Mobile Money Coverage, Financial Inclusion, and Ag-investment in Developing Countries:

Evidence from Ghana

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Abstract

How does the expansion of mobile money service affect household financial inclusion and the investment decisions of these households in agriculture? To answer the above research questions, we look at how the expansion of mobile money in Ghana has impacted financial inclusion and ag-investment and other interactions associated with mobile money use. To answer the research question in this study, we use a 3-wave household panel survey data combined with geospatial information on the rollout of mobile money service in Ghana. Using a fixed effect and accounting for spatial dependence, we find that living in areas with mobile money coverage positively affects household financial inclusion. And mobile money coverage positively affects households' decision to invest in agriculture through financial inclusion. The results we find vary by gender and location. The results suggest that total coverage of mobile money service in locations where agricultural production is the primary activity would be an important mechanism for mobile money to support financial inclusion and agricultural production.

Introduction

Agriculture is a major economic activity in Sub-Saharan Africa. Most households, especially the poor and vulnerable, engage in agricultural activity for sustenance. In some cases, after household has had its share of the output for sustenance, then take what is left to the market (Ayerekwa, 2018). Few people with the financial means engage in agricultural activity on a large scale. Because agriculture activity on a large scale requires these households to make productive investment on their farms. That is, agriculture on a large scale requires huge capital investment to acquire land and other farm inputs in preparation for the planting season (Doso Jnr. et al. 2015, MOFA, 2006). Productive investment in agriculture can play a significant role on agriculture productivity and that can have lasting effect on the welfare of the people (Gashu et al. 2019, Nino et al. 2022). In cases where lands for production are available, productive investment – financial products and credit facilities – could be another major challenge these households have to deal with. Most household farmers lack the wherewithal to make productive investments on their farms. That limits their potential for agriculture output – particularly on crop diversification and might have a lasting effect on food security for these households.

Mobile internet coverage in Sub-Saharan Africa has reached a record level (Cariolle, 2021; Wiser et al., 2019). The spike in internet service coverage has resulted in using mobile phones to perform financial services, including savings, sending and receiving money on phones, using phones to apply for loans from mobile network companies, and participating in insurance products, among others. These activities are known as mobile money (MM)[1]. Celltower coverage has increased dramatically, resulting in Africa Mobile phone penetration in Africa tripled from 24% to about 75% between 2010 to 2019 (GSMA, 2020). The internet coverage is coupled with mobile money rollout.

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[1] The use of phones to undertake services such as having a savings account on phones, transferring and/or receiving money and remittances through phones, and requesting loans, among others.

Mobile internet coverage has enormous potential for Africa's financial sector development, expansion of financial and credit access, wider coverage for the unbanked people, and improved financial inclusion (FI)[2]. Improved financial inclusion can improve productive investment in agriculture and offer them some resilience to guard against shocks.

However, despite the excitement about the growth of the network coverage and the potential mobile money offers for emerging development, there is limited empirical evidence on the spatial effect of mobile money service on household's financial inclusion and the effect on investment in agriculture – particularly among poor and vulnerable people and farmers in rural areas in sub-Saharan Africa. Tying mobile money coverage and productive investment in agriculture, our interest is to explore whether exposure to mobile money coverage plays a role on financial inclusion and whether lack of productive investment in agriculture might be tied to lack of financial inclusion.

There is a growing literature on outcomes correlated with mobile money and payment/transaction systems, household food security, household resilience to shock and risk sharing. These studies adopt different approaches and employ various measures to define mobile money. For instance, studies that use difference-in-difference methodology (Riley 2018; Ahmed and Cowan 2021) look at household risk sharing and healthcare utilization. Others use randomized control trials (RCT) (Apeti 2023; Lee et al. 2021; Bastista and Vincente 2020; Wiser et al. 2019; Blumenstock et al. 2015; Munyegera and Matsumoto 2014) to investigate the impact of mobile money on household welfare including consumption, remittances, savings, technology adoption. Others employ IV and panel approaches (Gurbuz, 2017; Kipchumba and Sulaiman, 2021) to examine mobile money effect on

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[2] The provision of a range of affordable and convenience financial products and service to people who are excluded from formal banking and financial systems and these people can effectively access and use to meet their needs in a timely fashion.

empowerment. These studies examine mobile money in the context of mobile banking, presence of mobile money agents (MMA)[3], or direct use of phones to send and receive money.

Despite the plethora of studies on mobile money from the developing context, there is limited empirical evidence on the rollout of MM coverage. Mobile money coverage is important for the following reasons. Mobile money coverage means that telecommunication network operators have rollout mobile money products that individuals can access. Without mobile money coverage, mobile money would not happen. There could be coverage but limited access. But the reverse is not true. There cannot be access without coverage. Existing studies, generally, have looked at mobile money from access broadly. In this case, mobile banking or mobile money agent presence or mobile banking but not mobile money coverage.

Given the knowledge gap in the literature, we look at mobile money through the lens of coverage. We are interested in how exposure to MM coverage affects financial inclusion (FI) and ag-investment, and whether the effect may differ by various household characteristics. Thus, we ask the following research questions: does mobile money coverage affect financial inclusion and agriculture investment, and does mobile money coverage mediate through FI and affect ag-investment. The research questions are relevant for developing economy's development and planning purposes as it will be beneficial for such economies to capitalize on the increasing growth in mobile money services for growth and financial sector development. The research questions are relevant for financial sector development in the sense that if these economies have majority of the people having access to internet through their mobile phones, then policymakers and governments can understand the roles that

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[3] Mobile money agent (MMA) serves as an intermediary between the telecommunications and the people. Mobile money is provided by the mobile money telecommunications (MNOs) and the MMA go on a contract with the MNOs and go to the communities and villages as representatives of the MNOs and offer them their services.

mobile money service coverage brings and inform discussions about mobile money interaction pathways that will have value for the people and the part of the sector that we might hope could benefit the most.

Ghana is among the few countries in SSA that have seen increasing penetration of mobile phones and smartphones and mobile money. To answer the research questions, we leverage three waves of a nationally representative longitudinal household survey on Ghana's agriculture activity and welfare indicators with geospatial information on mobile money service rollout between 2008 to 2019. By matching the panel survey with coverage maps of mobile internet, we can determine with precision the time when households in a particular district began receiving mobile money service coverage. With this in hand, we can empirically evaluate whether the staggered rollout of mobile money service coverage has contributed to changes in household financial inclusion and sustainable agricultural practices.

We employ fixed effect estimation method to account for spatial dependence and examine the effect of mobile money coverage (or availability)[4] using the rollout of specific mobile money network as our exogenous variation. We use a fraction of coverage provided by mobile money celltowers to estimate the impact of mobile money coverage on financial inclusion and ag-investment. Additionally, we perform manifolds validity checks to overcome the potential concern regarding the empirical strategy and endogeneity concerns associated with mobile money rolled in Ghana. We explore other mechanisms related to the exposure to mobile money coverage and other robustness checks.

The main results are as follows. Mobile money coverage has significant and positive effects on household financial inclusion. We see this through positive effect of mobile money coverage on

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[4] We use mobile money service coverage instead of mobile money service access because mobile money service coverage is independent of households consumptions decisions.

savings account ownership, access to credit, loans, and increase use of remittance. The fixed effects results show that mobile money coverage is positive and significantly influences financial inclusion and increases investment in agriculture, especially for rural folks where farming is a major activity. We find that an increase in the share of population around MM celltower by 10 percent increases financial inclusion by about 2 percent. We find no significant difference in the share of households in the non-mobile money service area. If a household is exposed to mobile money celltower, these households are likely to experience improved financial inclusion, which can have positive implications for agriculture investment. Again, we see that mobile money coverage varies by gender effect. The interaction effect of our treatment variable (MMC) and female is negative, but the total effect is positive. This result could be that there are constraints that limit coverage adoption by women. This study's findings are consistent with existing studies that have found similar effects using mobile broadband in other African contexts—a sign which reassures the important role of mobile technology in delivering on its promise.

