The Impact of Network Coverage on Adoption of Fintech Platforms and Financial Inclusion

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Abstract

We study the effect of mobile network coverage on adoption of financial technologies and financial inclusion. Using georeferenced survey data for nine sub-Saharan Africa countries combined with information on towers, we find that financial inclusion is positively influenced by coverage. We estimate that investment in Long-Term Evolution (LTE) towers to a radius of 2km per household would increase financial inclusion by 6% in Mozambique and 3% in Ghana, Rwanda and Senegal. In countries where mobile money is common, investment in Global System for Mobile Communications (GSM) and Universal Mobile Telecommunications System (UMTS) would have a larger impact on financial inclusion. We also find no gender disparities in digital financial inclusion. However, financial inclusion inequalities are still explained by differences in incomes, education level and location.

Key words: Digital finance, digital technologies, financial inclusion
JEL Classification: C18, D12, L11, L21, L22, L51

1. Introduction

Empirical research has shown that the Internet and the adoption of mobile phones have a remarkable impact on economic growth. Roller and Waverman (2001), Pohjola (2002) and Jalava and Pohjola (2002) identify a few potential mechanisms through which Internet and mobile phones, specifically smartphones, can stimulate economic growth. First, they accelerate productivity and innovation by improving access to information and reducing search costs. Second, they improve social well-being through increased social interaction (Jorgenson et al, 2008). In Africa, where more than 33 per cent of the population live in extreme poverty in remote areas and 36% are illiterate, the adoption of mobile phones and the Internet has the potential to serve as a virtual infrastructure for the provision of services that are generally not available to these vulnerable groups.

The proliferation of mobile devices has increased the adoption of digital services among remote-area dwellers and increased access to online education and programmes, health information, agricultural programmes and digital finance. The current study focuses on the role of investment in mobile network infrastructure for broadening access and the use of digital financial services in nine sub-Saharan African (SSA) countries, an area that is not critically addressed in the literature. Digital finance includes all financial services that are provided through mobile phones, personal computers, the Internet or cards linked to a reliable digital system. It encompasses a host of financial products and services delivered by fintech companies and innovative financial service providers, including mobile network providers, banks and finance-related software companies (Ozili, 2018). These platforms enable individuals and companies to have access to payments, savings and credit facilities without a need to visit a brick-and-mortar bank branch (Mothobi and Grzybowski, 2017).

Digital finance can increase the speed and reduce the cost of payments. It has also been found to enhance security due to increased transparency through digital accounting, and it can provide an entry point into the formal financial system while at the same time promoting increased saving and allow users to smooth consumption in the face of small adverse shocks (Demirgüç-Kunt et al, 2018). Digital financial services provide an opportunity to promote financial inclusion through innovative and cheaper platforms that link poor people with providers of savings, credit and insurance products (Radcliffe and Voorhies, 2012). In this context, financial inclusion means that individuals and businesses have access to affordable financial products and services: payments, transactions, savings, credit and insurance (Sarma and Pais, 2011). Digital finance platforms have opened doors for the poor, who were previously excluded from traditional financial systems, to have access to payment systems, savings and credit facilities via online and mobile phone financial services without the need to have a bank account or visit a bank branch (McKee et al, 2015).

These platforms can overcome the problem of poor infrastructure and expensive traditional banking models that rely on a network of physical branches. Despite the development of digital financial services, which provide the potential for improved financial inclusion, the banking sector in SSA remains underdeveloped. Based on a survey conducted by Research ICT Africa in 2017[1], only 29% of people in SSA countries have a bank account. This number is far below the average for developing countries worldwide.

The current study seeks to examine the effect of mobile network coverage on the adoption of digital financial technologies. In addition, the study aims to investigate how investments in network coverage might impact financial inclusion. Taking into consideration the differences in network technologies, where urban areas are more likely to have high-speed technology, the study contributes to the literature by providing insights on how different technologies are likely to drive financial inclusion. The current study differs from the existing literature in three ways. First, the study uses a two-stage procedure to account for sample selection in the adoption of financial technologies. Second, while the majority of the literature that studies the impact of technologies on financial inclusion focuses on the adoption of mobile phones, in this study we consider digital devices, including mobile phones, computers and access to the Internet as a virtual infrastructure for providing financial services and, finally, the study aims to investigate how different network technologies impact financial inclusion. Hence, this study is unique and provides an opportunity to disentangle how different technologies affect the adoption of financial services. The results obtained from this study can be generalized to other developing countries that have similar characteristics.

The results suggest that individuals who live near towers are more likely to own a digital device than those who live farther away. The results show that financial inclusion is positively influenced by mobile network coverage. Individuals who live near towers are more likely to adopt digital financial platforms. Our results further indicate that investment in Long-Term Evolution (LTE) towers to a radius of 2km per household would increase financial inclusion by 6% in Mozambique and 3% in Ghana, Rwanda and Senegal. However, in countries where mobile money is common, investment in Global System for Mobile Communications (GSM) and Universal

1 Research ICT Africa 2017 survey is a nationally representative survey conducted by Research ICT Africa in 10 African countries. The survey is publicly available and all documentation regarding the questionnaire and sampling methodologies can be accessed freely at https://www.datafirst.uct.ac.za/dataportal/index.php/catalog/765/related_materials

Mobile Telecommunications System (UMTS) would have a larger impact on financial inclusion than LTE. Our results also show that once the hurdle of device ownership has been overcome, gender disparities disappear. However, digital financial inclusion inequalities are still explained by differences in incomes, education level, location and employment status.

