penetration on both FI and MM does not significantly vary between countries with high and low levels of penetration.

This implication of these findings for our main model is firstly, that the lack of significance of the interaction effect suggests that our main model’s relationship are generally robust across different levels of mobile and internet penetration. Secondly, the significant positive effect of high internet penetration on FI underscores the importance of internet accessibility for FI in SSA.

In the following tables, the outputs from running the regressions with interaction variables are presented:

Table 6.3: High internet penetration on FII

	(1)
	index_100
highinternet	3.773*
	(2.33)
c.indinternet#c.highinternet	-0.0204
	(-1.75)
_cons	-42.26
	(-0.89)
N	72

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6.4: High internet penetration on MM

	(1)
	mma_100
highinternet	1.623
	(1.34)
c.indinternet#c.highint	-0.0042
	(-0.50)
_cons	-30.73
	(-0.85)
N	72

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6.5: High mobile penetration on FII

	(1)
	index_100
indinternet	1.349**
	(3.70)
c.mobcel#c.highmobcel	0.00257
	(1.02)
_cons	10.61
	(0.88)
N	72

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6.6: High mobile penetration on MM

	(1)
	mma_100
indinternet	1.028
	(2.03)
c.mobcel#c.highmobcel	0.00197
	(1.21)
_cons	-4.727
	(-0.57)
N	72

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

7

Conclusion

The purpose of this thesis was to examine if Information and Communication Technologies (ICT) can contribute to Financial Inclusion (FI) directly and indirect via the channel of Mobile Money (MM). We ponder upon the potential role of ICTs in bridging the gap for financially excluded individuals to participate in the financial system. Interestingly, our results highlight one key variable of interest, namely internet penetration, that shows substantial and positive influence on both FI and MM penetration, asserting its statistical significance.

We posit that within the SSA context, an upswing in internet adoption rates is likely to correlate with an enhancement in FI. This, in turn, would lead to a broader population gaining access to and making use of MM services, thereby fostering their inclusion within the digital-based financial ecosystem. Furthermore, our findings propose that the correlation is robust across the region and that it remains unaffected by other variables such as economic development, income inequality, urbanization rates and levels of rule of law. Additionally, our interaction analysis further strengthens these findings.

The effect of internet penetration in promoting FI is highly notable and could be applied broadly across diverse contexts. This universal applicability underscores its potential as an effective tool for FI. Thus, we assume that in line with what earlier research would suggest that internet connectivity can explain increased FI in SSA over the last decade.

Further, we draw the conclusion that the innovation of MM has been a key factor to why internet penetration has successfully dealt with the obstacles and costs in managing information exchange that have held people more financially excluded in the region relative to others. Increased internet penetration has extended the reach of MM services, creating financial opportunities for the unbanked population beyond traditional financial institutions. If this trend continues, MM innovation will further integrate into the SSA region's financial sector, supporting progress towards SDG 1(end poverty) and SDG 10(reduce inequality). MM, as a modern financial institution, is expected to reduce economic vulnerability for the SSA population.

Taking these establishments into consideration, there are a few suggestions on policy implications to put forth. In order to expand upon the occurred progress, the findings propose an economic environment that promotes MM development and greater access, quality and usage of internet. That includes a regulatory framework that fosters transparency and predictability making the products trustworthy which previous literature have highlighted (Allen et al., 2016). Further the same regulatory framework should inflate market efficacy regarding MM, making it worthwhile for both consumers and suppliers. Continuing, our findings speak for further investments and research in technological innovations that increase efficiency in managing financial services as well as in ICT infrastructure that can support such technologies and optimize the experience of the consumer.

While interpreting the findings of this thesis, several limitations have to be considered. First, as mentioned there are data limitations which is a fairly common problem in developing countries and within this research context. Having available data from 2014, 2017 and 2021 gives relatively few observations, however it is the best data available and some of the observations have never been used in previous research. Hence, the statistical power is reduced and lead to a decreased ability to capture trends and more difficulty in assessing temporal patterns impair the accuracy of estimating the variables.

Secondly, given that the population of interest is SSA, selection bias might be present. The decisions on countries to leave out of the study are based on lack of data. Add to that comprehensive data possible are associated with development in information based infrastructure. Hence, there is a risk for inadequate representativeness with regards to ICT infrastructure.

Thirdly, although conducting robustness tests and adding plausible control variables to the regression, the potential of omitted variables affecting the output has to be acknowledged. Because of data scarcity, demographic and economic variables such as employment rates, interest rates, poverty, education levels and literacy could not be examined. Being able to add those would have given more credibility to the findings mirroring the reality.

