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Determinants of Mobile Broadband Use in Developing Economies: Evidence from Sub-Saharan Africa

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Abstract

Broadband is seen as a vector of economic growth and social development. In the developing world, mobile technologies are widely adopted and mobile broadband is progressively rolled-out with high expectations on its impact on the countries' development. We highlight what the determinants of mobile broadband use are in four Sub-Saharan countries. Using micro-level data coming from household surveys over 5 years, from 2013 to 2017, we show that the ownership of a mobile phone is highly correlated with mobile broadband use. We also show that for non-mobile owners, the ownership of an active SIM card is a prerequisite for using mobile broadband. In addition, mobile money users tend to be more likely to use mobile broadband. This could highlight the existence of a learning effect. By using mobile money services, individuals gain more experience and are more inclined to use more advanced technologies, such as mobile broadband. Although we show that mobile broadband use is increasingly growing, a large part of the population, mainly composed of poor households living in rural areas, is still left behind. This raises concerns on the increase of the digital gap between people and territories.

Key Words: *Mobile Broadband Use; Developing Economy; Economic Growth; Inequality; Digital Gap.*

JEL Classification: I30, O12, L50, L96, O55.

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1 Introduction

Developing economies, especially in Sub-Saharan Africa, have become a new El Dorado for telecommunication operators. With their flourishing and dynamic markets, they show promising prospects in terms of return on investment. The mobile telecommunication market is booming, the young generation is getting more and more connected and the digitalization of the society is on the priority list of governments.

Broadband technologies have been praised worldwide to be key drivers of economic growth and social development. To ensure that the economic and social benefits stemming from these new technologies will spread out into their national economy, many countries have adopted broadband plans. Developing economies are no exceptions. Through the definition of these broadband plans they set ambitious targets in terms of network deployment and coverage.¹ However, very little is said on the demand-side. It is the role of a public authority to ensure that the supply-side effectively deploys the technology throughout the territory. But it is also its role to ensure that the technology is adopted or used by the population. That could be done by the implementation of demand-stimulation policies. The benefits expected from these new technologies will only materialize if there is a demand.

The contribution of this paper is to highlight what the determinants of mobile broadband use are in emerging economies. We provide policy makers with tools to ensure that the coverage of their territory with next generation mobile technologies is followed by their use and adoption by households. Developing economies bear their own specificities and cannot be compared to western economies. An understanding of these mechanisms would greatly help policy makers to ensure not only the complete coverage of their territories but also the uptake of mobile broadband by the population.

The analysis is performed using micro-level data coming from household surveys in four Sub-Saharan countries, namely Nigeria, Kenya, Tanzania and Uganda, over 5 years, from 2013 to 2017. These countries are good candidates for this analysis as they are representative of post-colonial and developing countries which attract foreign direct investment, especially in the telecommunication sector. They also convey a fairly exhaustive picture of the state of technology adoption in developing economies. Nigeria and Kenya have similar profiles. They are the most developed with a higher rate of mobile phone and SIM card ownership. While Uganda is the least penetrated country, with a large proportion of non-mobile owners and non-SIM card owners. In Tanzania, more than two third of our sample owns a mobile device, but slightly more than half owns a SIM card. Access to both mobile devices and SIM cards are much more pronounced in Tanzania and especially in Uganda.

¹National broadband plans:

For Kenya: The national broadband strategy: Kenya vision 2030, 2013.

For Nigeria: The national broadband plan 2013, now version 2018.

For Tanzania: National Information Communication and Technology Broadband Backbone (NICTBB), 2014.

For Uganda: Draft National Broadband Strategy 2016-2020, date of the version unknown.

Nigeria is a lower middle income country and one of the leading economies in Africa. But it still shares the characteristics of developing countries with (low-scale) agriculture being a key sector of the economy, a dependency on export of primary commodities, a fairly low income per capita and a high poverty rate.² Kenya, Tanzania and Uganda share similar economics characteristics but differ in terms of development level, poverty rate, government's stability, land property rights, easiness of conducting a business or presence of essential infrastructures. Kenya is seen as an example in all developing countries with regards to mobile market development and especially the uptake of mobile money services. Tanzania and Uganda are lower income economies. The telecommunication market is thriving in these countries but in a lower state of development. Having these four countries into the analysis allow us to strengthen the generalization of our results for developing economies worldwide.

We highlight that the digital divide perpetuates and is reinforced with the introduction of new information and communication technologies. Indeed, we show that the ownership of a mobile phone is an important driver of mobile broadband use. In developing economies, it is not rare to encounter people not owning their own mobile device, but using the one of someone else. We highlight that for those not owning their own device, the ownership of an active SIM card is a prerequisite for using mobile broadband. Thus, those who are excluded from mobile technologies are also excluded from mobile broadband adoption. Moreover, we show that mobile money use has a positive effect on mobile data use. Once again, those who do not use it are excluded from mobile internet adoption. This raises alarming concerns over a potential increase of inequalities, as we also highlight that the population left behind is mostly composed of lower-income households, households living in rural areas and women.

These results have strong policy implications. A first step in order to encourage the use of mobile broadband technologies and allow the most vulnerable to reap the expected benefits of this technology would be to facilitate access to mobile phones, SIM cards, as well as mobile financial services. We also argue that filling the digital gap requires more intense investments in mobile network coverage.

The remainder of the paper is organized as follows. Section 2 discusses the relevant literature on the mobile technology on economic growth and deployment. Section 3 provides an overview of the Nigerian telecommunication sector. Section 4 presents the data while Section 5 introduces the econometric framework. Section 6 presents the estimation results. Finally, Section 7 concludes.

²See the World Bank in Nigeria Report, last available for 2018.

2 Literature Review

Political institutions are deeply linked with growth and economic development, with a long-lasting influence over time (Michalopoulos & Papaioannou, 2013). Political instability, common in sub-Saharan Africa, causes major harms to growth (Fosu, 1992). In particular, countries with important natural resources, which were intensively extracted during colonial times face today a higher growth volatility, which may come from institutional fragility (Acemoglu, Johnson, Robinson, & Thaicharoen, 2003). Economic institutions also have a strong positive impact on economic growth (Acemoglu, Johnson, & Robinson, 2002; Acemoglu & Robinson, 2010), and countries with, for instance, weak property rights face lower growth and higher volatility.

The impacts of macroeconomic and institutional factors on ICTs adoption in sub-Saharan Africa have also been well established in the literature. For instance mobile phone penetration has a positive effect on the reduction of poverty in Africa (S. Asongu, 2015), on financial development (S. A. Asongu, 2013), as well as on entrepreneurship (S. A. Asongu, Nwachukwu, & Orim, 2018). However, because of its novelty, mobile broadband has yet not been studied in depth, despite the fact that its positive effects should be higher than fixed broadband (Thompson Jr & Garbacz, 2011). We review here the literature on ICT adoption, uses and impacts, and how they change depending on macroeconomic and institutional factors.

2.1 Institutions and ICT

Billon, Marco, and Lera-Lopez (2009) and Kiessling (2007) highlight that institutional factors such as government effectiveness have a strong impact on the adoption of ICT. Formal institutions drive ICT adoption in particular in sub-Saharan Africa, with government effectiveness having the largest positive effects (S. A. Asongu & Nwachukwu, 2016b), as well as regulation quality (S. A. Asongu, 2018). Moreover, S. A. Asongu and Nwachukwu (2016a) find reversely a positive effect of mobile phone on the quality of institutions. Similarly, positive effects of growth on ICT and reversely are commonly found in the literature.³ Thus, enhancing mobile phone penetration would foster a snowball effect.

Focusing on Internet, regulation of entry is found to have negative effect on penetration, and price regulation a positive effect on prices in developing economies (Wallsten, 2005). These results support the idea that countries regulatory decisions can have a strong impact on Internet penetration. The vital importance of infrastructure is also emphasized, which opens the debate on which service to provide to which region (Oyelaran-Oyeyinka & Adeya, 2004; Oyelaran-Oyeyinka & Lal, 2005).

³See for instance (Dasgupta, Lall, & Wheeler, 2005; Norris et al., 2001; Steinmueller, 2001).

2.2 Socio-demographic factors of adoption, uses and impacts of ICT

Turning to social determinants of ICT adoption, GDP, income, low inequality, availability of infrastructure and education are found to have a significant role (Bagchi & Udo, 2007). Moreover, Brown and Licker (2003) show that social factors influence the decision to adopt the technology. Higher social groups would be more sensitive to factors such as perceived usefulness, enjoyment, and long term profitability, while perceived usefulness and ease of use will be positively correlated with ICT adoption for the most vulnerable households.