The remainder of the paper is organized as follows: In Section 2, we discuss the state of digital finance and financial inclusion in SSA countries, Section 3 reviews the literature while Section 4 discusses the data sets used in the paper. Section 5 introduces the econometric model and Section 6 presents the estimation results. Finally, Section 7 concludes.

2. Digital financial inclusion in Africa

Since 2011, new technologies, innovative business models and the number of banked individuals have continued to rise. Between 2011 and 2014, the number of individuals with a bank account increased by 700 million.[2] Data from the World Bank shows that as of 2017, 1.2 billion adults worldwide have been able to access an account since 2011. Today, 69% of adults have an account. However, 31 per cent of all adults worldwide are still unbanked, with most living in developing economies, where 46% of adults are unbanked, compared with just 6% of adults in high-income economies.[3]

The COVID-19 pandemic has amplified the urgency of utilizing fintech to keep financial systems functioning and keep people safe during a time of social distancing, falling demand, reduced input supply, tightening of credit conditions and rising uncertainty. While the digital platforms such as Internet banking are on the rise in developed countries, the use of Internet banking is still very low in Africa. This is mainly due to the low levels of Internet use in these countries. Only an elite of individuals who have access to the Internet can access these platforms, more specifically fintech services that are routed through the Internet. For example, less than a third (27%) of the population in Africa have this access. However, in contrast to African and Asian countries, Latin American countries have reached a critical mass, with about 75% of adults among the surveyed Latin American countries using the Internet. Among individuals who have access to the Internet in Africa, only a small proportion transact online via online stockvel[4] (8%), online betting (4%) and financial transaction with government (4%).

The most common form of digital finance in SSA is M-Pesa, which is a mobile money transfer and micro-financing service launched in 2007 by Vodafone in Kenya for the operators Safaricom and Vodacom. It enables users to transact using a mobile

2 https://documents.worldbank.org/en/publication/documentsreports/documentdetail/187761468179367706/theglobal-findex-database-2014-measuring-financial-inclusion-around-the-world

3 https://www.worldbank.org/en/topic/financialinclusion/overview

4 Online stockvel allows individuals or communities to pull their finances together for a common goal – commonly savings for burial societies and to insure against risks. Furthermore, online stockvel can be used for crowdsourcing.

account (referred to as a wallet) that is linked to a unique mobile phone number of a subscriber. It also allows accessing a wide range of services such as domestic and international money transactions, payments for bills, flights, hotels, and airtime top-up (see Morawczynski and Miscione, 2008). M-Pesa is most common in East African countries, such as Kenya, Uganda, Tanzania, Rwanda and Burundi, but it has expanded to other African countries such as Côte d'Ivoire, Senegal, Madagascar, Mali, Niger, Nigeria, Botswana, Cameroon and South Africa. Outside of Africa, M-Pesa operates in Afghanistan, Jordan and other countries. Several banks in Africa have also rolled out a similar service called e-wallet. E-wallet differs from M-Pesa in that it requires the sender to have a bank account even though the receiver can only withdraw cash from an ATM using their mobile phone number and a personal identification number (PIN), which is sent to their mobile phone. At present, mobile money supports electronic payments and airtime top up/transfers, mobile banking, digital lending, international remittances and fintech.

The introduction of digital platforms and, more specifically, mobile money services has contributed significantly to increased financial inclusion in developing countries. For example, Demirgüç-Kunt et al (2018) find that between 2014 and 2017, the share of adults who have an account with a financial institution or through a mobile phone rose globally from 62% to 69%. In high-income countries, 94% of adults have an account, while in developing economies 63% do. Based on the Research ICT Africa survey, financial inclusion rose from less than 20% in 2011 to more than 50% in 2017. The main reasons for the low levels of formal bank accounts in Africa are infrastructure deficits, inaccessibility and financial illiteracy (Mothobi and Grzybowski, 2017).

3. Literature review

The literature on financial inclusion is relatively new but growing rapidly (see, for example, Honohan, 2008; Demirgüç-Kunt and Klapper, 2012; Sarma, 2016). These studies have relied mostly on financial inclusion indexes. Honohan (2008), for example, provides a measure of financial inclusion by econometrically estimating the proportion of adult population/households using formal or semi-formal financial intermediaries for 162 countries. The estimates are constructed by combining information about the number of accounts held at commercial banks and at microfinance institutions together with banking depth and GDP data. These estimates might effectively quantify one aspect of financial inclusion, that is, financial penetration. Such a measure of financial inclusion, however, has many deficiencies as several crucial aspects of an inclusive financial system are ignored, including availability, affordability, quality and usage of the financial services that together form an inclusive financial system (Sarma, 2016). Furthermore, several studies have shown that merely having bank accounts may not be sufficient to imply financial inclusion if there are some barriers or limitations preventing people from adequately using the accounts, such as remoteness of bank branches, cost of transactions and psychological barriers (see, for example, Kempson et al, 2004; Diniz et al, 2012).