We do not find any effect on mobile money coverage and ag-investment, but we see that mobile money coverage affects ag-investment through financial inclusion. By inference, coverage alone might not be enough to affect ag-investment, but if coverage exists, we expect a positive effect on financial inclusion which can influence ag-investment. Other early estimates of possible mechanisms we find on mobile money coverage are the effect on crop diversity and household dietary diversity through ag-investment. An increase in investment positively affects crop diversity and household dietary diversity. Field data we gathered from Ghana on mobile money use and the interactions people have with mobile money corroborate the results in this study. For example, evidence from the field study indicates that if people have access to unconstrained credit, they will invest in the activities they do. Individuals for whom agriculture is their main economic activity suggest if they have access to unconstrained credit, they will invest in their farm activity to increase yield. We

conclude from the evidence in this study that one of the constraints that can keep most poor and vulnerable people from reaching their potential can emanate from lack of financial inclusion, as shown using the effect of the expansion of MMC on financial inclusion and ag-investment and a field study on mobile money from Ghana. Putting the pieces of the results in this study together, we can deduce that if people are exposed to innovative financial products and services, in this case, mobile money, can have access to these products to meet their financial and credit needs on a timely manner, can have significant impact on the people's wellbeing. Thus, when you give people credit and financial products that meet their needs, especially for those living in locations where agriculture is their main source of livelihood, they can be better off.

Our findings are relevant to the growing literature on mobile money in developing countries and financial inclusion on the one hand and mobile money service and ag-investment on the other. Specifically, we contribute to the discussion of the role of mobile money and financial inclusion. Most studies have focused on mobile technology's effect on financial inclusion, such as improvement to business, management, and market information (Aker andMbiti, 2010; Jensen, 2007), and mobile penetration on financial inclusion (Andrianaivo and Kpodar, 2012). While there is limited evidence about the direct effect of mobile money on financial inclusion (Ahmad, Green, and Jiang 2020), we focus on the role of mobile money coverage, which looks at mobile money availability while controlling for spatial dependence, a measure which is different from other studies measurement for mobile money. The novelty in our approach is worth highlighting in the literature, given that the primary means to access mobile money services is through internet service coverage and mobile phones.

Our study also contributes to the broader literature studying the economic effect of mobile technology on rural households' welfare in developing countries (Wiser et al., 20.19; Tavneet and William, 2016; Kalvin et al. 2021) and mobile money adoption and input use and farm output (Abdul-

Rahaman and Abdulai, 2022). Our study focuses on the effect of mobile money coverage on household welfare through household investment, their farm decision during planting season and effects on crop diversity and household diets.

The rest of this paper proceeds as follows. Section 2 presents the background and context. Section 3 describes the data sources and empirical strategy. Section 4 discusses the results and discussions, and Section 5 concludes.

Study Area and Context

Ghana is a country in West Africa of 32 million people (Ghana Statistical Report, 2022) that sits on the Atlantic Ocean and is boarded by Togo, Cote d'Ivoire, Burkina Faso. Over 25 percent of the population lived below the poverty line in 2020 (World Bank, 2022). The agriculture sector heavily supports Ghana's economy (Teye and Torvikey, 2018). Most households engaged in agricultural production are characterized as poor and vulnerable since these households heavily rely on subsistence agriculture as the primary source of livelihood (Hilson and Garforth, 2012; Abbam et al., 2018). Vulnerable and poor households are susceptible to external negative shocks that adversely affect their consumption smoothing (DeLoach and Smith-Lin, 2018; Harttgen and Günther, 2006; Jack and Suri, 2014). They are prone to crop damage and illness, thus adversely affecting their welfare (DeLoach and Smith-Lin, 2018; Demirgüç-Kunt et al., 2018; Harttgen and Günther, 2006). For these households to better cope with shocks, they must be provided with innovative solutions that meet their financial need that they can swiftly access in times of need. Additionally, most households are unbanked, lack access to financial and credits that meets their needs in a timely fashion (Demirgüç-Kunt et al., 2018).

The advent of mobile money in sub-Saharan Africa, and Ghana in particular, has been recognized as a path affecting the financial sector and bringing financial services access and use to the doorstep of people, notably for poor and vulnerable households (Bukari and Koomson, 2020;

Demirgüç-Kunt et al., 2018; Koomson et al., 2020a). Historically, Ghana had about six mobile network operators (MNOs) – Airtel, Vodafone, Expresso, MTN Ghana, Glo Ghana, and Tigo – to provide internet and flexible phone call services to the people. Today, Ghana has fewer MNOs due to market competition and other MNOs' mergers over time.

In 2008, the government of Ghana implemented policies allowing the MNOs to rollout mobile money as part of the services they render to the Ghanaian people. The goal was to accelerate technologically friendly development in mobile payments, increase access to finance and credit, expand financial inclusion, and get the country to a cashless payment system. Table 1 shows the phases in which each MNO added mobile money as part of their services. MTN Ghana is the first MNO to rollout mobile money service in Ghana, followed by Tigo Ghana, Airtel Ghana, and Vodafone Ghana in that order.

[Table 1]

Mobile money and financial life of Ghanaians

Mobile money has thrived in Ghana for over a decade. But available data that documents the individuals' financial lifestyle and interaction with mobile money is spare or, in most cases, not well documented. Report on mobile money from the national level is either recent or at the aggregated level. For example, in 2021, the Bank of Ghana reports that there were about 40.9 million registered mobile money accounts and 43% of that number were active accounts. Also, Ghana was one of Africa's fastest-growing mobile money markets (IFC 2022). While registered internet banking accounts declined, registered mobile banking accounts increased that year.

In 2010, Ghana's adult financial inclusion stood at 44%. Ghana sets a target to ensure that 85% of its adult population is financially inclusive by 2025 (Ghana News Agency, 2022). Through

mobile money, Ghana is on track to achieve that target. As of 2022, the adult unbanked adult population stood at 19%, accounting for about 5.9 million. The 2021 Demand Side Survey in Ghana (DSS) conducted by the Ministry of Finance through FinMark shows that out of the 19.7 million adult population[5] that are termed as financially inclusive – that is, they are served either by the formal banks or non-bank financial institutions – mobile money accounts for more than half (65%) of this population (Ghana News Agency, 2022).

Ghana is making progress in ensuring that everyone is financially inclusive, but there is still work to be done. Today, about 5.9 million people are not financially inclusive (Ghana Business News, 2022). Of this number, 19% are people with no formal education, 12% with primary education, secondary education 57%, 4% with vocational or specialized training, and 8 % with tertiary education. Other qualitative studies show that most people in the rural areas that do not have direct access to mobile money services also fall into financial inclusion difficulties. Mobile money is still new in Ghana but impacting the people's lives. To add to the sparse literature that documents individual's interaction with mobile money, since such information is not well established, we undertake a field study to document some of these effects.

A field exploration of mobile money penetration in Ghana

Despite the positive effect of mobile money on ordinary Ghanaian lives, there is still limited quantitative evidence on the individuals' interactions with mobile money in relation to their success and challenges stories for using it. An important question that has implication on mobile money use is, are there differences between individuals actual and expected access to finance and credit if people

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[5] Age 15 years and above.

can access mobile money at a minimal interest rate and pay later? How large would expected credit access be and what would people invest such an amount in? We answer these questions using a field study on a sample of Ghanaians' understanding, attitude, and interaction with mobile money.