As regards fixed Internet, Oyelaran-Oyeyinka and Adeya (2004) highlight the importance of the computer cost in the decision to adopt the technology. They also show that to avoid a costly computer ownership, users turn to Internet cafe or use computers at friends or colleagues' places, which is in line with Rangaswamy and Cutrell (2012). Besides, Birba and Diagne (2012) and Touray, Salminen, and Mursu (2015) show that other factors such as education, gender, and social network membership play an important role. Overall, Internet is adopted mostly by young educated people familiar with the uses of technology (Pénard, Poussing, Zomo Yebe, & Ella, 2012).

The use of mobile Internet, however, requires fewer skills and less financial resources than fixed Internet, and is not conditioned to home electricity (Donner, Gitau, & Marsden, 2011; Stork, Calandro, & Gillwald, 2013). However, Chigona, Beukes, Vally, and Tanner (2009) highlight that socially excluded households in South-Africa have limited awareness of the existence and potential uses of mobile Internet. On top of this informational issue, cell phone cost has a strong negative influence on respondents decision to use mobile Internet.

Focusing on smartphone owners, Mathur, Schlotfeldt, and Chetty (2015) emphasize how the cost of data hinders mobile Internet use. They show that regulating the easiness of smartphone acquisition, the cost of data as well as educating the population to use mobile internet could remove the barriers remaining for mobile Internet adoption. They recommend notably to educate the population to use mobile Internet as a practical tool for networking on social media, information gathering and job seeking.

3 State of Social, Economic and Technological Development

3.1 Countries Profile

In this study, we analyse the case of four Sub-Saharan countries, namely Nigeria, Kenya, Tanzania and Uganda. We argue that they are good candidates as they are representative of post-colonial and developing countries which attracts foreign direct investment, especially in the telecommunication sector.

Nigeria is located in west Africa and is the most populated country in Africa, with approximately 197 million inhabitants in 2019. It is a stable country when it comes to politics: the political regime is a democracy, stable since its introduction in 1999. Kenya, Tanzania and Uganda are located in east Africa in the Great Lakes region and are less populated with, in 2017, 49.7 million inhabitants in Kenya, 57.7 million in Tanzania and 42.56 million in Uganda. While Tanzania and Uganda are stable politically, Kenya has experienced more political uncertainty. It has a new constitution since 2010 which led to a first election in 2013. All of them are democracies.

In all countries, (low-scale) agriculture is a key sector of the economy with a strong dependency on export of primary commodities. The population growth rate and the infantile mortality rate are high as it is the case in developing countries. The income per capita is fairly low and there are large pockets of the population still living under the poverty level. Nigeria is one of the countries with the highest number of extreme poor in the world.⁴ In Tanzania, the poverty level is decreasing, but not in absolute numbers due to the high population growth. However, financial inclusion is increasing with 62% of the population financially included in 2017 compare to 45% in 2009. Tanzania is the second country in terms of mobile money use. The transaction value-to-GDP ration reaches 53% in 2017. In Uganda, the level of poverty is rising along with infantile mortality due to the unfavourable weather conditions and the ongoing civil war in South Sudan. Uganda is hosting 800,000 refugees from South Sudan and 1.35 million refugees in total making it the largest refugee host in Africa.

The poor weather conditions paired with the civil war in South Sudan, the conflicts in the Democratic Republic of Congo and the difficulty to conduct business for the private sector had a negative impact on Uganda's economic growth. The economic growth rate stagnated around 4.5% from 2011, while it culminated at 7% in the 1990's and early 2000's. However, the economic growth has been increasing again in the latter part of 2017 largely driven by growth in ICTs and better weather conditions favourable to agriculture.

The Kenyan economy is mostly driven by low oil prices, tourism and strong remittances. Kenya ranks first in terms of mobile money use. In 2018, Kenya was one of the fastest growing economies in Sub-Saharan Africa with high agriculture exportation and tourism. The Nigerian economy performs well, with an average growth rate of 5.7% between 2006 and 2016, driven up by the exportation of natural resources. The economy slowed down recently, with a recession in 2016, and growth rates of 0.8% in 2017 and 1.9% in 2018.⁵ Unemployment is very high, as it reached 23% of the working force in the end of 2018.⁶

⁴Half of the worlds poor live in just 5 countries.

⁵Data are available on World Bank.

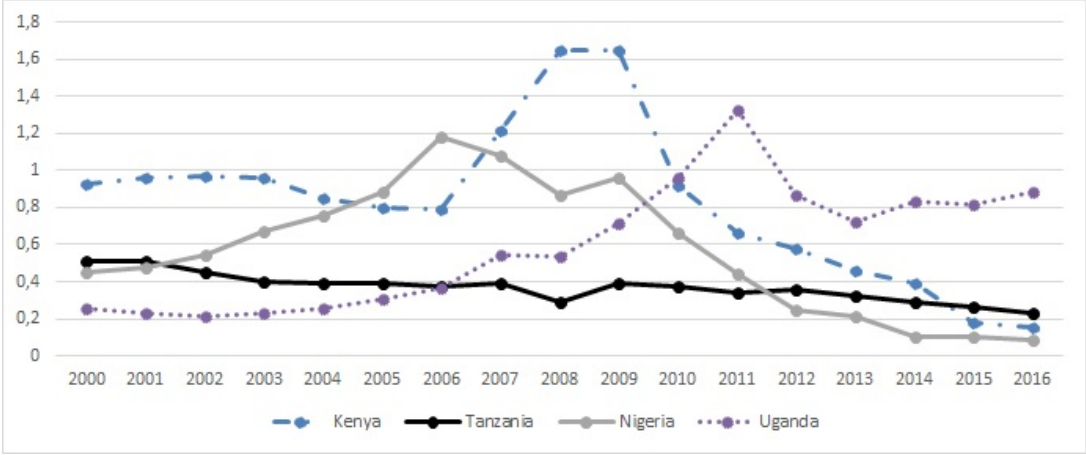
⁶IMF, World Economic Outlook.

These four countries are good candidates for this analysis as they share the characteristics of developing economies and experience different states of economic and social development. Nigeria and Kenya are the most similar countries. But while in Kenya the use of mobile money is well spread in the society, it is not so common in Nigeria. In both countries, the use of mobile internet is the most probable. The countries already show encouraging signs of a potential quick increase of penetration rates. Nigeria is the country with the highest penetration rates of mobile phones and of Internet between 2013 and 2016. Tanzania and Uganda are somewhat lagging behind. [Uganda mobile money](#). In Uganda, the ownership of a mobile device or of a SIM card is the least common, while access is used the most compared to the other countries. The concept of common devices is the strongest in Uganda especially and Tanzania.

3.2 Telecommunications Market in Sub-Saharan Africa

In developing countries, the fixed telephone network is mostly inherited from the past colonial time. The network was primarily rolled out to enable communications between the colonial cities and the old continent. It was not meant to connect cities within a country or within Africa. As a result of the colonization, the fixed telephone network coverage is limited and covers mostly urban areas. The penetration rate of fixed telephony is rather low. As shown in Figure 1 the subscription rate to the fixed telephony has remained very low since 2000 and hardly reached 2% in Kenya, Tanzania, Nigeria and Uganda.

Figure 1: Fixed-telephone subscriptions per 100 inhabitants.



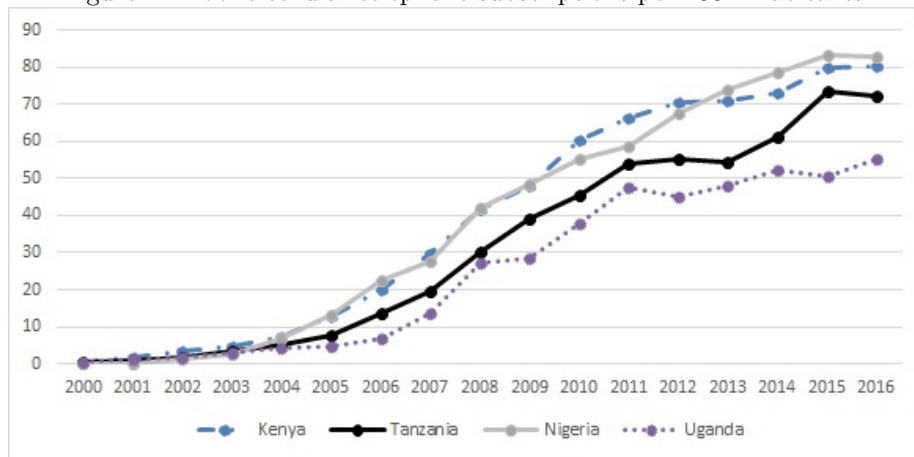
Source International Telecommunication Union databases, 2018.