The second strand of literature concentrates on examining the determinants of financial inclusion (see, for example, Fungáčová and Weill, 2015; Allen et al, 2016; Zins and Weill, 2016). Based on the 2012 World Bank Global Findex Database on 98 developing countries, Demirgüç-Kunt et al (2013) find that gender matters for financial inclusion. The study shows evidence that a significant gender gap exists for account ownership, formal saving and formal credit. The likelihood of being financially excluded increases with being a woman. Zins and Weill (2016) performed probit estimations on the World Bank's Global Findex Database for 37 African countries. The empirical results indicate that male, richer, more educated, and older individuals, to a certain extent, are more likely to be financially included, with education and income having the most influence. Mobile banking and traditional banking basically have the same determinants.

However, these studies have failed to account for the remoteness of bank branches and cost of transactio. Allen et al (2016) also utilized the 2012 World Bank Global Findex Database to explore the individual and country characteristics associated with financial inclusion on a global scale. They find that greater financial inclusion is related to lower banking costs, greater proximity to financial intermediaries, and better institutions such as stronger legal rights and more politically stable environments. Furthermore, being richer, more educated, older, urban, employed, married or separated individuals are shown to be favourable characteristics for financial inclusion in terms of having an account at a formal financial institution. The same individual characteristics are also linked with the increased probability of saving formally. Finally, the probability of borrowing formally is higher for older, educated, richer and married men. However, the literature does not consider the effect of digitization and the availability of infrastructure on financial inclusion.

There is another growing body of literature that investigates how the adoption of mobile phones and M-Pesa have impacted financial inclusion in low-income countries. For example, Mbiti and Weil (2013) use two waves of individual-level data on financial access to analyse the use and economic impact of M-Pesa in Kenya. They find that accelerated use of M-Pesa lowers the propensity of people to use informal savings mechanisms, but raises the probability of being banked. While their results suggest that M-Pesa improves individual welfare by promoting banking and increased transfer, they find little evidence that people use M-Pesa accounts to store wealth. Jack et al (2013) also uses two waves of panel data for 3,000 households in Kenya to test transactional networks and whether M-Pesa users make different kinds of transactions. They conclude that households with M-Pesa users exhibit more remittance activity than those without. They also find that households that use M-Pesa are more likely to remit for routine support, credit and insurance purposes. They conclude that mobile money allows households to spread risk more efficiently through deeper financial integration and expanded informal networks.

Murendo et al (2018) assess the social network effects on mobile money adoption among rural households in Uganda. They find that mobile money is positively influenced by the size of social networks. In another paper, Munyegera and Matsumoto (2016) use panel data for 846 rural households to analyse adoption of mobile money, remittances and household welfare in Uganda. They find a positive and significant effect of mobile money access on household welfare. Similar to Jack et al (2013), they conclude that households that use mobile money are more likely to receive remittances than non-user households. They also find that the total value of remittances received by households that use mobile money is significantly higher than that of non-user households. Other studies focus on how the regulatory framework affects mobile money usage. Gutierrez and Singh (2013) used data for 37,000 individuals from 35 countries to analyse determinants of mobile banking usage, with a particular focus on the regulatory framework. They conclude that a supporting regulatory framework is associated with higher usage of mobile banking for the general public as well as for the unbanked.

Using a mixed-method approach to analyse the development and diffusion of mobile money innovations across and within countries, Lashitew et al (2019) find that a supportive regulatory framework played a key role in guiding innovations and accelerating mobile money diffusion in Kenya. Using a qualitative approach

Bourreau and Valletti (2015) assess the economic features of digital payment systems in developing countries. They conclude that mobile money has the potential to drive the financial inclusion of poor households at low cost.

The body of literature that analyses how the availability of infrastructure influences the adoption of mobile phones and mobile money services is scarce. Mothobi and Grzybowski (2017) combine a micro-level survey data for 11 African countries with night-time light intensity to assess the effect of infrastructure on the adoption of mobile phones and mobile money services. They find a positive and significant relationship between the adoption of mobile phones and the availability of infrastructure. Their results also show that individuals who live in areas with poor infrastructure are more likely to use mobile phones for financial transactions. They conclude that mobile phones improve the livelihood of individuals residing in remote areas. The current study contributes to this literature by analysing the effect of digitization on financial inclusion with a particular focus on examining how the availability of the Internet infrastructure and Internet use influence financial inclusion. Moreover, the study adds to existing literature by assessing how proximity to various network technologies influence financial inclusion. We use a non-binary measure of development to investigate how the availability of infrastructure influences the uptake of digital financial services.

Despite the importance of digital finance platforms, there is a very small body of literature that investigates the use and adoption of digital finance in developing countries. Most existing studies have focused on the use of mobile money services, with particular attention given to M-Pesa in Kenya, and some other East African countries (see, for example, Jack et al, 2013; Mbiti andWeil, 2013; Munyegera and Matsumoto, 2016). The literature that analyses the role of infrastructure availability on financial inclusion is very scarce but developing. The scarcity of this literature is mainly due to a lack of data that can measure the level of development at a micro level. Among the few studies, Mothobi and Grzybowski (2017) analyse how the level of infrastructure at the place of residence influences the adoption of mobile money. This research adds to this literature by analysing the effect of mobile network infrastructure on the adoption of digital platforms for financial transactions. For this analysis, non-binary measures of development are used to investigate how the availability of mobile network infrastructure influences financial technology services.