We randomly sample individuals and mobile money agents from various locations in Ghana for this study. We used the Qualtrics platform to send our survey to respondents. The survey consists of two questionnaires: one for individuals and another for mobile money agents. We use snowballing approach to reach out to our sample respondents. The individual and mobile money agents sample stood at 44 and 46, respectively. One qualification for a person to qualify to take the survey is if the person owns a mobile phone. In addition to the survey, we conducted interviews to source further information where necessary.

Summary of findings from the field exploration

Appendix figures A3-1 and A3-2 show the distribution of the respondents we randomly sampled for the study. The distribution indicates that respondents' views represent broader coverage of the country. Figures A3-3 and A3-4 present the distribution of the share of the MNOs' mobile money accounts operated by mobile money agents and individuals. MTN Ghana is the leading MNO having a larger share of accounts operated by mobile money agents, followed by Voda cash and Airtel/Tigo cash, respectively. Similarly, more than half of the respondents use MTN mobile money accounts, followed by Airtel/Tigo cash and Voda cash. The mobile money service account operated by mobile money agents and individuals shows that MTN Ghana dominates and has the largest market share compared to the other MNOs. This evidence puts MTN as the MNO with the largest market share in Ghana. Among the many reasons to account for this market capture by MTN Ghana is that they are the first MNO to enter the Ghanaian market.

Figures A3-5 and A3-6 report respondents' education level and economic activity distribution. Most of the people, about 48 percent, have basic education, and 23 percent have no education level. Regarding economic activity, about 66 percent of the respondents are farmers, 16 percent are traders, 7 percent are businessperson, and 11 percent are in other forms of activities. We can infer from Figures 4 and 5 that most people are farmers, and most have basic education. This evidence echoes our initial assertion that most households who engage in agriculture production for subsistence purposes are vulnerable individuals who have only basic education. These attributes are important when it comes to accessing credit or financial assistance from the traditional banks. Such people normally face challenges and most of them normally do not meet the traditional banks' requirements.

We ask respondents about the usefulness of mobile money to them. Most of the respondents find mobile money useful and most of these people are either farmers or do work that is agriculture related. Most respondents find mobile money useful particularly due to convenience and timely access to meet needs (See Figure A3-7, A3-8). Again, as supported in other existing studies, we find mobile money product is used for multiple things by the respondents. The most frequent use is for mobile phone call credit recharge (known as internet bundle or voucher recharge browse internet or to make phone calls). Other frequent use of mobile money includes sending and receiving money through phones is the next most use of mobile money, followed by payment of any kind (e-voucher payment, prepaid airtime, pay bills), then for savings, loans, and insurance, in that order.

Below are sample statements from farmers in response to mobile money use:

> *"If you need something for your farm, you can send money on your phone for someone to buy what you need. My neighbors do that a lot."*

> *"Anytime I am financially in need, the first point is to borrow money and pay later."*

> *"I needed some chemicals sometimes to use on my farm. And I send money to seller through my phone. It was helpful since I do not need to travel there."*

[Figure A3-7 to A3-9]

Table A-1 presents a report of respondents' interaction in terms of frequency of mobile money use, account ownership by gender, and perception regarding mobile money service in comparison to the formal banking system. All the respondents we interviewed have mobile money accounts and are active users. Most people use the service once every month. One reason the majority use the service once a month is that most of the users are aged (average age is 43) and are also farmers who make up most of the respondents. These people usually use the service when their children send them money, mostly at the end of the month. We ask how people compare mobile money to the banking system regarding service delivery. Most respondents find mobile money more convenient and easier to use compared to the banking system.

[Table A2-1]

Unconstrained credit access and finance access

One unique attribute of mobile money is its quick access to small amounts of money in times of need. Table A2-2 presents a summary of transactions between individuals with mobile money agents and the amount of financial assistance individuals and mobile money agents are willing to borrow at no interest. Respondents were asked if they have a mobile money account, if the account is active, and whether they have applied for loan before. If they have applied for loan using mobile money, and how much. Row 4 column 3 shows the average amount of financial assistance respondents borrowed as loan amount. The maximum amount respondents ever applied for is Ghc2000 ($150). The average loan amount respondents have applied for is Ghc613 ($50). Most of the respondents are farmers. We

14

asked these individuals if they could borrow money at no interest but pay later, how much they would borrow and for what purpose such money would be put to use. Overall, we see an increase in the money people would borrow if they could pay later at no interest. On average, our sample respondents indicate that if they could borrow at a low interest rate and pay later, the expected amount could be about nine times the actual amount they have already borrowed. Reasons people give for access unconstrained credit include business expansion, investing in farm activity to increase revenue generation. Respondents who are farmers are likely to invest the credit in their farm activity to reap benefit as possible as they can.

[Table A2-2]

The descriptive evidence suggests that if people have access to unconstrained credit – in this case, credit at minimal or no interest rate – they can add value to their lives. Offering credit or financial support in the smallest means to the people at a lower rate of interest could open opportunities to many poor and vulnerable people. We see evidence of this in the effect of mobile money. People are transforming their lives in many ways – taking up job opportunities as mobile money agents or accessing smaller credits to meet their economic activity needs.

Data Sources and Measurement

We empirically test the effect mobile money rollout (exposure) on household financial inclusion and ag-investments using four main data sets: the number of mobile money agents per district, geographical coverage of mobile money service, three rounds of the Ghana socioeconomic panel survey and grided population per district for Ghana. We use the geographical location coverage of the mobile money service to link the household and district datasets. This approach allows us to determine the availability of mobile money service of a share of the population in each district.

Mobile Money Agent Dataset: The mobile money agent (Mobile money agent is a person who serves as an intermediary to carry out business between the mobile network operators and the people to facilitate the traction of financial products and other services from the telecommunication companies to the people) dataset is a dataset on the number of mobile money agents per district. It is a yearly dataset observation from 2012 to 2020 collected by the Ghana government (Bank of Ghana). This dataset has the number of mobile money agents that opened an account with any of the telecommunication networks and active agents who opened an account with the telecommunication networks and operate it at least once in a year of account opening.

Mobile Money Service Coverage Dataset: The mobile money service coverage data is extracted from the OpenCelliD database of cell towers. The OpenCelliD is the world's largest open database of cell towers that provide cellular networks. The cellular towers locate devices without GPS and explore mobile operator coverage. The database offers the opportunity to identify devices to network coverage by mobile network operators. We use mobile money service coverage (or availability) to identify our treatment variable instead of mobile money service access. Access would mean the individual has an active and registered mobile money SIM card that can be used in a mobile or smartphone to access the service. Using coverage is unique in this study because coverage decision is not determined at the household level. Additionally, coverage is critical to explore spillover effects other than the direct impact of the individuals using the mobile money service. Spillover effects may include service users' information sharing with non-users, and productivity gains, for example, among farmers due to flexibility in the use of the service, among others.

We compute the mobile money service dataset based on two components: mobile networks service availability and whether the network has and add-on mobile money product.

Telecommunication networks have two primary components: core network and radio access network. The former ensures network intelligence, including switching and routing user calls or data to and from the internet. The latter is the collection of relay sites (radio access network) that links the network user's phone to the core network. And through electromagnet signals, real sites are able to communicate with user's mobile phones at a particular location. The network communication link process (availability and quality of the network) can be affected by several factors, including geographical landscape, distance between the relay site and the user's mobile phone location. Geographical location is deemed covered when the location has any relay sites signal strong enough to connect mobile phones in that location to create a usable connection. Each year, total coverage (aggregate coverage) of a mobile network is computed by adding up all coverage of all relay sites in the radio access network. We collect aggregate coverage data for Ghana by extracting network infrastructure data directly from OpenCelliD. Each network infrastructure contains the following information geographical coordinates, signal emitting power, antenna parameters, frequency band use, type of technology available, and date of creation.