The telecommunications market is mostly driven by the use of mobile phones. Considering the high

cost of fixed network deployment, which is mostly sunk, mobile infrastructures have been rolled out throughout the countries to bring telecommunications services to households and companies. Civil engineering represents 80% of the costs of deployment. The penetration rate of mobile phone is rapidly increasing. The boom in mobile phone subscriptions has surprised the telecommunication operators themselves. As a well cited example, Safaricom, a national operator in Kenya, projected to reach 3 million subscribers by 2020, but reached 14 million customers in 2010.

The spectacular growth of the mobile market has also been primarily driven by the liberalisation of the telecommunications markets, which have been progressively opened-up to competition along with the introduction of independent regulatory authorities. Another important factor has been the introduction of mobile-money services, which enable everyone using a mobile phone to make financial transactions, to store money and even to start or expand their own business. These services have been exceptionally well received because a large proportion of households, notably in Sub-Saharan Africa, is excluded from the banking system or do not wish to be part of it. Besides, the use of mobile-money services doesn't require broadband, which makes the services even more attractive, and thus boosting mobile phone adoption.

Figure 2: Mobile-cellular telephone subscriptions per 100 inhabitants.



Source International Telecommunication Union databases, 2018.

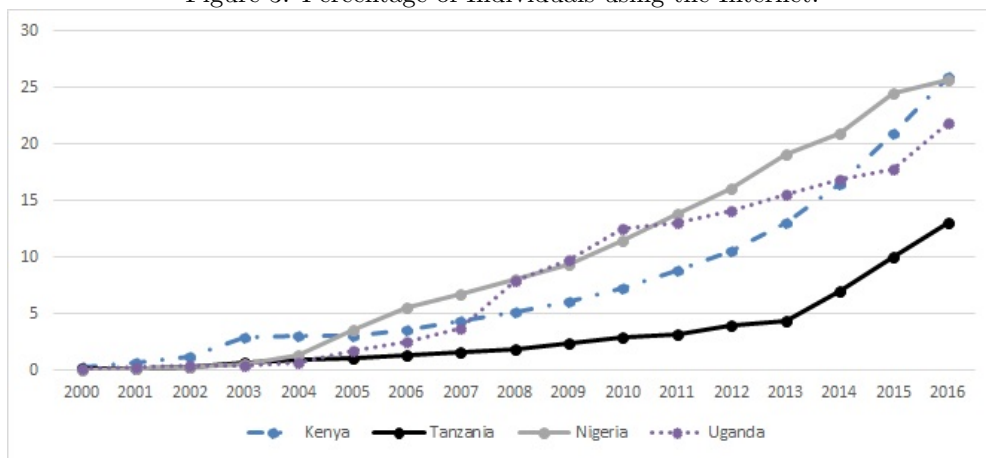
In Kenya and Nigeria, the mobile subscription growth rate has been very high. In 2005, around 10% of the population had a mobile phone subscription, while in 2016, more than 80% have one. In Uganda, the rise of mobile phone subscriptions has been of a slower pace. In 2005, less than 5% of the population had a mobile phone subscription, in 2016 it is a bit more than half of the population which has a subscription.

The figures here are not representative of mobile phone use by the population. In developing economies, mobile phone use is not exclusive as it is in Europe or in the US. The mobile phone is

not considered as an individual device, but could be shared among several people, either within a household or a community. It is not rare to have individuals owning a SIM card, but no mobile phone. They would make use of someone else’s mobile phone. Others may not have a SIM card but use the one of someone else’s. In developing economies and specifically in Sub-Saharan Africa, where the poverty level remains high, there are still households, which cannot afford to purchase a mobile device.⁷

Internet use has also become more popular in developing economies. While almost non-existent in the early 2000’s, it reached approximately one fourth of the population in Kenya, Nigeria and Uganda. Tanzania is still lagging behind with only 13% of the population making use of the Internet in 2016. Considering the low rate of fixed-broadband subscriptions, individuals access the Internet using wireless technologies, with mobile broadband becoming increasingly popular. Figure 3 shows the evolution of Internet use over from 2000 to 2016.

Figure 3: Percentage of Individuals using the Internet.



Source International Telecommunication Union databases,2018.

While all countries benefit from a fairly good GSM (2G) coverage, the UMTS (3G) coverage is more limited and the LTE (4G) technology starts to be introduced onto the markets. Table 1 shows the percentage of the population covered by 2G, 3G and 4G mobile networks respectively. Based on the Inclusive Internet Index: Measuring Success 2018, “the mobile network coverage refers to the percentage of inhabitants within range of a mobile-cellular signal; irrespective of whether or not they are subscribers or users”.

⁷“Poverty in a Rising Africa”, Africa Poverty 2016 Report, World Bank.

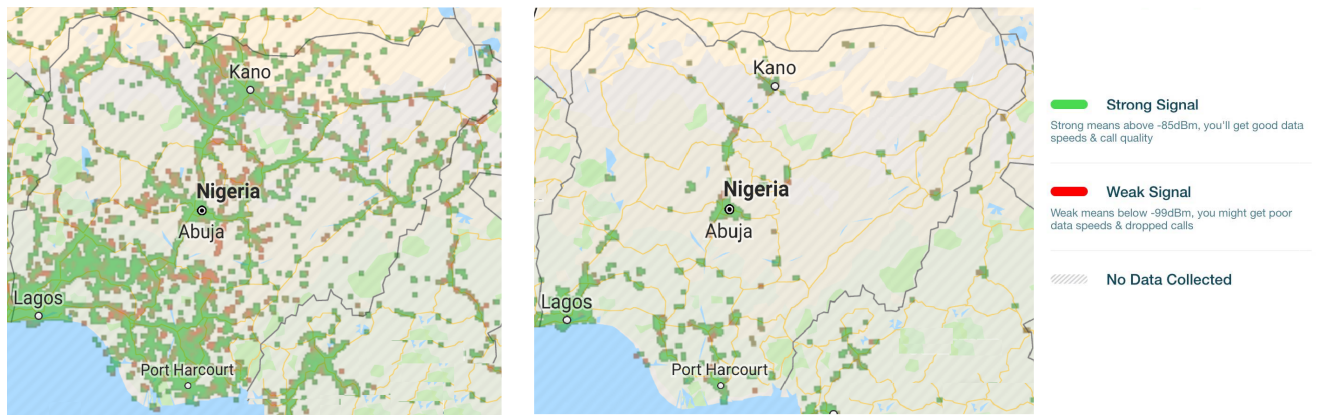
Table 1: Mobile network coverage in 2018, in percentage of the population

	Nigeria	Kenya	Tanzania	Uganda
2G	93%	99%	95%	93%
3G	54%	78%	85%	64%
4G	51%	22%	13%	15%

Source: The Inclusive Internet Index: Measuring Success 2018.

While big cities such as Abuja, Lagos and Kano, as well as their neighbouring areas benefit from high quality signals, rural areas lag behind with, in most cases, almost no connectivity. This structural factor may be the biggest hinder for mobile internet adoption in rural areas.

Figure 4: Mobile networks coverage in Nigeria, by all networks: 2G, 3G and 4G and by 4G.

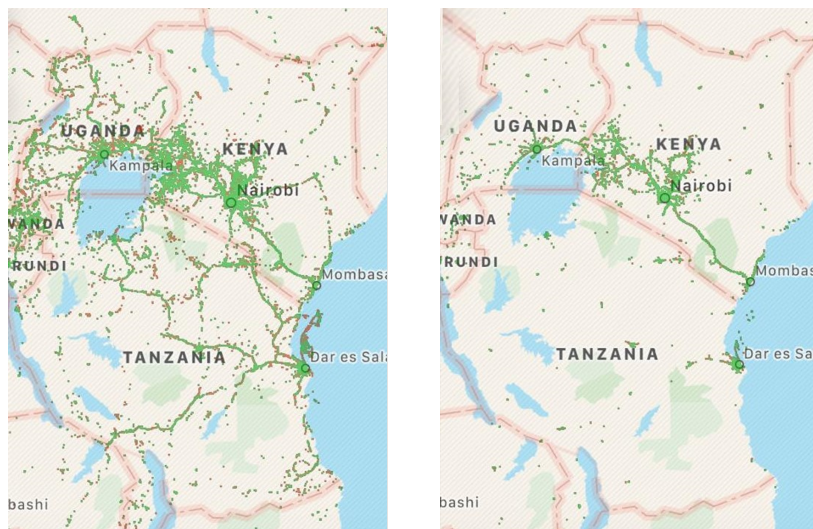


Source Open Signal, 2019.