This study is motivated by a new and developing literature that investigates the role of infrastructure availability on the adoption of innovative financial services. A dominant theme in this literature is that individuals who live in areas with poor infrastructure rely on digital financial technologies to conduct financial transactions. For example, Mothobi and Grzybowski (2017) conclude that mobile phones have the potential to improve the livelihoods of people living in rural areas by providing them with access to financial services that are generally not available physically. In that sense, mobile networks have the potential to broaden financial services to areas that are not covered by physical bank branches. Perlman and Wechsler (2019) find that the adoption of digital financial services has improved financial inclusion in developing countries. These services are found to provide the unbanked and underserved with access to basic financial services. The examination of the availability of mobile network infrastructure, which is the focus of this paper, is an important contribution and offers new insights into how the availability of mobile network infrastructure may promote access to financial services and improve financial inclusion. In another paper, Grzybowski et al (2023) examine the effect of coverage on the adoption of mobile phones and mobile money, and conclude that mobile coverage increases the adoption of mobile phones and have a positive impact on financial inclusion. We deviate from Grzybowski et al (2023) by using a broader definition of financial technology services. In their paper, Grzybowski et al (2023) only consider non-Internet-based fintech services while the current study considers both Internet-based financial technologies and mobile money services.

This study contributes to the existing literature on mobile coverage and financial inclusion by using geo-referenced nationally representative survey data covering nine African countries: Ghana, Kenya, Mozambique, Nigeria, Rwanda, Senegal, South Africa, Tanzania and Uganda. We use GPS coordinates to match the survey data, which collects information on ICT access and use by households and individuals, to the GPS coordinates of towers. Using the coordinates, the Euclidean distance is then used to measure how far a household is to various infrastructural variables such as Global System Mobile (GSM) communication, Universal Mobile Telecommunication System (UMTS), Long Term Evolution (LTE) and other variables that measure the level of development in the location where a household is situated.[5]

The current study seeks to examine the effect of mobile network coverage on the adoption of financial technologies. Second, the study aims to investigate how investment in network coverage might impact financial inclusion. We use unique data constructed by combining a nationally representative household and individual survey for nine African countries with geo-referenced information for an inventory of network towers (LTE/4G, UMTS/3G). Using GPS coordinates, we calculate household distance from towers, major roads and other infrastructure.

5 UMTS is a third-generation mobile cellular system for networks based on the GSM standard, which supports 2G and 2.5G, while LTE can support 4G communication with better speed compared to UMTS. Thus, distance to tower is used to measure network coverage. Moreover, the data allows for differentiation of mobile network towers according to their ability to support different generations such as 2G, 3G and 4G networks.

4. Data

Data sources

In this paper, we combine a few different data sets to investigate the influence of availability on the adoption of digital finance technologies and financial inclusion. The first data set includes a set of representative individual and household surveys conducted in 2017 by Research ICT Africa in the following nine African countries: Ghana, Kenya, Mozambique, Nigeria, Rwanda, Senegal, South Africa, Tanzania and Uganda.[6]

Table 1 shows the number of individuals surveyed in each country and the share of mobile phone users. There are 4,554 individuals who declared having a bank account among a total of 12,778 survey respondents. Furthermore, 5,729 individuals used digital finance platforms such as mobile money, mobile banking and Internet banking for transactional purposes. The survey was conducted using electronic Android tablets and an external GPS device, which was used to capture the exact coordinates of the household. We use geographic coordinates to merge the survey data with the other data sets, including information on the availability of coverage and proximity to mobile network antennas. The second database, on cell tower location, was downloaded from OpenCelliD.[7] In addition to the exact geolocation of each cell, the date of creation and the kind of technology can be observed: GSM (2G), UMTS (3G) and LTE (4G). We only use antennas constructed before 2017 to ensure that individuals in our survey could use these antennas. For each household we calculate distance to the closest antenna of each technology.

6 There was also a pilot survey conducted a year earlier in Lesotho, which is not included in our analysis. For details on the representativeness, sampling and data collection see https://www.datafirst.uct.ac.za/dataportal/index.php/catalog/765

7 https://www.opencellid.org/downloads.php

Table 1: Adoption of digital devices and digital financial services

	Devices		Digital	Financial			
Country	Internet	Smartphone	Finance	Mobile money	Bank account	Credit card	N
Ghana	25.9%	25.8%	55.7%	51.6%	30.6%	8.0%	1196
Kenya	36.4%	33.6%	88.1%	80.5%	42.2%	19.9%	1216
Mozambique	20.3%	17.0%	25.2%	23.9%	24.4%	20.6%	1220
Nigeria	29.7%	16.5%	6.3%	2.5%	38.2%	31.0%	1804
Rwanda	14.2%	10.7%	34.2%	33.9%	32.7%	9.0%	1217
Senegal	32.0%	22.1%	35.3%	32.8%	10.6%	4.7%	1233
South Africa	45.7%	43.9%	21.3%	7.6%	57.2%	33.2%	1794
Tanzania	22.2%	20.3%	55.5%	55.4%	17.4%	10.6%	1200
Uganda	32.0%	13.2%	47.8%	47.8%	2.7%	6.8%	1855
Total	28.2%	22.8%	38.5%	34.80%	28.9%	17.0%	12735

Statistics

Table 1 presents information on the adoption of financial services, Internet use and smartphone adoption across the surveyed countries. The overall number of interviewed individuals in our sample is 12,735, with some variation across countries ranging from 1,196 in Ghana to 1,855 in Uganda. The level of bank account ownership among the sampled individuals is 28.9% of individuals, while 38.5% of individuals use digital financial platforms to conduct their financial transactions. In this paper, we define digital finance as the use of online services and mobile apps to access financial services without the need to visit a physical bank branch. In our sample, 34.8% use mobile money, and 17.0% have a credit card. Using mobile money, owning a bank account and owning a credit card are not mutually exclusive.