As indicated before, mobile money service was a nationwide program that came into force in 2008. Table 1 details the period the various MNOs added the service to their operations. To define our treatment and control indicators, first, we identify all mobile network celltowers (see Figure 1). Next, we identify whether the MNO for a particular celltower has rollout mobile money product. If the MNO associated with a celltower offers mobile money product, then we define that celltower as out treatment celltower indicator – that is, a network with mobile money service (MMS); an MNO that has not rollout mobile money product (NMMS) celltower serves as our control network.

Having identified our treatment and control celltowers, we create a 20km buffer around each celltower, as shown in Figure 3. Research shows that the extent of each network infrastructure at a

location can extend to about 5km to 100 km, depending on the nature of the area's terrain. In this study, we use a 20 km buffer around each network infrastructure for all networks. Using 20km is reasonable because regardless of the geographical landscape, a 20km buffer around a network infrastructure can produce a usable network from a phone to a relay site. With this measurement, we are able to define our treatment and control indicator. The novelty of this approach is to isolate the effect of living within a network area and investigate whether exposure to mobile money service plays a key role on household financial inclusion and decision relating to investment in agriculture.

Grided Population for Ghana: We do not know the locations of the households. The household panel data does not include the locations of the households. So, we rely on the grided population at the district level and use that to create share of the population per district per year. Then, we merge this information with the celltower information. The gridded population for Ghana comes from the world grided population density. We use the gridded population density to proxy for household location to network infrastructure. Generally, it would have been clean to use household-specific location information and connect to the mobile network tower. We do not have this information. Therefore, using the gridded population density on Ghana enables us to identify the share of the population that lives within the tower area. The novelty in this approach lies in the fact that we are able to distinguish between three different groups of population and use those as treatment variables for our analysis: share of population that lives 20km withing SMT area, share of population that lives 20km SNMT area, and other population that lives 20km outside SMT and SNMT area. Our variable of interest is SMT and SNMT.

Household Data: The household data on Ghana is from the three rounds of Ghana's Socioeconomic Household Panel Survey (GSHPS) conducted in 2009/2010, 2013/2014/ and 2016/2017. We use this data, in addition to the mobile money geospatial data, to understand household behavior and financial inclusion and their behavior on investment in agriculture. This panel data was collected jointly by Economic Growth Centre at Yale University and the Institute of Statistical, Social and Economic Research (ISSER) at the University of Ghana. The GSHPS collected information on a range of topics including credit and account holdings, agriculture production, socioeconomic characteristics, food security, household consumption, consumption expenditures, non-farm income activities, among others. The objective of the GSHPS was to provide a framework studies or researchers can use to inform medium and long-term economic changes in the country's development process. This panel data tracks households and individuals over time. Thus, we can control for household-specific characteristics. At the time of the survey collection, there were about ten representative regions in Ghana[6]. The original sample size for the first-round survey, conducted (in 2009/2010) of the survey was 5010 from 334 Enumeration Areas (EAs). This same sample was used for the second (2013/2014) and third (2017/2018) rounds of the survey. Each EA representation in the sample was based on Ghana's 2009 estimated population share per region; each EA has 15 households.

The main objective of the GSHPS is to provide a framework for scientific studies of the medium to long-term changes in the Ghanaian economic landscape in the development process. The survey collected extensive topics on households, communities, and districts. Topics the survey covered include demographic characteristics, employment, time-use, health, migration, asset, savings, lending and borrowing, risk attitudes, non-farm enterprises, agricultural production activities, education, credit, savings, etc. This study focuses on topics relating to credit and finance, agriculture investment,

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[6] Note: As of 2020, Ghana has 16 regions

and other household demographic information. Table 4a is a summary of variables of interest on both our treatment and outcome variables.

Empirical Strategy

We discuss the empirical approach we use in this study, highlight important assumptions and other potential threats to the estimation process. This study's focus is straightforward: we are interested in assessing whether exposure to mobile money coverage affects household welfare. Specifically, we investigate the effects of mobile money coverage on financial inclusion and agriculture investment and whether the effects differ by some household characteristics. But, identifying effects of mobile money coverage on financial inclusion and agriculture investment might have endogeneity concerns because exposure to the coverage is not (in this case, coverage serves as our treatment indicator) random. First, for a location to have mobile money coverage, the location already has mobile network service (also known as mobile broadband service coverage). Without the presence of mobile broadband coverage, mobile money coverage would not happen. Having mobile broadband coverage is a necessary condition for mobile money coverage. Secondly, households residing in locations with access to mobile broadband coverage might be distinct from households without mobile broadband coverage since mobile network (broadband internet needed to ensure the operation of mobile money service) is provided by profit-maximizing firms whose objective is to supply service where maximum economic benefit is expected. Thus, households that live closer to a mobile broadband coverage area are more likely to consume the product.

We overcome these endogeneity concerns by taking advantage of temporal and spatial variation in exposure to mobile money coverage by applying a fixed effect approach that offers us the opportunity to capture the outcome of the households that live in locations that are exposed to mobile

money coverage and those that within similar locations but are not exposed to mobile money coverage. Without mobile broadband availability, there would not be mobile money coverage. Therefore, mobile broadband coverage is the first step leading to our assumption. That is, households located in places with mobile broadband services are assumed to be comparable. We estimate the effect of mobile money service effect on household financial inclusion denoted by beta as stated in equation (1):

$$Y_{idt} = \alpha_1 + b_1 smt_{dt} + b_2 snmt_{dt} + \theta X_{idt} + \alpha_i + \alpha_t + \epsilon_{idt} \quad (1)$$

Y_{idt} (FI, Ag-investment, Crop diversity) is the outcome for household i in district d at year t smt_{dt}: share of population that lives 20km within a MM celltower in district d at year t, $snmt_{dt}$ is the share of population that lives 20km within a non-MM celltower in district d at year t, X_{idt}: time-varying controls (HH size, access to electricity, dwelling ownership …), α_i is household fixed effects, α_t : year fixed effects and ϵ_{idt}: error term. snt_{dt} and $snnt_{dt}$ are the variables of interest and therefore interpreting b_1 and b_2 as the effect of household that lives within a mobile money service area and non-service area on financial inclusion in that order.

While mobile money coverage might directly affect ag-investment, we investigate whether financial inclusion could mediate the effect. In equation 2, we estimate the effect where we interact financial inclusion with both our treatment and control variables.

$$Y_{idt} = \alpha_1 + b_1 smt_{dt} * FI_{idt} + b_2 nmt_{dt} * FI_{idt} + \theta X_{idt} + \alpha_i + \alpha_t + \epsilon_{idt} \quad (2)$$

Where FI is financial inclusion and all other variables are as before.

Identifying assumptions

As indicated above, mobile broadband coverage is a first step for mobile money service; we assume that households located in places with mobile broadband services have similar characteristics and are assumed comparable. Next, we assume celltower data is randomly distributed between mobile and non-mobile money celltowers. A noteworthy point in our identifying assumption is that differences in our treatment and non-treatment indicators are accounted for through the time-variant characteristics – the X variables – or time-invariant characteristics – household fixed effects. That is, conditional on time, household fixed effects and household time-variant characteristics contained in X, coverage timing is orthogonal to unobserved characteristics related to economic development. Standard errors clustered at the district level.

We account for spatial and serial correlations in the panel estimation by adapting Hsiang (2010) and estimate adjusted least-squares standard errors for spatial correlation as outlined in Conley (1999) and Conley (2008). The approach allows for serial correlation over all periods and spatial correlation among units that are within a certain distance of each other. Cameron and Miller (2015) argue that failure to account for such dependence can significantly affect estimator precision, leading to incorrect conclusions.