The figure on the left shows the areas in which there is a mobile connectivity. The figure in the middle shows the areas in which there is 4G connectivity. The green dots represent a strong signal and the red ones a weak signal. The maps have been crowdsourced by users.

Having a look at Kenya, Tanzania and Uganda, we clearly see the same patterns with the areas located close to the capital cities and the most tourists areas well deserved with all kind of mobile broadband technologies, including 4G.

Figure 5: Mobile networks coverage in Kenya, Tanzania and Uganda, by all networks: 2G, 3G and 4G and by 4G.



Source Open Signal, 2019.

The figure on the left shows the areas in which there is a mobile connectivity. The figure in the middle shows the areas in which there is a 4G connectivity. The green dots represent a strong signal and the red ones a weak signal. The maps have been crowdsourced by users.

4 Data

We exploit a survey led by Intermedia's financial Inclusion Insights program, providing data for Nigeria, Kenya and Uganda (separately) for each year between 2013 and 2017. Data are available for the years 2014-2017 for Tanzania. Data are at the household level, and households are chosen randomly, based on the national census. Summary statistics are displayed in Annex. For Nigeria, we have data on more than 30,000 individuals over five years, from 2013 to 2017. We have data over 15,000 individuals for Tanzania and for Uganda, from 2013 to 2017. Finally, we have data on more than 12,000 individuals over four years, from 2014 to 2017 for Tanzania.⁸

Each cross-section contains information on mobile phone use and ownership. As it is common in Africa to have a SIM card, but no mobile phone, we also have access to data on SIM card ownership and mobile phone access. Considering the fact that it is not rare to encounter people having neither a mobile phone or a SIM card, but having access to someone else's SIM card, we also have data on SIM card access for those having no SIM card. The databases provide us with socio-demographical information on

⁸Data on mobile broadband use are unavailable for the year 2013.

gender, age, socio-professional occupation, years of education and localisation among others.

On average in our weighted sample, we have for the years 2013-2017, around 80% of the respondent who owns a mobile in Nigeria and in Kenya and slightly more than half of the respondents in Uganda owns a mobile device. In Tanzania, a bit more than two third of the respondent owns a mobile on average between 2014 and 2017. Almost everyone owning a mobile phone owns an active SIM card. SIM card ownership seems to be slightly more popular than mobile phone ownership in all four countries. Access to a mobile phone is more common in Tanzania and especially Uganda, where mobile phone ownership is lower, with one fourth of the respondent accessing the mobile device of someone else. Figures 6 to 9 show the proportions of individuals in our sample owning, accessing or not having a mobile and/ or a SIM card.

Table 2 shows that about one third of mobile owners use the Internet in Nigeria and Kenya. Internet use is less democratised in Tanzania and Uganda, which is reflected by the lower rate of Internet users in these two countries with one fifth and one fourth of the respondent respectively. The statistics show also that mobile money services are highly used in East Africa compared to Nigeria. Less than 2% of mobile owners in our sample for Nigeria uses mobile money services. Conversely, a vast majority of Kenyan and Ugandan respondents owning a mobile phone uses mobile money with respectively 92% and 72%. More than half of Tanzanian respondent owning a mobile device uses mobile money services.

Having a closer look at the composition of the mobile owners and non-mobile owners populations, we see that mobile owners are quite equally distributed between urban and rural areas, with a slight majority of those living in rural areas, except for Uganda where 69% of mobile owners lives in rural areas. Besides, mobile owners are somehow equally distributed between gender. However, almost three quarter of them live below the poverty level in Nigeria and in Tanzania.

As regards the non-mobile owners' population, Table 2 shows that the vast majority of them do not use the Internet. The proportion of those using the internet ranges between 2% and 7%. Except in Kenya, where mobile money is extremely spread into the population, the proportion of respondents using these services is of a lower magnitude. Around 80% of non-mobile owners are found in rural areas. A gender gap is observed here as non-mobile owners are mostly composed of women. Besides non mobile phone owners are primarily living under the poverty level.

Table 2: Proportions of individuals owning a mobile or not owning a mobile depending on different characteristics for the years 2013-2017 for all countries but Tanzania (2014-2017).

	Nigeria		Kenya	
	Ownership	Non-Ownership	Ownership	Non-Ownership
Internet users	34%	7%	29%	7%
Mobile money users	1.6%	0.3%	92%	39%
Rural	59%	72%	60%	77%
Male	53%	35%	51%	41%
15-25	31%	40%	31%	53%
25-34	29%	19%	29%	17%
Over 55	10%	16%	12%	12%
Below poverty	73%	83%	37%	69%

	Tanzania		Uganda	
	Ownership	Non-Ownership	Ownership	Non-Ownership
Internet users	22%	4%	16%	2%
Mobile money users	58%	26%	72%	21%
Rural	63%	79%	69%	87%
Male	54%	36%	55%	37%
15-25	26%	39%	30%	39%
25-34	29%	23%	29%	21%
Over 55	12%	13%	9%	17%
Below poverty	77%	90%	51%	83%

Own weighted statistics.

We complete our database with data from ? and from the Worldwide Governance Indicators project led by the World Bank.⁹ This data base is built on polls of experts and surveys composed of six institutional factors: voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law, and control of corruption. These factors encompass various dimensions of institutional quality, both for politic, legal, and economic institutions. For instance, rule of law takes into account the respect for intellectual property, which directly relates to the legal and economic issue of protection of innovation. Each indicator is normalized between -2.5 and 2.5 , and is positively linked with the quality of the institutions.¹⁰

5 Econometric Model

To answer our question about the drivers of mobile broadband use in Sub-Saharan countries, we develop for each country a discrete choice model with time and region effects. We take into account that not everyone owns a mobile phone or a SIM card. However, everyone using the Internet has either his/ her

⁹Worldwide Governance Indicators.

¹⁰Each indicator also has a zero mean and a standard deviation of one.

own mobile phone or access to the one of someone else. Besides, even though mobile money services are not as popular as they are in Kenya, by using these services people gain a higher experience and may be more inclined to use other services available on the mobile device.

Then, we have:

$$\begin{aligned}
mobile_bb_{ijt} = & \alpha + \beta_1 own_mobile_{ijt} + \beta_2 cat_sim_{ijt} + \beta_3 education_{ijt} + \beta_4 socio_pro_{ijt} \\
& + \beta_5 urban_{ijt} + \beta_6 male_{ijt} + \beta_7 age_{ijt} + \beta_8 ppi_score_{it} + \beta_9 m_money_{ijt} \quad (1) \\
& + \beta_{10} television_{ijt} + \beta_{11} bank_account_{ijt} + year_t + \eta_k + \epsilon_{ijt},
\end{aligned}$$

where $mobile_bb_{ijt}$ is a dummy variable representing mobile broadband use by respondent i in country j at time t , either on its own phone or on a phone he/ she has borrowed, at time t . Mobile broadband use could be influenced by the possession of a mobile phone, denoted by own_mobile . own_mobile equals 1 if respondent i in country j owns a telephone at time t and 0 if he/ she has access to a mobile device. We also introduce a categorical variable to indicate whether the respondent owns an active SIM card or has access to one. It is denoted by cat_sim_{ijt} and equals 2 if respondent i in country j owns a SIM card at time t , 1 if he/she has access to a SIM card and 0 otherwise.

The level of education may affect the decision to use mobile broadband by an individual, as it requires specific digital and literacy skills. The level of education taken into account in our model consists of four different levels, no formal education, primary education, secondary education and tertiary education. The PPI, a measurement of the poverty level, is included to take into account the level of poverty of the household. We also control for the use of mobile money, which has been the service driving mobile phone adoption. For Nigeria and Kenya, we add a control for the ownership of a television, which is mostly considered as an entertainment platform and could also be a proxy for access to electricity. The information was not available for Tanzania and Uganda. Finally we control for the ownership of a bank account, as banking is mostly common among richer households.

Socio-demographical characteristics may also influence mobile broadband use. It may be more common to use mobile broadband in urban areas, rather than in rural areas. The gender of the respondent is also taken into account, as well as the age category. The variable age has five categories, 15-24 years old, 25-34 years old, 35-44 years old, 45-54 years old and over 55 years old. The socio-professional group, denoted by $socio_pro_{ijt}$ may also have an impact on the use of mobile broadband. White collars may use mobile broadband more than retired for example.

η_k is a region dummy capturing cross-region differences. $year$ is a dummy variable for each year capturing potential time-effects. Finally, ϵ_{ijt} is an error term clustered at the state (or province) level.