There are substantial differences in the usage of digital finance platforms and bank ownership across the surveyed countries. For example, South Africa has the largest proportion of individuals who own a bank account (57.2%) while only 21.3% use digital finance applications. In Kenya, the country with the second-largest proportion of individuals owning a bank account, 88.1% of surveyed individuals use digital finance apps to access financial services. The high uptake of digital finance in Kenya is attributed to the success of mobile money in this country, with 80.5% of the Kenyan population using mobile money to send, receive and save money. In South Africa, 43.9% of the population are smartphone users and 45.7% use the Internet. The lowest smartphone penetration was in Rwanda at 10.7%. With respect to usage of mobile money, Kenya is at the top (80.5%) followed by Tanzania (55.4%). More economically developed countries, Nigeria and South Africa, have the lowest share of mobile money users, 2.5% and 7.6%, respectively. As discussed earlier, this may be due to the relatively high penetration of bank accounts in South Africa (57.2%). Conversely, in Nigeria the very low usage can be attributed to regulation that meant initially only banks were allowed to provide mobile money services.

Table 2 shows that there are large differences in average distance to infrastructure by individuals from different countries in our sample. Coverage by mobile infrastructure is approximated by distance to antennas from different networks such as GSM, UMTS and LTE.

Table 2: Households' average distance to towers across countries

	Ghana	Kenya	Mozambique	Nigeria	Rwanda	Senegal	South Africa	Tanzania	Uganda	Total
Mobile										
GSM	4.15	1.48	10.78	3.95	2.83	1.33	1.98	8.91	5.87	4.48
UMTS	5.79	1.84	12.98	5.68	4.19	2.42	2.23	11.31	6.61	5.73
LTE	79.65	14.6	499.7	163.11	25.21	101.13	10.9	106.92	69.69	112.8

Table 3 compares the summary statistics for the control variables between users and non-users of digital financial technologies that we use in our estimation. The explanatory variables that we use in this study include gender, marital status, employment status, age group and income level. The statistics show that women are less likely to own a digital account while married people are more likely to own a digital account than those who are not married.

Table 3: Summary statistics

	(1) Full sample	(2) Digital account	(3) No digital account
Female	0.53 (0.49)	0.49 (0.50)	0.58 (0.49)
Married	0.50 (0.50)	0.52 (0.50)	0.48 (0.50)
Household size	4.11 (2.45)	3.77 (2.29)	4.49 (2.55)
No education	0.17 (0.37)	0.05 (0.22)	0.30 (0.46)
Employed	0.18 (0.38)	0.29 (0.45)	0.06 (0.23)
Self employed	0.29 (0.45)	0.30 (0.46)	0.28 (0.45)
House worker	0.17 (0.38)	0.11 (0.31)	0.24 (0.43)
Student	0.12 (0.33)	0.10 (0.29)	0.15 (0.36)
Retired	0.06 (0.23)	0.05 (0.21)	0.07 (0.25)
Own house	0.65 (0.48)	0.58 (0.49)	0.73 (0.44)
Own car	0.09 (0.29)	0.14 (0.35)	0.04 (0.20)
Motorbike	0.08 (0.27)	0.09 (0.28)	0.08 (0.26)
TV	0.53 (0.50)	0.66 (0.47)	0.37 (0.48)
Account	0.52 (0.50)		
Sample (N)	12735	6684	6051

Notes: mean coefficients; sd in parentheses, $*$ $p < 0.05$, $**$ $p < 0.01$, $***$ $p < 0.001$

In this paper, we consider individuals who live within a 2km radius to have full coverage. The coverage by these different networks is highly correlated, where approximately 66% of individuals in our sample live within 2km from a GSM tower, 64% from a UMTS tower and 21% from an LTE tower. There are large differences in coverage across countries, as shown in Table 4.

Table 4: Percentage of households within a 2km radius from a tower

Country	GSM	UMTS	LTE
Ghana	68%	71%	19%
Kenya	77%	66%	46%
Mozambique	58%	57%	0%
Nigeria	64%	67%	7%
Rwanda	61%	50%	14%
Senegal	83%	78%	12%
South Africa	74%	71%	47%
Tanzania	59%	53%	32%
Uganda	54%	58%	14%
Total	66%	64%	21%

5. Empirical model

Our empirical model has two decision stages. In the first stage, consumers are allowed to decide whether to have a digital device or not. In the second stage, those who had adopted a digital device are faced with two choices: use a digital financial service or not. Digital finance in this context implies the use of digital technologies for financial transactions. All individuals who use mobile money, online banking or mobile banking are assumed to have adopted digital financial services. Logically, as the usage of any of these financial services is related to the decision whether to have an account or not, the two-decision process should be jointly modelled.