Other possible threats that could arise include the following. Mobile network operators might target specific areas with economic or expected economic development. These could have some regional trends correlate with outcome variables. We control these effects by including non-linear and non-linear time trends on household observable characteristics, as Abadie (2005) suggested.

$$Y_{idt} = \alpha_1 + b_1 smt_{dt} + b_2 snmt_{dt} + (b_3 smt_{dt} + b_4 snmt_{dt}) * D + \theta X_{idt} + \alpha_i + \alpha_t + \epsilon_{idt} \quad (3)$$

Where D is a binary indicator $= 1$ if rural (female) or 0 otherwise (male). All other variables are the same as before.

Summary statistics

Table 2 reports definition and measurement of key variables, and Table 3 reports summary statistics of key variables of interest at the district and household levels. Financial inclusion is measured as an index of four financial services – savings account ownership, loan access, credit access, and remittance. The four financial services are binary measures that indicate whether one has and/or uses the product. The share of population variable is measured in percentage of people who live within a 20km network or non-network area per the total population. The year of the mobile money service rollout thus covers the various waves of the Ghana socioeconomic household survey (i.e., wave 1 2008/2009, wave II 2013/2014, and wave III 2016/2017). The distinction between the mobile money service coverage periods and the three waves of the Ghana socioeconomic panel survey is important for empirical identification purposes. We see that about 27, 37, and 34 percent of the household in waves I, II, and III respectively indicate access to loan, about 42, 51, and 56 percent of the household indicate remittance use, about seven and five percent have access to credit, and 32, 41, and 47 percent are owners of savings account of any form. On average see an appreciable increase in access and use of financial products as we can see from the financial inclusion variable. On average, financial inclusion for waves II and III were about 24.1 and 31.4 percent higher than wave I (wave I =1.08, wave II=1.34, Wave III =1.42). Thus, the increase in financial inclusion over the three waves supports our earlier assertion that, on average, there has been an increase in access and use of financial products over the years 2009 to 2017. We note again that access and use of financial products and financial inclusion indicate an appreciable increase in the use of the products and services, and the evidence cannot be

trivialized. The increase in the use of financial products is more pronounced, especially in wave II, the period when Africa and Ghana, particularly, experienced a big wave of mobile money. The increase access and use of financial services is nonrandom, as a t-test we carried out rejects the null hypothesis of no relationship between the products and the time periods. On average, the share of the population that lives within a mobile money service coverage area is 21, 67, and 77 percent while the share of the population that lives within a non-mobile money network service area is 16 and 61 percent.

Regarding household level variables included to control for any confounders, at the baseline (wave I), age of the household head was 47 years old, and 77 percent male-headed households, more than half of the household heads (52%, 54%, and 56%) are owners of their dwellings, have access to electricity, and own phones. About 60 percent reside in rural areas with an average household size of approximately four people. The age of the household head increases in waves II and III (50 and 53 years respectively). We note similar patterns of increase in dwelling ownership, electricity access and phone ownership in waves II and III. However, average household size remains relatively constant across the three waves.

Crop diversity (measured as the number of crops grown and the Simpson diversity index) and household dietary diversity score (HDDS) are crop and food group indexes, respectively. While crop diversity records a decline from wave I to wave III, HDDS shows a constant pattern overtime. For instance, we note that average crop diversity in wave I is about two crops (1.49), one crop (0.96), and about two crops (1.18); average HDDS for waves I, II, III are 10.37, 10.37, and 10.13 respectively.

[Tables 2, 3]

Results and Discussion

This section highlights the relationship between financial products and services access and use, financial inclusion, and the effect on agriculture investment and food security. Other robustness checks are also discussed. We test for differences in our assumption that households located in places with mobile broadband services have similar characteristics and are assumed comparable. Our panel data has 3 waves – wave I (2008/2009), wave II (2014/2015), and wave III (2016/2017). Mobile money came into effect in Ghana in 2009, but the big news about mobile money adoption happened around 2015. So, we use the panel data, wave I, as our baseline balance test. Table 1 reports the baseline balance of the outcome variable and other important covariates. The treatment indicator represents districts with the most MM celltowers, and the control indicator represents districts with the most non-MM celltowers. Overall, the districts with the most MM celltowers and non-MM celltowers are comparable. Only loan access and savings account ownership are the variables that are different from the treatment and control. Thus, we are confident that households located in places with mobile broadband services have similar characteristics and are comparable.

[Table 4]

Mobile money coverage, credit, and financial inclusion

We explore the relationship between the effect of mobile money coverage savings, loan access, account ownership, and remittances. We employ fixed effect estimation technique to examine these relationships; the results are presented in Appendix Table A2-3. Overall, we see a positive relationship between our treatment indicator (SMT) and a negative relationship on our control indicator (SNMT) among loan access, remittance, access to credit, and savings account ownership. By inference, if household is in places where there is mobile money coverage, there is the likelihood for people to access financial products such as loan, remittance, access to credit or to own a savings account.

25

However, we find a negative relationship between exposure to celltower that does not offer mobile money service and use of financial products.

Figures A3-10 shows that mobile money adoption in Ghana has been slow in the early years, but the later years received acceptance, as indicated in the trends of mobile money agents before 2015. Many African countries, including Ghana, accepted mobile money during that period. Figures A3-11 and A3-12 show financial inclusion and investment trends from the household panel data. Each hollow represents a household's average financial inclusion or ag-investment in a district for a particular wave. We see a gradual increase in financial inclusion and ag-investment overtime. These periods are the early periods mobile money was gaining momentum. Among the questions we ask is controlling for all other changes happening, can we see the effect of these changes because of the mobile money coverage. This led us to our empirical examination of the effect of mobile money coverage on financial inclusion and ag-investment.

Now, we explore household behavior induced by the changes in mobile money service rollout on financial inclusion. Equation (1) estimates of parameters betas 1 and 2 results from the fixed effects estimation are presented in Table 5. Table 5, column (1) does not control for household characteristics. Table 4 column (2) reports the same estimates from equation 1, same as column (1), but controls for household controls and household fixed effects. The estimated coefficients are economically meaningful. The results in columns (1) and (2) are similar, but due to household heterogeneity concerns, column (2) is our preferred model. Based on our fixed effect specification, we find that all other things being equal, a percentage increase in the share of household that lives around a mobile money service area increases financial inclusion by about 20 percent.

On the other hand, a percentage point increase in households near network towers that do not offer mobile money services decreases financial inclusion by about 15 percent, but the effect is insignificant. We test whether the estimated coefficients of the treatment variables are different from

each other. At five percent significance level, we reject the null hypothesis that the difference between the estimated coefficients of our treatment variables is zero.

[Table 5]

Mechanism associated with mobile money coverage and financial inclusion

We disaggregate the mobile money effect on financial inclusion by location and gender. Table 6 column (3) reports the fixed effect result of this mechanism. We find no effect between the interaction of our treatment and control indicators and location (rural versus urban areas). But we see a significant effect between our treatment, control variables, and gender. The interaction effect of mobile money coverage (non-mobile money coverage) and women has a negative (positive) relationship on financial inclusion. The total effect of mobile money service (non-mobile money service) for female groups is positive (negative) compared to their male counterparts. The overall effect of mobile money coverage and gender suggests that financial inclusion for female groups overtime has increased but at a decreasing rate. Another reason to account for the smaller overall effect for the female group compared to their male counterpart could also be explained by a lower probability of most women in Africa for adopting mobile broadband (Rodriguez-Castelan et al. 2021).