Considering that almost one fifth of the population does not own a mobile device. We also estimate more specifically what the determinants of mobile broadband use are in the sub-population of non-mobile owners.

$$\begin{aligned}
mobile_bb_{ijt} = & \alpha + \beta_1 cat_sim_{ijt} + \beta_2 education_{ijt} + \beta_3 socio_pro_{ijt} + \beta_4 urban_{ijt} \\
& + \beta_5 male_{ijt} + \beta_6 age_{it} + \beta_7 ppi_score_{ijt} + \beta_8 m_money_{ijt} \\
& + \beta_9 television_{ijt} + \beta_{10} bank_account_{ijt} + year_t + \eta_k + \epsilon_{ijt},
\end{aligned} \tag{2}$$

An insight on this specific question seems highly relevant for policy makers, who seek to reduce the digital divide among their population.

6 Estimation Results

Tables 9 to 12 show that typical mobile broadband users in Sub-Saharan countries appear to be relatively wealthier young educated males, living in an urban area.¹¹ Mobile broadband use is also more common among bank account owners. Considering the specific case of Nigeria and controlling for the regions, Table 9 highlights that households are more likely to use mobile broadband in the southern region, located right on the ocean shore, where the fixed network deployment started in colonisation time. The northern region, which is the least developed and has suffered terrorist attacks from the Boko Haram radical islamist groups, is the one with the lowest mobile broadband use. Naturally, the further we go back in time, the less probable it is for a respondent to use mobile broadband.

The results from specification (1) show that the ownership of a mobile phone has a positive impact on mobile broadband use. Mobile owners are more likely to use mobile broadband compare to those only having access to a mobile phone. Besides, those owning a SIM card are more likely to make use of the technology. Taking into account that in developing countries part of the population does not own a SIM card, but has access to one, shows that both ownership and access to a SIM card increase the probability of using mobile broadband. Interestingly, the impact is of similar magnitude in Nigeria. This is not the case either in Kenya or in Uganda, where SIM cards owners are more likely to use the Internet compared to those accessing a SIM card. In Tanzania, we don't show any significant impact of SIM card ownership or access on mobile broadband use.

We also find, for Nigeria and Kenya where the data is available, that the relative importance of accessing a mobile phone, compare to owning a mobile phone, increases with the number of households member.¹² Higher is the number of households member, higher is the likeliness to use mobile broadband

¹¹The estimations have been run without the PPI variable, the results are qualitatively similar.

¹²We also tested how the number of household's member impacted the relative effect of owning a mobile device or having

if one has access to a mobile phone compare to owning its own device. This reflects the importance of device sharing in developing economies. Similarly, with a higher number of household members, the relative importance of owning a SIM card increases. However, we also find that even though the relative importance of accessing a mobile phone increases, those owning a mobile phone are still more likely to use mobile broadband.¹³

Turning to mobile financial services, our results suggest that mobile money users are more likely to use mobile broadband. In some African countries and East Africa essentially, mobile phone adoption has been primarily boosted by the introduction of mobile money services. Those using mobile money may have been using mobile phones for a longer time and may have gained therefore more experience. In turn, more experimented users of a technology are more inclined to switch to a more advanced version. This could underline the existence of a learning effect.

In addition, it appears that mobile broadband is mostly used by students, which is in line with previous literature. Pénard et al. (2012) show that students use the Internet for information gathering purposes. On the contrary, the unemployed and the farmers are the least likely to use mobile broadband. Besides, the ownership of a television has a negative impact on mobile broadband use in Nigeria. Mobile broadband could also be used for leisure activity, as underlined in the literature. It could be considered as a substitute for the entertainment programs provided by television.

As shown above, a singularity of developing economies is that mobile phones are not necessarily considered as an individual device and can be shared among a community. It is common that part of the population does not own a mobile phone. Almost one fifth of our sample doesn't own a mobile phone. It is important to take into account this specific category of mobile internet users to get an accurate picture.

In specification 2, we highlight that the ownership of a SIM card is a pre-requisite to use mobile broadband when one doesn't own its personal mobile phone. This is especially clear in Nigeria and in Kenya. Access to a SIM card is relatively more common to access mobile broadband in Uganda. Even though, SIM card owners, in Uganda, are also more likely to use mobile broadband compared to those access someone else's SIM card. In Tanzania, the coefficient are still not significant. Therefore, in all countries but Tanzania, the access to a SIM card has a positive effect on mobile broadband use, owning an active SIM card increases the probability of using the service. This finding may reflect that SIM card owners are more likely to have a subscription to mobile broadband than those only accessing someone else SIM card. Making use of mobile broadband by accessing the SIM card (and mobile phone) of someone else would imply to either use it for free or contribute to the cost of the subscription.

In this particular category of users who do not possess a mobile phone, we also find a significant

access to one on mobile broadband use.

¹³Results are available upon request.

effect from using mobile money on broadband use in east African countries. This in turn strengthens the potential existence of a learning effect. We do not find any significant effect of having a television either in Nigeria. Another interesting finding is that non-mobile owners using the internet in Nigeria are more likely to be unemployed. This result is also in line with the literature. Pénard et al. (2012) highlight that the internet and specifically Facebook can be used as a job portal.

7 Conclusion

Using micro-level data coming from household surveys in four Sub-Saharan countries, namely Nigeria, Kenya, Tanzania and Uganda, over 5 years, from 2013 to 2017, we estimate what are the determinants of mobile broadband use in developing economies. We have shown that the use of mobile broadband is strongly preconditioned by SIM card ownership, the ownership of a mobile phone, and finally by the use of mobile money. These results highlight a reproduction of the digital divide as new technologies are developed. As respondents excluded from these uses of the use of mobile phone technologies are also the ones that would benefit the most from it, namely the rural poor, we argue that there is a urge for regulators to fill this digital gap.

Considering the importance of mobile phone and SIM card ownership for mobile broadband use, it seems important that policy makers implement demand stimulation policies. First, decreasing the price of mobile device and, in particular of feature phones, would increase their adoption and palliate to one of the identified issue. Such a price reduction could be achieved partly by subsidisation or by promoting the reconditioning of old devices.

Secondly, regulators can encourage the use of mobile Internet among mobile users by lowering the price of data, as suggested Mathur et al. (2015). Finally, as our results show a digital divide in terms of territories, social groups and gender, we argue that campaigns of education of the population left behind might help them overcome the technical barrier to the use of mobile broadband. Digital educational programs could be implemented at schools to familiarize the young generation to the use of the Internet. This is especially important as the young generation is the most likely to adopt the technology.

One of the limitation of this work is that we could not access data on the price of mobiles devices or broadband services. Besides, the study has been realized for only one country in Sub-Saharan Africa. However, we argue that Nigeria is a good candidate, representative of post-colonial and developing economies. In addition, it is the most advanced in terms of ICTs adoption which allow us to perform robust estimations.

Further research should focus on cross-country analysis to assess whether the determinants of mobile

broadband adoption are similar across countries located in Sub-Saharan Africa.

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Appendix

Table 3: Summary statistics for Nigeria (years 2013-2017)

Variable	Obs.	Mean	Std. Dev.	Min	Max
Mobile broadband use	30.397	0.306	0.461	0	1
Urban	30.397	0.384	0.486	0	1
male	30.397	0.554	0.497	0	1
Age	30.397	33.061	19.977	15	117
Education	30.397	2.707	0.992	1	4
Number of household member	30.397	3.035	1.770	1	6
TV	30.397	0.309	0.462	0	1
Mobile only	30.397	0.009	0.096	0	1
SIM card only	30.397	0.024	0.152	0	1
Mobile and SIM card	30.397	0.774	0.418	0	1
No mobile phone. no SIM card	30.397	0.193	0.395	0	1

Table 4: Summary statistics for Kenya (years 2013-2017)

Variable	Obs.	Mean	Std. Dev.	Min	Max
Mobile broadband use	15.111	0.223	0.416	0	1
Urban	15.111	0.378	0.485	0	1
Gender (male)	15.111	0.393	0.488	0	1
Age	15.111	35.606	14.939	15	98
Education	15.111	2.462	0.816	1	4
Number of household member	15.111	3.104	1.785	1	6
Mobile only	15.111	0.006	0.078	0	1
SIM card only	15.111	0.044	0.206	0	1
Mobile and SIM card	15.111	0.778	0.416	0	1
No mobile phone, no SIM card	15.111	0.172	0.377	0	1

Table 5: Summary statistics for Tanzania (years 2013-2017)