Fourth, due to the absence of a natural experiment, which would provide the most robust conditions for causality inference, we cannot in a strict sense assert causal relations between the variables of interest. However, we posit that the correlations observed between internet penetration, FI, and MM usage are likely reflective of causal relationships, as suggested by existing literature. For example, we find it plausible that FI initiatives could spur internet penetration. This potential mechanism, while merely speculative, could be large and impactful. Moreover, there could exist a dual relationship wherein these factors mutually reinforce each other's effects.

Taking on from the limitations of the study, future research suggestions become an appropriate last step. It is naive to overlook the fact that the data on this subject is far from optimally abundant. Future research could be dedicated to gathering more data and extending the examined time period. Such an initiative would be useful for impact evaluation and solidification of the state of causality including ICT, MM, and FI in SSA. Moving on, it is well-repeated in the previous literature about certain groups that are especially excluded. Rural-living, women, young people and unemployed are among those. It would be interesting to conduct a demographic analysis on what group of people are prone to use MM. Recall that one of the purposes of the services is to target the unbanked. By such an examination, the degree to which the innovations are intervening in the intended way could be evaluated.

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Graph box [Accessed: 2023-06-05]. (2023). https://www.stata.com/manuals/g-2graphbox.pdf

A

Appendix 1

Table A.1: Accessibility weighted index

	(1)	(2)
	fii_a_100	fii_u_100
indinternet	0.486	1.245***
	(1.94)	(4.00)
gini_100	0.688	0.722
	(0.71)	(1.08)
gdp	-0.00131	0.00162
	(-0.44)	(0.73)
rule_of_law	-0.321	0.106
	(-0.70)	(0.23)
2017.year	2.482	-7.002
	(0.67)	(-1.74)
2020.year	7.082	-13.07
	(1.23)	(-2.03)
_cons	3.950	-33.04
	(0.06)	(-0.73)
N	72	72

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A.2: Usage weighted index

	(1)
	fii_a_100
indinternet	0.486
	(1.94)
gini_100	0.688
	(0.71)
gdp	-0.00131
	(-0.44)
rule_of_law	-0.321
	(-0.70)
2017.year	2.482
	(0.67)
2020.year	7.082
	(1.23)
_cons	3.950
	(0.06)
N	72

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A.3: Sub-Saharan African Countries

Country	**Included**	**Excluded**
Angola		X
Benin	X	
Botswana	X	
Burkina Faso	X	
Burundi		X
Cabo Verde		X
Cameroon	X	
Central African Republic		X
Chad	X	
Comoros		X
Congo		X
Democratic Republic of the Congo	X	
Cote d'ivoire		X
Equatorial Guinea		X
Eritrea		X
Eswatini		X
Ethiopia	X	
Gabon	X	
Gambia		X
Ghana	X	
Guinea	X	
Guinea-Bissau		X
Kenya	X	
Lesotho		X
Liberia		X
Madagascar		X
Malawi		X
Mali	X	
Mauritania	X	
Mauritius	X	
Mozambique		X
Namibia	X	
Niger		X
Nigeria	X	
Rwanda		X
São Tomé and Príncipe		X
Senegal	X	
Seychelles		X
Sierra Leone	X	
Somalia		X
South Africa	X	
South Sudan		X
Sudan		X
Tanzania	X	
Togo	X	
Uganda	X	
Zambia	X	
Zimbabwe	X	

Table A.4: Correlation between "Accounts" and Mobile money

	acco_100	mma_100
accounts_100	1.00	
mma_100	0.6227	1.00

A.1 Box plot calculation

The information is presented in the form of quartiles, where the bottom of the box represents the 1st quartile(25% percentile), the middle bar represents the median or 2nd quartile (50% percentile) and the top of the box represents the 3rd quartile(75% percentile). The top and bottom whiskers are calculated by using the inter quartile distance (IQR). IQR is calculated by subtracting the value of the 1st quartile from the 3rd quartile (IQR $= Q_3 - Q_1$). The whiskers can be seen as fences, meaning that they apply a limit to what values can fall inside its range. The limit of the top whisker is $Q_3 + 1.5 \cdot \text{IQR}$ and the bottom $Q_1 - 1.5 \cdot \text{IQR}$. To calculate the value of the top respectively the bottom whisker: Let x represent a variable for which the whisker value are being calculated. Define x_i as the ith ordered value of x. Then define U as the limit for the top whisker, previously calculated and L for the lower. Then the upper whisker value is defined as x_i, such that $x_i \leq U$ and $x_{i+1} > U$. The the lower whisker value is defined as x_i, such that $x_i \geq L$ and $x_{i-1} < L$ (“Graph Box”, 2023). There is the potential that data-points does not fall inside the $1.5 \cdot \text{IQR}$ range. These are depicted as dots, and interpreted as outliers.

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