Combining the above results, we can say that mobile money coverage drove significant effect on financial product usage (savings, loan access, credit access, and remittances) in Ghana and that had a gain on financial inclusion. The evidence is consistent with previous studies. The findings so far are explained by individuals' willingness to use the mobile money product once there is coverage. While individual study on mobile service use is not available in the Ghana socioeconomic panel survey, we carried out a field study we carried out in August 2022 to investigate the use of mobile money in 2022. Most of the respondents who have mobile accounts were male (55%) compared to women (45%) (see

Table A2-1). The field study reveals that mobile money use has potential and many beneficial outcomes, including time-saving, meeting emergency financial needs, and flexibility (Figure A3-7).

[Table 6]

Mobile money coverage and agriculture investment

We report the effect of mobile money coverage on ag-investment by estimating equation 1 (see Table 7 column 1) and equation 2 (see Table 7 column 2). Column 1 reports the direct effect of mobile and non-mobile money coverage on ag-investment. In column 2, we interact our treatment and control with financial inclusion. Early estimates show no effect between mobile money coverage and ag-investment. Still, we find a negative effect of the celltowers without mobile money coverage and ag-investment. One plausible reason to account for no direct effect between mobile money coverage and ag-investment could be that coverage alone might not be enough to stimulate household decisions to invest. Mobile money coverage might not directly affect ag-investment but can mediate through other channels. We evaluate this by interacting mobile money coverage with financial inclusion and report these results in Table 7, column 2. The estimated coefficients suggest that mobile money coverage interacted with financial inclusion positively affects ag-investment. By inference, if there is mobile money coverage, and we see improvement in financial inclusion, then we can expect a positive influence on households' decision to invest in agriculture. The reason behind this mechanism is that when there is coverage, one can easily access finance and credit, which might trigger farmers need to use it during the planting season. Hence, if mobile money coverage increases access to and use of financial products and credit, there is potential for a positive effect on agriculture investment.

[Figure 7]

Mobile money service, ag investment, crop diversity, and food security

As reviewed in the earlier sections, we have seen suggestive evidence that exposure to mobile money coverage affects financial inclusion and can affect ag-investment if there is access to financial products and services. Other mechanisms effect of coverage can have might include crop diversity and food security. Table 8 reports evidence of MMC and ag-investment on crop and household dietary diversity. We use MMC as an instrument for ag-investment since we see that MMC does not directly affect ag-investment but through financial inclusion. We find ag-investment to have mixed effects on crop diversity and food security. There is a positive relationship between ag-investment and food security, even though the effect is insignificant.

[Table 8]

Conclusions

The agriculture sector agriculture continues to play a vital role in Africa's economy. It serves as a major economic activity for most poor and vulnerable people, especially those living in rural areas. One major challenge confronting agriculture activity for most vulnerable people is the lack of productive investment, including access to financial and credit facilities. Something that is accessible when people are financially inclusive. As a result, agriculture activities are usually on a smaller scale and most households miss out potentials on increased output. But whether lack of productive investment in agriculture is tied to factors such as financial inclusion is an under-explored area. Ghana has taken drastic measures to ensure that all adults population are financially inclusive. While the country has made progress in closing the gap in financial inclusion, there remains a challenge; some people still face difficulty accessing financial and credit products that meet their needs promptly. In this study, we look at how mobile money expansion affects financial inclusion and ag-investment. Ghana is a good

candidate for this study because bringing the gap in financial inclusion among the poor and vulnerable people is one of the pressing issues on the government's radar.

We leverage rich nationally representative household panel survey data and link it with mobile money coverage overtime for Ghana to explore mechanisms through which mobile money expansion has affected financial inclusion and ag-investment. The results show that mobile money coverage is positive and significantly influences financial inclusion and increases investment in agriculture, especially for rural folks where farming is a major activity. If a household is exposed to mobile money, there is a probability for improved financial inclusion, which can have positive implications for agriculture investment. We find positive effect on investment in agriculture resulting from the interaction effect of mobile money coverage and financial inclusion. This study's findings are consistent with existing studies that have found similar effects using mobile broadband in other African contexts—a sign which reassures the key role of mobile money in delivering on its promise.

We also explored the relationship between mobile money coverage on crop diversity and food security. We see a positive association between mobile money coverage, crop diversity and food security. An increase in ag-investment positively affects crop diversity and household dietary diversity. These results are corroborated by the field data we gathered from Ghana on mobile money use and the interactions people have with mobile money. Evidence from the study indicates that if people have access to unconstrained credit, they will invest in the activities they do. Individuals for whom agriculture is their main economic activity indicate to invest in their farm activity to increase yield. We conclude from this study's evidence that one of the constraints that can keep most poor and vulnerable people from reaching their potential can emanate from financial inclusion and evidence using the expansion of MMC and a field study on Ghana. Putting the pieces of the results in this study together, we can deduce that if people are exposed to innovative financial products and services, such as mobile money, and can have access to these products to meet their financial and credit needs on a timely

manner, it can have significant impact on the people's wellbeing. In summary, when you give people credit and financial products that meet their needs, especially for those living in locations where agriculture is their main source of livelihood, they can be better off.

Our findings are relevant to the growing literature on mobile money in developing countries and financial inclusion, and mobile money service and ag-investment on the other hand. Specifically, we contribute to the discussion of the role of mobile money and financial inclusion. Most studies have primarily focused on the effect of mobile technology on financial inclusion such as improvement to business, management, and market information (Aker and Mbiti, 2010; Jensen, 2007), Mobile penetration on financial inclusion (Andrianaivo and Kpodar, 2012). While there is limited evidence on the direct effect of mobile money on financial inclusion (Ahmad, Green, and Jiang, (2020), our study focuses on the role of mobile money expansion using coverage which is a step beyond just mobile internet availability or mobile banking while controlling for spatial dependence. The novelty in our approach is worth highlighting in the literature, given that the primary means to access mobile money services is through mobile internet service coverage and mobile phones.

Our study also contributes to the broader literature studying the economic effect of mobile technology on rural households' welfare in developing countries (Wiser et al., 20.19; Tavneet and William, 2016; Kalvin et al. 2021) and mobile money adoption and input use and farm output (Abdul-Rahaman and Abdulai, 2022). Our study focuses on the effect of mobile money coverage on household welfare through household investment on agricultural production. We focus on the total investment household put into their farm decision during planting season and the effect on crop diversity and household diet.

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Tables and Figures

Table 1

Year of Mobile Money Rollout by MNOs in Ghana

Network	Coverage	Period
MTN Ghana (called MTN momo)	Nationwide	Jul-09
Tigo (called Tigo cash)	Nationwide	Oct-10
Airtel Ghana (called Airtel money)	Nationwide	Apr-10
Vodafone Ghana (called Voda cash)	Nationwide	Mar-15
AirtelTigo meager (called AirtelTigo cash)	Nationwide	Apr-18

Source: acquired from the bank of Ghana in 2020

Table 2

Summary of selected variable of interest

Variable(s)	Definition	Measurement	Data source
Ag-investment	It is the total count of investment – plots, plough, seed, chemical - households invest in during the last planting season	Continuous	GSPS: All three waves
Financial inclusion(FI)	An index of four financial products – savings account ownership, access to loan, access to credit, remittance	Continuous	GSPS: All three waves
Mobile money service (MMS)	Two treatment: A: share of households that live within 10 km of service coverage areas B: share of household that live within a 20km area of non-mobile money service area C: control group	Continuous	Cell towers, Population density
Food security (FS): Household dietary diversity	An index of all 12 crop groups	Continuous	GSPS all wave
Crop diversity: A: Crop counts B: Simpsons diversity index	A: Counts of all crops planted on a size of plot in the previous season B: An index of all crops which takes into account number of crops present, as well as the relative abundance of each crop	Continuous	GSPS all waves