Variable	Obs.	Mean	Std. Dev.	Min	Max
Mobile broadband use	12,046	0.143	0.351	0	1
Urban	15,043	0.342	0.474	0	1
Gender (male)	15,043	0.439	0.496	0	1
age	12,046	35.737	14.674	15	100
educ	15,043	2.182	0.655	1	4
m_only	15,043	0.027	0.162	0	1
active_sim y	15,043	0.042	0.200	0	1
m_active_sim	15,043	0.668	0.471	0	1
no_sim_phone	15,043	0.212	0.408	0	1

Table 6: Summary statistics for Uganda (years 2013-2017)

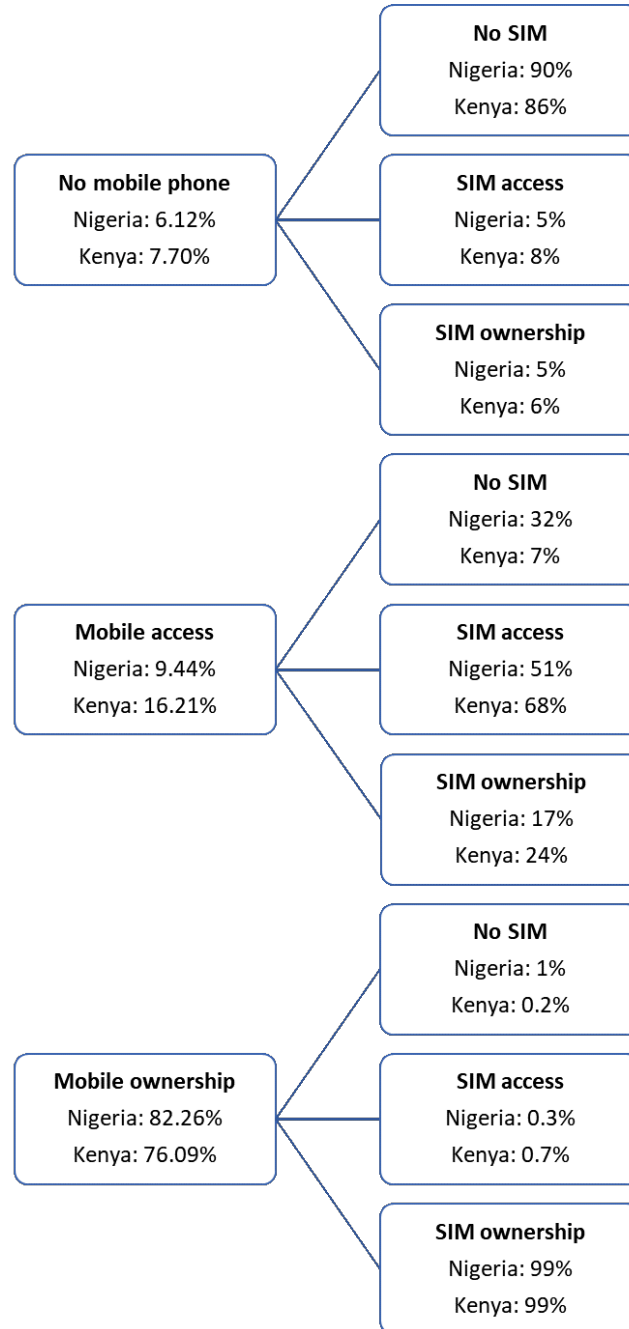
Variable	Obs.	Mean	Std. Dev.	Min	Max
Mobile broadband use	15.002	0.086	0.280	0	1
Urban	15.002	0.248	0.432	0	1
Gender (male)	15.002	0.400	0.490	0	1
Age	14.476	34.9238	14.90364	15	100
Education	15.002	2.235	0.762	1	4
Number of household member	12.001	3.955	1.823	1	6
Mobile only	15.002	0.008	0.089	0	1
SIM card only	15.002	0.037	0.188	0	1
Mobile and SIM card	15.002	0.549	0.498	0	1
No mobile phone, no SIM card	15.002	0.406	0.491	0	1

Table 7: Weighted summary statistics for Nigeria, Kenya, Tanzania and Uganda respectively for the years 2013-2017; in percent

Variable	Nigeria	Kenya	Tanzania	Uganda
Mobile broadband use	30.11	24.18	16.06	9.71
<i>Education</i>				
No Education	15.85	9.17	10.87	13.68
Primary	15.20	42.01	63.18	50.71
Secondary	49.94	38.18	23.12	30.70
Tertiary	19.01	10.64	2.84	4.90
Urban	39.28	36.05	31.93	23.47
<i>Age</i>				
15-24	32.51	36.02	30.01	33.89
25-34	27.44	25.90	27.23	25.51
35-44	17.31	15.80	18.48	16.66
45-54	11.46	10.12	11.67	11.05
Over 55	11.10	12.16	12.27	12.88
Gender (male)	50.18	48.95	48.19	47.14
TV	64.74	-	-	-
Mobile only	1.11	0.72	2.69	0.85
Active SIM card only	1.93	4.39	4.14	3.83
Mobile phone and SIM card	83.29	75.97	65.57	55.29
No mobile phone, no SIM card	13.67	19.52	21.07	40.03

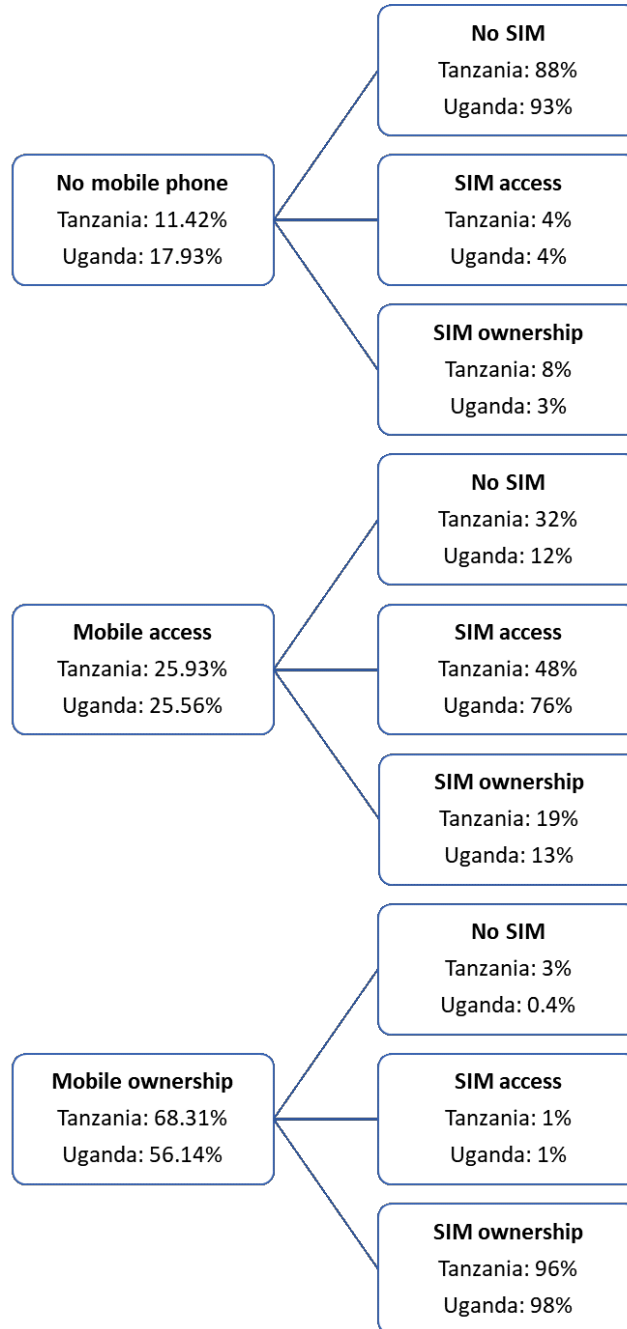
For all countries, except Tanzania, mobile broadband is measured for the years 2013-2017. For Tanzania, mobile broadband is measured for the years 2014-2017.

Figure 6: Proportions of individuals in our sample for Nigeria and Kenya accessing or owning a mobile phone who either access or own a SIM card.