We take this into account by estimating a selection correction model with two stages. We start by presenting a standard multinomial logit. The selection correction models based on the multinomial logit were developed by Lee (1983); Dubin and McFadden (1984); Dahl (2002) and, more recently, Bourguignon et al (2007), which is discussed below.

In our sample, there are some individuals who do not have a mobile phone and cannot use any of the financial services. We take this into account by estimating Heckman's sample selection model in two stages (see Heckman, 1979). In the first stage, we estimate a sample selection equation by means of a probit model:

$$y_i^* = \alpha X_i + \varepsilon_i \qquad (1)$$

where y_i^* takes a value of 1 for individuals having a mobile phone and 0 otherwise. The vector of estimated parameters is denoted by $\varphi = (\alpha, \sigma_\varepsilon)$. In the second stage, the modified usage equation is estimated for the sample of individuals with an account:

$$y_i = \alpha X_i + \beta Z_i + \sigma_{u\varepsilon}(X_i;\hat{\varphi}) + e_i \qquad (2)$$

In Equation 2, we use the fact that the error term ε_i can be decomposed into the sum of two terms, $\varepsilon_i = \sigma_\varepsilon \lambda(X_i, h_i, \hat{\varphi}) + e_i$, whereby construction e_i is mean zero conditional on $X_i X_i$. The hazard function (inverse Mills ratio), denoted by $\lambda(X_i, h_i, \hat{\varphi}) \lambda(X_i, h_i, \hat{\varphi})$, is computed using the first-stage probit estimates:

$$\lambda_i(N_i, W_i, h_i, \hat{\varphi}) = \frac{\phi(\ddot{\delta} Z_i)}{\Phi(\hat{\delta} Z_i)} \quad (3)$$

Heckman's selection model also needs to satisfy exclusion restrictions. We need at least one variable that determines the adoption of digital financial services and is included in X_i, but that does not impact the adoption of mobile phones and is not correlated with the error term e_i in usage Equation 2.

In the first stage we estimate the following equation:

$$device_i = \alpha X_i + \gamma_1 tower_{dist} + \epsilon_i \quad (4)$$

where $device_i$ takes the value of 1 for individuals owning any of the following: mobile phone, computer, laptop or Internet access, and 0 otherwise. $X_i X_i$ denotes a vector of individual and household characteristics such as gender, income, education, household access to electricity and household size. Our main variable of interest is availability of infrastructure measured by distance to tower ($tower_{dist}$), where distance to UMTS and GSM measures mobile coverage and distance to 4G/LTE towers measures the availability of Internet infrastructure. All the infrastructure variables are expected to have a negative effect on financial inclusion, implying that as distance away from mobile network towers increases the probability of an individual to be financially included declines. For the second stage the modified usage equation is estimated for the sample of individuals that have a mobile phone as follows:

$$DFS_i = \alpha X_i + \gamma_1 tower_{dist} + \beta Z_i + \sigma_{us} h(X_i; \hat{\varphi}) + e_i \quad (5)$$

where DFS_i denotes digital financial services and takes the value of 1 if an individual uses one of the digital financial technologies and 0 otherwise. Digital finance includes all individuals who use digital technologies to conduct financial transactions, such as Internet banking and mobile wallets (mobile banking and mobile money). All other variables are as per the definition in Equation 4. To identify the impact of investment in Internet infrastructure on financial inclusion, we conduct a counterfactual simulation. In the counterfactual simulation, we assume that the whole population lives within 2km of the towers of any of these networks (GSM, UMTS and LTE/4G), and assess the impact on financial inclusion and take-up of digital financial services.

6. Results

The estimation results of the effects of network coverage on financial inclusion are presented in Table 5. We estimate three Heckman probit model specifications. In the first stage, consumers decide whether to adopt a digital device or not. In the second stage, those who had adopted a digital device face a choice of deciding whether to use a digital financial platform or not. All the decisions are denoted as a 0–1 variable with a variable taking 1 if a consumer decides to adopt or 0 otherwise. We exclude computer ownership in the first-stage estimation to meet the Heckman exclusion criteria. In Table 5, columns 1 and 2, network coverage is measured by the Euclidean distance between a GSM tower and household, while in columns 3 and 4 coverage is measured by calculating the distance between a household and a UMTS tower. Finally, columns 5 and 6 presents the results of the effect of LTE coverage on financial inclusion using distance between households and LTE tower as a measure of coverage. The results are consistent across all specifications.