Table 3
Summary Statistics

Variables	Wave I (2009/10)		Wave II (2014/15)		Wave III (2017)	
	Mean value	Std. ev.	Mean value	Std. dev.	Mean value	Std. dev.
Loan access	0.27	0.44	0.37	0.48	0.34	0.47
Remittance	0.42	0.49	0.51	0.50	0.56	0.50
Credit access	0.07	0.25	0.05	0.22	0.05	0.22
Account ownership	0.32	0.47	0.41	0.49	0.47	0.50
Financial inclusion	1.08	0.83	1.34	0.84	1.42	0.84
Mobile money agent density	0.00	0.00	0.00	0.00	0.01	0.00
Share of population within MMS area	0.21	0.36	0.67	0.33	0.77	0.28
Share of population within NMMS area	0.16	0.33	0.61	0.37	0.61	0.37
Household size	3.75	2.44	3.46	2.27	3.52	2.27
Location (rural)	0.60	0.49	0.60	0.49	0.61	0.49
Phone ownership	0.56	0.50	0.80	0.40	0.76	0.43
Electricity access	0.54	0.50	0.69	0.46	0.76	0.43
Dwelling ownership	0.52	0.50	0.56	0.50	0.57	0.50
Age	47.42	15.98	50.30	15.87	53.09	15.38
Gender (female)	0.33	0.47	0.38	0.49	0.41	0.49
Crop diversity	1.49	2.05	0.96	1.25	1.18	1.49
Household dietary diversity (HDDS)	10.37	1.73	10.37	1.73	10.13	2.05

Note: the summary statistics reported here are the key variables for our estimated models.

Table 4

Baseline balance (wave I)

	Control	Treatment	
	Mean (s.d)	Mean (s.d)	Std difference
Loan	0.284 (0.451)	0.362 (0.481)	0.167
Remittance	0.480 (0.500)	0.501 (0.500)	0.042
Access to credit	0.055 (0.229)	0.057 (0.231)	0.005
Have savings account	0.449 (0.497)	0.364 (0.481)	0.173
Financial inclusion	1.268 (0.842)	1.283 (0.854)	0.018
Access to electricity	0.740 (0.439)	0.615 (0.487)	0.069
Age	49.830 (15.807)	50.360 (15.983)	0.034
Ethnicity	21.280 (59.562)	21.390 (94.151)	0.001
Religion	3.198 (23.709)	3.848 (14.196)	0.033
Save at home	0.422 (0.494)	0.441 (0.497)	0.038

Balance on outcome variable and important covariates for districts with most MM celltowers (treatment) and non-MM celltowers (control) for wave 1. Standardize difference greater than 0.1 and above is an indication of imbalance between groups (see Austin 2001).

Table 5

Effect of mobile money coverage on financial inclusion

	(1) Financial inclusion	(2) Financial inclusion
Share of household within MMC area	0.223**	0.240**
	(0.105)	(0.108)
Share of household within NMMC area	-0.195*	-0.195
	(0.117)	(0.119)
Constant	1.061***	0.587***
	(0.0283)	(0.159)
Mean outcome	1.277	1.277
Household controls	No	Yes
Household fixed effect	No	Yes
Year fixed effects	Yes	Yes
Observations	10,396	10,332
R-squared	0.052	0.058

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

Table 6

Heterogeneity effect of mobile money effect on financial inclusion

	(1)	(2)	(3)
	Financial inclusion	Financial inclusion	Financial inclusion
Share of household within MMC area	0.223**	0.240**	0.393***
	(0.105)	(0.108)	(0.129)
Share of household within NMMC area	-0.195*	-0.195	-0.349***
	(0.117)	(0.119)	(0.125)
MMC *Rural			-0.109
			(0.154)
NMMC * Female Rural			0.122
			(0.158)
MMC*Female			-0.239**
			(0.102)
NMMC *Female			0.228**
			(0.104)
Constant	1.061***	0.587***	0.595***
	(0.0283)	(0.159)	(0.158)
Mean outcome	1.277	1.277	1.277
Household controls	No	Yes	Yes
Household fixed effect	No	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Observations	10,396	10,332	10,332
R-squared	0.052	0.058	0.059
Number of households	4,081	4,080	4,080

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors are clustered at the district level.

Table 7

Mobile money coverage and ag-investment

VARIABLES	(1) Ag-investment	(2) Ag-investment
Share of household within MMC area (SMMC)	-0.016	-1.021
	(0.452)	(0.637)
Share of household within NMMC area (SNMMC)	-1.239***	-0.417
	(0.400)	(0.534)
SMMC*FI		0.535*
		(0.318)
SNMMC*FI		-0.605*
		(0.345)
Constant	0.954*	1.411**
	(0.550)	(0.639)
Household controls	Yes	Yes
Household fixed effect	Yes	Yes
Year fixed effects	Yes	Yes
Observations	6,812	5,561
R-squared	0.124	0.105
Number of FPrimary	2,776	2,669

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors are clustered at the district level.

Table 8

Effect of Ag-investment on crop diversity and food security

	(1)	(2)	(3)	(4)	(5)	(6)
	Crop diversity	Crop diversity	Simpson index	Simpson index	HDDS	HDDS
	OLS	IV	OLS	IV	OLS	IV
Ag investment	0.208***	0.240**	0.0144***	-0.0143	0.0399***	0.0457
	(0.0166)	(0.118)	(0.00229)	(0.0241)	(0.0114)	(0.168)
Constant	2.557***	2.590***	0.353***	0.432***	9.867***	10.22***
	(0.635)	(0.569)	(0.0681)	(0.0795)	(0.492)	(0.528)
Mean output	1.201	1.201	0.247	0.247	10.294	10.294
Household controls	Yes	Yes	Yes	Yes	Yes	Yes
Household fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,548	6,812	5,548	6,812	5,548	6,812
R-squared	0.225		0.040		0.027	
Number of households	2,669	2,776	2,669	2,776	2,669	2,776

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

Figure 1

Number of network towers as of 2019

Ghana Mobile Tower Distribution, 2008 to 2019
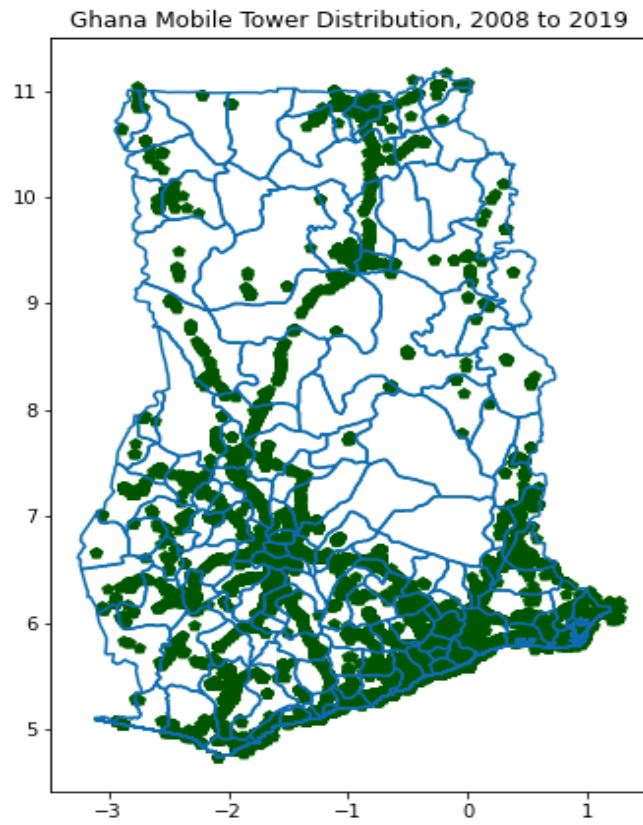
Figure 2