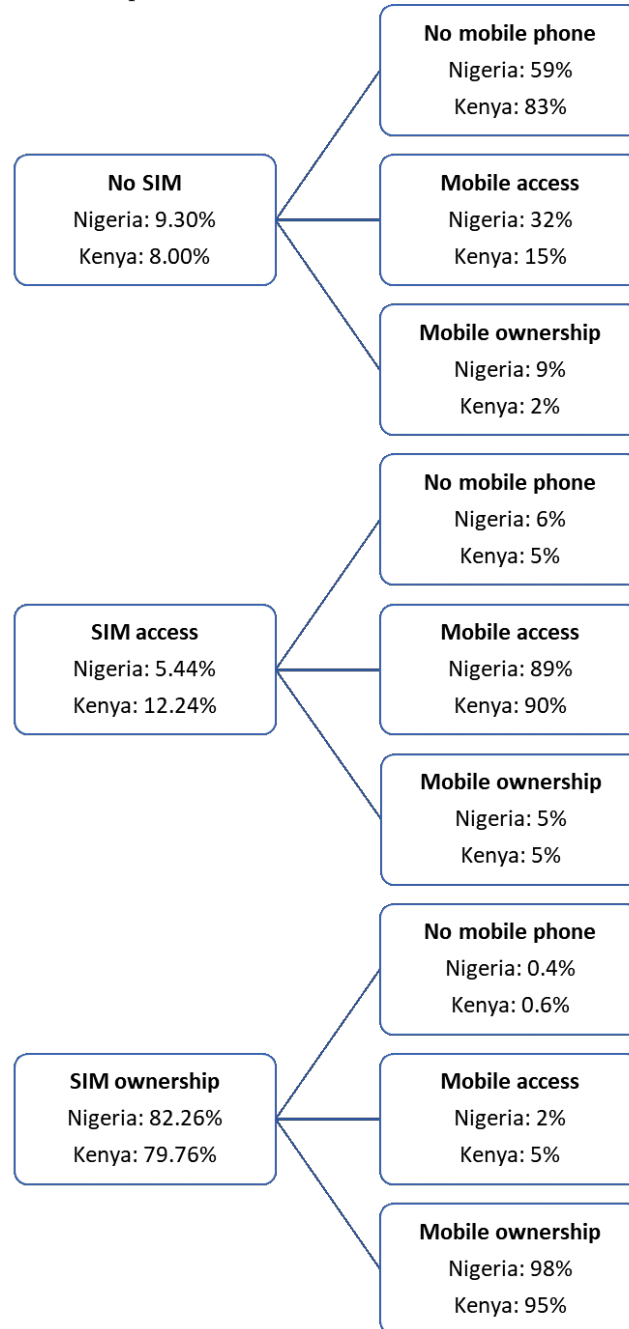
Own statistics: On the left part, from up to down. Proportion of individuals in our sample having no mobile phone, access to a mobile phone or owning a mobile phone which simultaneously have no SIM card, access to a SIM card or own a SIM card. On the right part, from up to down. Proportion of individuals in our sample having no SIM card, access to a SIM card or own a SIM card, which simultaneously have no mobile phone, access to a mobile phone or owning a mobile phone .

Figure 7: Proportions of individuals in our sample for Tanzania and Uganda accessing or owning a mobile phone who either access or own a SIM card.



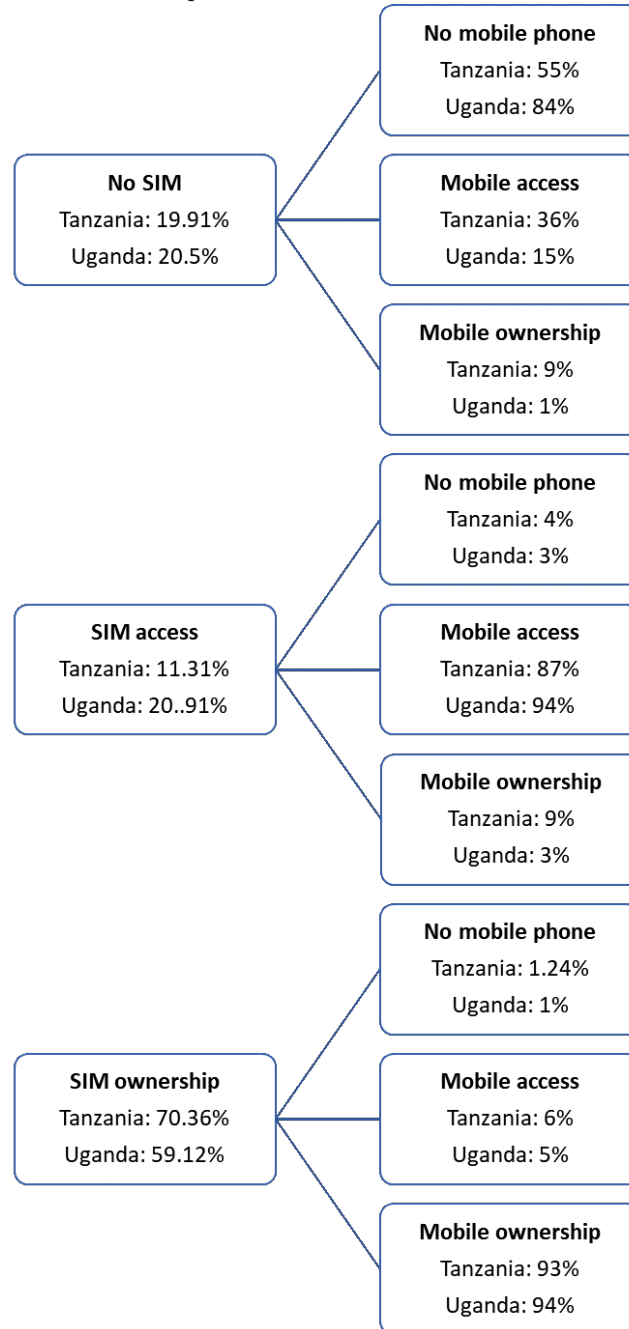
Own statistics: On the left part, from up to down. Proportion of individuals in our sample having no mobile phone, access to a mobile phone or owning a mobile phone which simultaneously have no SIM card, access to a SIM card or own a SIM card. On the right part, from up to down. Proportion of individuals in our sample having no SIM card, access to a SIM card or own a SIM card, which simultaneously have no mobile phone, access to a mobile phone or owning a mobile phone .

Figure 8: Proportions of individuals in our sample for Nigeria and Kenya accessing or owning a SIM card who either access or own a mobile phone card.



Own statistics: On the left part, from up to down. Proportion of individuals in our sample having no mobile phone, access to a mobile phone or owning a mobile phone which simultaneously have no SIM card, access to a SIM card or own a SIM card. On the right part, from up to down. Proportion of individuals in our sample having no SIM card, access to a SIM card or own a SIM card, which simultaneously have no mobile phone, access to a mobile phone or owning a mobile phone .

Figure 9: Proportions of individuals in our sample for Tanzania and Uganda accessing or owning a SIM card who either access or own a mobile phone card.



Own statistics: On the left part, from up to down. Proportion of individuals in our sample having no mobile phone, access to a mobile phone or owning a mobile phone which simultaneously have no SIM card, access to a SIM card or own a SIM card. On the right part, from up to down. Proportion of individuals in our sample having no SIM card, access to a SIM card or own a SIM card, which simultaneously have no mobile phone, access to a mobile phone or owning a mobile phone .

Table 8: Evolution of Mobile Internet Use over 2013 and 2016 in urban and rural areas in our sample

Year	Urban	Rural	Overall
2013	0.403	0.233	0.304
2014	0.539	0.458	0.489
2015	0.505	0.419	0.459
2016	0.394	0.481	0.456
All year	0.465	0.404	0.427

Table 9: Determinants of mobile broadband adoption in Nigeria and Kenya between 2013-2017: part 1

	Whole sample	Non-mobile owners	Whole sample	Non-mobile owners
Mobile ownership	0.768*** (0.211)	- -	0.436*** (0.150)	- -
SIM card access	1.444*** (0.248)	1.902*** (0.299)	0.662** (0.258)	0.697** (0.281)
SIM card ownership	1.527*** (0.267)	2.057*** (0.323)	1.560*** (0.265)	1.859*** (0.307)
<i>Mobile money: never used</i>				
Less than 1 month	0.653 (0.535)	- -	0.904*** (0.279)	2.120*** (0.527)
Between 1 and 6 months	0.905*** (0.271)	1.263* (0.645)	0.636*** (0.178)	1.350*** (0.439)
Between 6 months and 1 year	0.564* (0.299)	- -	0.669*** (0.166)	1.478*** (0.409)
More than 1 year	1.248*** (0.379)	-0.846 (1.136)	1.027*** (0.125)	1.902*** (0.281)
Average mobile money user	5.650*** (1.556)	4.554 (5.166)	0.406 (0.375)	-0.271 (0.987)
Wealth (PPI index)	0.017*** (0.002)	0.024*** (0.007)	0.032*** (0.003)	0.019** (0.008)
Bank account	0.791*** (0.069)	0.633* (0.362)	0.661*** (0.066)	0.641** (0.280)
TV	-0.370*** (0.085)	-0.234 (0.193)		
Urban	0.381*** (0.076)	0.535** (0.236)	0.126* (0.069)	0.014 (0.231)
Gender (male==1)	0.501*** (0.072)	0.820*** (0.216)	0.744*** (0.060)	0.463** (0.185)
Constant	-5.162*** (0.259)	-7.922*** (0.833)	-6.448*** (0.423)	-4.852*** (0.905)
Observations	30,350	6,567	12,406	2,981
Pseudo R-squared	0.26	0.27	0.36	0.26
AIC	27405.02	1785.566	9724.034	1490.214
BIC	27704.56	2009.63	10006.22	1706.215
Log Likelihood	-13666.51	-859.7829	-4824.017	-709.107
Region	YES	YES	YES	YES
Year Trend	YES	YES	YES	YES
Country	Nigeria	Nigeria	Kenya	Kenya