Table 5: Estimation results

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Variables	digital gsm	digital gsm	digital umts	digital umts	digital LTE	digital LTE
ln_gsm	-0.151***	-0.279***				
	(0.0375)	(0.0133)				
ln_umts			-0.153***	-0.250***		
			(0.0288)	(0.0118)		
ln_lte					-0.0378***	-0.125***
					(0.0145)	(0.00898)
female	-0.0403	-0.211***	-0.0517	-0.215***	-0.0215	-0.193***
	(0.0396)	(0.0271)	(0.0385)	(0.0272)	(0.0378)	(0.0269)
HHsize	-0.0100	-0.0149***	-0.0106	-0.0159***	-0.0110	-0.0165***
	(0.00751)	(0.00558)	(0.00750)	(0.00558)	(0.00752)	(0.00554)
employed	0.499***	0.663***	0.521***	0.666***	0.512***	0.717***
	(0.0703)	(0.0462)	(0.0637)	(0.0462)	(0.0706)	(0.0459)
self_ employed	0.163***	0.350***	0.185***	0.363***	0.157***	0.339***
	(0.0566)	(0.0338)	(0.0536)	(0.0338)	(0.0541)	(0.0334)
none	-0.668***	-0.835***	-0.719***	-0.840***	-0.668***	-0.886***
	(0.112)	(0.0366)	(0.0953)	(0.0365)	(0.110)	(0.0361)
student	0.255***	-0.406***	0.237***	-0.404***	0.281***	-0.362***
	(0.0691)	(0.0420)	(0.0679)	(0.0420)	(0.0648)	(0.0417)
retired	-0.217**	-0.225***	-0.225***	-0.217***	-0.200**	-0.195***
	(0.0860)	(0.0579)	(0.0849)	(0.0579)	(0.0848)	(0.0577)
laptop_comp	0.433***		0.427***		0.457***	
	(0.0529)		(0.0531)		(0.0526)	
car_ motorbike	0.165***	0.406***	0.172***	0.398***	0.161***	0.389***
	(0.0560)	(0.0416)	(0.0530)	(0.0416)	(0.0542)	(0.0409)
Constant	0.470***	1.254***	0.457***	1.260***	0.479***	1.416***
	(0.0789)	(0.0599)	(0.0775)	(0.0598)	(0.0781)	(0.0660)
Observations	12,650	12,650	12,650	12,650	12,650	12,650

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

After controlling for household and individual characteristics, we find a negative and significant relationship between distance to a mobile network tower and adoption of digital devices. That is, people who live in areas with mobile network coverage are more likely to own a digital device than those who live in households that are far away from towers. However, the results suggest that the effect of mobile network towers on adoption of a digital device varies significantly. In terms of magnitude, the results indicate that the GSM network infrastructure has a larger impact on digital device adoption than the UMTS and LTE networks. When controlling for UMTS coverage, the effects in Model 4 decrease only slightly from 0.279 in Model 2 to 0.250.

The effect of LTE coverage, presented in Model 6, is much smaller, almost half of the effect of UMTS coverage. Results obtained from the second stage suggest that individuals who live near towers are more likely to adopt digital financial platforms than those who live far away from network towers. In terms of magnitude, the results indicate that GSM and UMTS coverage has a larger impact on the adoption of digital financial platforms than LTE. To illustrate this, the latter finding suggests that GSM and UMTS are the main drivers of financial inclusion, especially among those who are generally excluded. It can also be discerned from this finding that non-Internet-based digital financial services such as mobile money are the main drivers of financial inclusion in SSA countries. These results suggest that high investment in coverage, especially in rural areas, is more likely to increase access to digital financial services to those who were previously excluded. That is, policy makers can leverage mobile network coverage to expand access to financial services.

The results also show that while there is a persistent inequality between male and female across all specifications in adopting digital devices, there is no significant difference in the adoption of digital financial technologies. While our results are consistent with the existing literature in terms of inequalities in digital device ownership, our results indicate that once the digital device ownership hurdle has been overcome gender disparities disappear. This finding does not support the conclusion of Demirgüç-Kunt et al (2013) and Zins and Weill (2016), who stated that males are more likely to be financially included than females. Moreover, the results indicate that individuals who have no form of education are more likely to use digital financial services than those who have some form of education.

Consistent with the findings of Bourreau and Valletti (2015) and Mothobi and Grzybowski (2017), our results suggest that digital financial services have the potential to drive financial inclusion among poor households and individuals. As per the conclusion of Mothobi and Grzybowski (2017), it can also be inferred from this finding that digital financial services act as a substitute among the poor and as a complement to those who are already included. Furthermore, it can be concluded that digital financial services, more specifically mobile money, are seen as inferior goods among the educated. This finding could be attributed to the fact that the most common digital financial service in SSA is a mobile money platform.

Our results remain robust under different specifications. Conversely, the study shows a positive and significant relationship between digital financial services and employment, with an employed individual more likely to adopt a digital financial service than those who are not employed. The results also indicate that employment is a significant determinant of digital device ownership. In addition, we show a positive and significant relationship between students and digital finance account ownership.

We also find that income is a significant determinant of usage of digital financial platforms. That is, as income increases, the probability of adopting digital financial platforms increases. Given the fact that there are several studies that show that the probability of bank account ownership increases with an increase in individual income, we can infer that digital financial platforms act as complements to a bank account.

Regarding other individual and household characteristics, we find no significant relationship between household size and the adoption of digital financial platforms. However, the results from the first-stage estimation show that individuals who live in larger households are less likely to own a digital device than those who live in smaller households. Conversely, individuals who live in households that own a car or a motorbike are more likely to use a digital financial platform than those who do not. These results are a further indication of inequalities that exist in the financial inclusion space, with individuals who live in poor households less likely to included. Consistent with the findings of Demirgüç-Kunt et al (2013) and Zins and Weill (2016), our results also indicate that digital technologies exacerbate historical inequalities and are determined by wealth, education and employment status.

In Table 6, we present the results obtained from counterfactual simulations. When analysing the impact of mobile coverage on financial inclusion, it is important to identify whether the choice of placement of towers are an outcome of a historical phenomenon or a commercial choice. For example, if the placement is a commercial choice, it implies that mobile network operators will only consider developed areas and, hence, there is likely to be a directional relationship between distance to towers and financial inclusion. However, in our context, we argue that our results are less likely to be biased as the placement of towers is not only an outcome of a commercial choice, but government and regulators also intervene to ensure universal access via universal service funds.