Robust standard errors in parentheses : *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 10: Determinants of mobile broadband adoption in Nigeria and Kenya between 2013-2017: part 2

	Whole sample	Non-mobile owners	Whole sample	Non-mobile owners
<i>Age: 15-24</i>				
25-34	-0.438*** (0.078)	-0.522** (0.259)	-0.750*** (0.077)	-0.193 (0.248)
35-44	-0.952*** (0.114)	-0.441 (0.402)	-1.506*** (0.095)	-0.886** (0.345)
45-54	-1.368*** (0.152)	-0.200 (0.470)	-2.152*** (0.124)	-0.822* (0.435)
Over 55	-1.853*** (0.148)	-1.369** (0.601)	-2.728*** (0.142)	-0.642* (0.358)
<i>No formal education</i>	(0.072)	(0.216)	(0.060)	(0.185)
Primary education	0.063 (0.146)	0.345 (0.456)	-0.045 (0.178)	-0.175 (0.334)
Secondary education	0.792*** (0.146)	1.447*** (0.401)	0.683*** (0.176)	0.217 (0.347)
Tertiary education	1.685*** (0.125)	1.371** (0.551)	1.816*** (0.195)	0.229 (0.619)
Number of household members	0.077*** (0.019)	0.129* (0.068)	0.102*** (0.023)	0.028 (0.070)
<i>Intermediate professions</i>				
Farmers	-0.440*** (0.125)	0.584 (0.531)	-0.305*** (0.103)	0.036 (0.459)
Craftmen, self-employed	0.002 (0.095)	1.071** (0.498)	-0.105 (0.112)	-0.124 (0.578)
White collars	0.229* (0.135)	0.566 (0.979)	0.349** (0.149)	
Manual workers	-0.004 (0.082)	0.535 (0.525)	-0.044 (0.108)	0.143 (0.514)
Military	0.517** (0.221)	- -	0.458 (0.482)	2.066 (1.693)
Unemployed	-0.082 (0.091)	1.181*** (0.403)	-0.209** (0.097)	-0.067 (0.436)
Students	0.548*** (0.100)	0.899** (0.391)	0.431*** (0.134)	1.119** (0.482)
Constant	-5.162*** (0.259)	-7.922*** (0.833)	-6.448*** (0.423)	-4.852*** (0.905)
Observations	30,350	6,567	12,406	2,981
Pseudo R-squared	0.26	0.27	0.36	0.26
AIC	27405.02	1785.566	9724.034	1490.214
BIC	27704.56	2009.63	10006.22	1706.215
Log Likelihood	-13666.51	-859.7829	-4824.017	-709.107
Region	YES	YES	YES	YES
Year Trend	YES	YES	YES	YES
Country	Nigeria	Nigeria	Kenya	Kenya

Robust standard errors in parentheses : *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 11: Determinants of mobile broadband adoption in Tanzania and Uganda between 2013-2017: part 1

	Whole sample	Non-mobile owners	Whole sample	Non-mobile owners
Mobile ownership	1.479*** (0.242)	- -	0.687*** (0.217)	- -
SIM card access	-0.032 (0.256)	0.353 (0.428)	1.788*** (0.540)	2.001*** (0.606)
SIM card ownership	-0.236 (0.273)	0.413 (0.362)	2.146*** (0.582)	2.514*** (0.674)
<i>Mobile money: never used</i>				
Less than 1 month	1.111*** (0.236)	2.428*** (0.550)	0.240 (0.228)	1.019 (0.822)
Between 1 and 6 months	0.760*** (0.147)	1.074* (0.601)	0.689*** (0.209)	0.149 (0.651)
Between 6 months and 1 year	0.884*** (0.145)	1.489*** (0.453)	0.539*** (0.184)	0.317 (0.508)
More than 1 year	1.008*** (0.157)	1.590*** (0.369)	0.764*** (0.109)	0.690* (0.360)
Average mobile money user	0.013 (0.299)	-0.957 (0.683)	1.055*** (0.356)	0.148 (0.755)
Wealth (PPI index)	0.013*** (0.004)	0.006 (0.008)	0.022*** (0.004)	0.023** (0.011)
Bank account	0.429*** (0.093)	-0.137 (0.487)	0.738*** (0.108)	1.539*** (0.512)
Urban	0.134 (0.104)	0.132 (0.306)	0.372*** (0.107)	-0.014 (0.326)
Gender (male==1)	0.455*** (0.076)	0.295 (0.245)	0.766*** (0.083)	0.749*** (0.280)
Constant	-4.994*** (0.392)	-4.032*** (0.958)	-7.712*** (0.613)	-9.398*** (1.493)
Observations	9,925	2,570	12,514	5,698
Pseudo R-squared	0.29	0.24	0.37	0.25
AIC	6135.344	699.9004	5551.178	901.972
BIC	6567.512	992.4834	5833.693	1141.295
Log Likelihood	-3007.672	-299.9502	-2737.589	-414.986
Region	YES	YES	YES	YES
Year Trend	YES	YES	YES	YES
Country	Uganda	Uganda	Uganda	Uganda

Robust standard errors in parentheses : *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 12: Determinants of mobile broadband adoption in Tanzania and Uganda between 2013-2017: part 2

	Whole sample	Non-mobile owners	Whole sample	Non-mobile owners
<i>Age: 15-24</i>				
25-34	-0.537*** (0.077)	-0.329 (0.292)	-0.780*** (0.122)	-0.802*** (0.305)
35-44	-0.973*** (0.096)	-0.370 (0.311)	-1.455*** (0.172)	-1.013** (0.469)
45-54	-1.491*** (0.148)	-0.506 (0.385)	-1.515*** (0.148)	-0.915** (0.463)
Over 55	-1.744*** (0.168)	-0.927 (0.666)	-2.049*** (0.267)	-2.064*** (0.630)
<i>No formal education</i>				
Primary education	0.847*** (0.267)	0.932* (0.483)	-0.275 (0.225)	0.103 (0.530)
Secondary education	1.589*** (0.288)	1.753*** (0.638)	0.593*** (0.222)	0.780 (0.539)
Tertiary education	2.469*** (0.338)	2.259 (1.645)	1.871*** (0.251)	3.103*** (0.538)
<i>Intermediate professions</i>				
Farmers	-0.448*** (0.121)	-0.852 (0.539)	0.197 (0.130)	1.581* (0.925)
Craftmen, self-employed	0.014 (0.142)	0.108 (0.615)	0.140 (0.118)	1.680* (0.860)
White collars	0.718*** (0.207)	- -	0.376** (0.162)	0.646 (1.743)
Manual workers	0.144 (0.091)	-0.370 (0.414)	-0.063 (0.148)	0.989 (1.207)
Military	0.529 (0.325)	- -	-0.053 (0.487)	- -
Unemployed	0.053 (0.153)	-0.237 (0.526)	0.174 (0.182)	0.065 (1.248)
Students	0.244* (0.135)	-0.490 (0.640)	0.399*** (0.127)	1.841* (1.009)
Constant	-4.994*** (0.392)	-4.032*** (0.958)	-7.712*** (0.613)	-9.398*** (1.493)
Observations	9,925	2,570	12,514	5,698
Pseudo R-squared	0.29	0.24	0.37	0.25
AIC	6135.344	699.9004	5551.178	901.972
BIC	6567.512	992.4834	5833.693	1141.295
Log Likelihood	-3007.672	-299.9502	-2737.589	-414.986
Region	YES	YES	YES	YES
Year Trend	YES	YES	YES	YES
Country	Uganda	Uganda	Uganda	Uganda

Robust standard errors in parentheses : *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$