We consider that the whole population lives within a 2km radius of these networks. We find that in such a scenario, the adoption of digital finance platforms would increase by 2% on average. Our results indicate that investment in the LTE network would have a much larger effect on financial inclusion than investing in GSM and UMTS. Where the whole population resides within a radius of 2km from an LTE tower, financial inclusion will increase by 6% in Mozambique and 3% in Ghana, Rwanda and Senegal. However, investment in GSM and UMTS towers will only increase financial inclusion by 1%–2% and 0%–3%, respectively.

Table 6: Estimation results

	(1)	(2)	(3)
	Full sample	Digital account	No digital account
Female	0.53 (0.49)	0.49 (0.50)	0.58 (0.49)
Married	0.50 (0.50)	0.52 (0.50)	0.48 (0.50)
Household size	4.11 (2.45)	3.77 (2.29)	4.49 (2.55)
No education	0.17 (0.37)	0.05 (0.22)	0.30 (0.46)
Employed	0.18 (0.38)	0.29 (0.45)	0.06 (0.23)
Self-employed	0.29 (0.45)	0.30 (0.46)	0.28 (0.45)
House worker	0.17 (0.38)	0.11 (0.31)	0.24 (0.43)
Student	0.12 (0.33)	0.10 (0.29)	0.15 (0.36)
Retired	0.06 (0.23)	0.05 (0.21)	0.07 (0.25)
Own house	0.65 (0.48)	0.58 (0.49)	0.73 (0.44)
Own car	0.09 (0.29)	0.14 (0.35)	0.04 (0.20)
Motorbike	0.08 (0.27)	0.09 (0.28)	0.08 (0.26)
TV	0.53 (0.50)	0.66 (0.47)	0.37 (0.48)
Account	0.52 (0.50)		
Sample (N)	12735	6684	6051

In Tanzania, our results indicate that investment in GSM and UMTS would have a larger effect than investment in LTE towers. The varying effects on investment in coverage can be attributed to varying financial infrastructures across these countries. For example, in some countries such as Kenya, Tanzania and Uganda digital financial technologies are mobile-network based and often run on GSM and UMTS networks, while in Southern African countries, South Africa and Mozambique, financial technologies are bank-led and often require the Internet to operate. Conversely, the effect of network coverage in Nigeria is very minimal despite the majority of Nigerians not being financially excluded. This can be attributed to the disabling regulatory environment that requires individuals to have a bank account to use financial technologies such as mobile money. Our results emphasize the role of investment in network coverage, especially in rural areas, for improving access to services that are usually not available to the poor. To the best of our knowledge, this is the first study that uses very detailed individual-level data for a number of African countries, with geolocation information combined with detailed geographical data on infrastructure coverage.

7. Conclusion

In this paper, we analysed how the proximity to mobile network infrastructure impacts the decision to adopt digital devices and to use digital financial services. This was done using rich data from a survey of 12,735 individuals that was conducted in 2017 in nine SSA countries: Ghana, Kenya, Mozambique, Nigeria, Rwanda, Senegal, South Africa, Tanzania and Uganda. The survey data was combined with detailed information on the proximity of physical infrastructure using information on the geolocation of respondents. We approximated coverage using distance from the household location to mobile towers of the GSM, UMTS and LTE networks.

We estimated a two-stage model where, in the first stage, consumers make the decision to adopt a digital device. In the second stage, they decide whether to use digital financial services. We found that network coverage has a significant impact on the decision to adopt a mobile phone. Individuals who live within a 2km radius from GSM, UMTS and LTE towers are more likely to adopt a mobile phone. Conversely, results from the second-stage estimation show that UMTS and GSM coverage has a larger impact on the use of digital financial services than LTE networks.

After considering both individual and household characteristics, we found substantial gender disparities in digital device ownership, but once this hurdle had been overcome the gender disparity in digital financial inclusion disappears. However, the study shows that even after adopting a mobile phone wealth, employment and education are the main determinants of digital financial inclusion. The results show that the educated, wealthy and employed are more likely to be digitally financially included than the non-educated, the poor and the unemployed.

Conversely, the results suggest that digital financial services act as a complement to the wealthy, educated and employed individuals, and act as a substitute to those who were previously marginalized and could not access formal financial services. The results are a further indication that mobile money, which does not necessarily require a user to have access to Internet, is the most common driver of financial inclusion in SSA.

In counterfactual simulations, we considered that the whole population lives within a 2km radius from any of these networks. Here we found that the adoption of digital financial services would increase by 0%–6% depending on country and network. We found that investment in LTE coverage would have a larger impact in Mozambique, Ghana, Rwanda and Senegal. Conversely, in some countries such as

Tanzania, investment in GSM and UMTS coverage would increase financial inclusion by a larger margin than LTE coverage. This outcome can be attributed to the differing financial market structures across these countries. For example, in South Africa and Mozambique most of the financial innovation is bank-led and operated on an LTE network, while in most of the East African countries financial innovations are mobile phone-network led and often run on GSM and UMTS networks. Despite the differing effects, our results are an indication of the importance of investment in network coverage to reduce financial exclusion and digital inequality in African countries.

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