20km buffer around a mobile network infrastructure
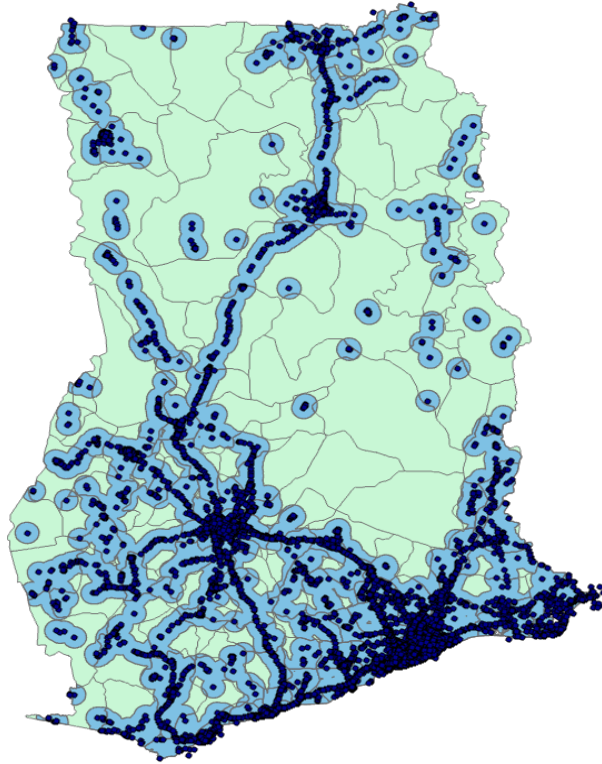
Figure 3: Spatial distribution of treatment and control celltowers overtime
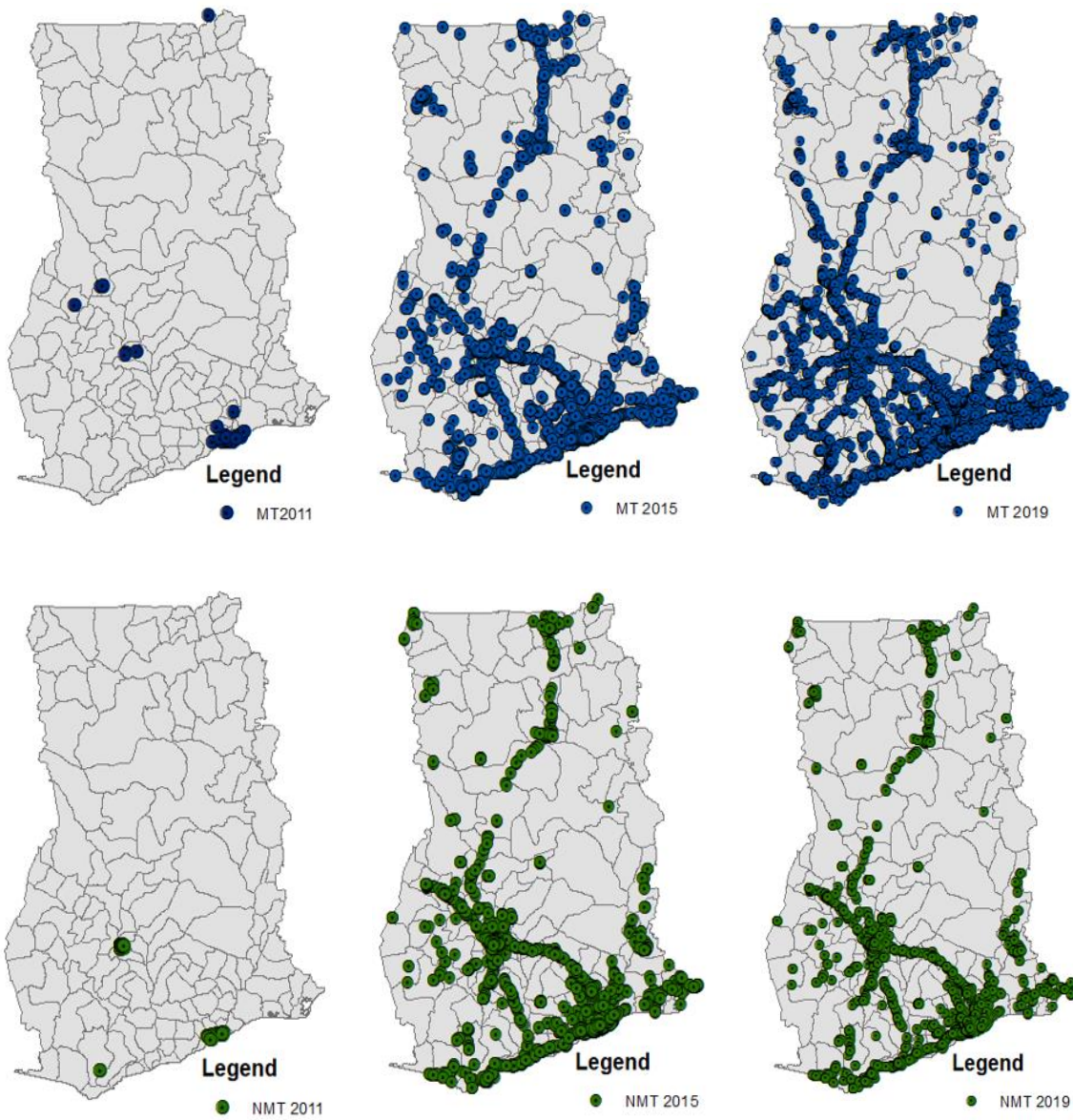
A. Questionnaire for Individuals

B. Questionnaire for Mobile money agents

C. Questionnaire for Mobile Network Operators

Appendix 2: Additional Tables

Table A2-1

Distribution of frequency of mobile money use, account ownership by gender and mobile money use flexibility

	Freq.	Percent
How often you use mobile money		
Every day	5	11.36
Once a week	8	18.18
Twice a week	5	11.36
Every other week	7	15.91
Once a month	19	43.18
Total (N=44)		
Have Momo account		
Male	20	45.45
Female	24	54.55
Total (N=44)		
How is accessing Momo compared to banking institution.		
Very easy	17	38.64
Easy	27	61.36
Total (N=41)		

Table A2-2

Summary statistics for value of mobile money loans applied

Variable name	Obs.	Mean	Std. dev.	Min	Max
Age of agent	46	31.07	7.40	19	52
Years worked as a mobile money agent	38	4.66	2.75	1	10
Recent loan applied by mobile money users (Ghc)	32	613.31	418.39	176	2000
Unconstrained credit (Users: Ghc)	44	5727.27	4716.94	1000	20000
(Dollar equivalent)		$572	$472	$100	$2000
Unconstrained credit (Agent: Ghc)	37	36837.84	47276.24	0	200000
(Dollar equivalent		$3,684	$4,727	0	$20,000

47

Table A2-3

Effect of mobile and non-mobile money coverage on financial products

VARIABLES	(1) Loan	(2) Remittance	(3) Access to credit	(4) Savings account
SMT	0.0577	0.124**	0.0401**	0.0173
	(0.0528)	(0.0508)	(0.0185)	(0.0445)
SNMT	-0.0244	-0.126***	-0.0339*	-0.0101
	(0.0593)	(0.0453)	(0.0179)	(0.0465)
Constant	-0.0130	0.589***	0.0264	-0.0174
	(0.0824)	(0.0938)	(0.0415)	(0.0976)
Household controls	Yes	Yes	Yes	Yes
Household fixed effect	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
District fixed effect	Yes	Yes	Yes	Yes
Observations	10,332	10,332	10,326	10,332
R-squared	0.025	0.045	0.010	0.043
Number of households	4,080	4,080	4,079	4,080

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

Appendix 3: Additional Figures

Figure A3-1, A3-2

Distribution of respondents in Ghana, by mobile money agents and individual

Note: MMA
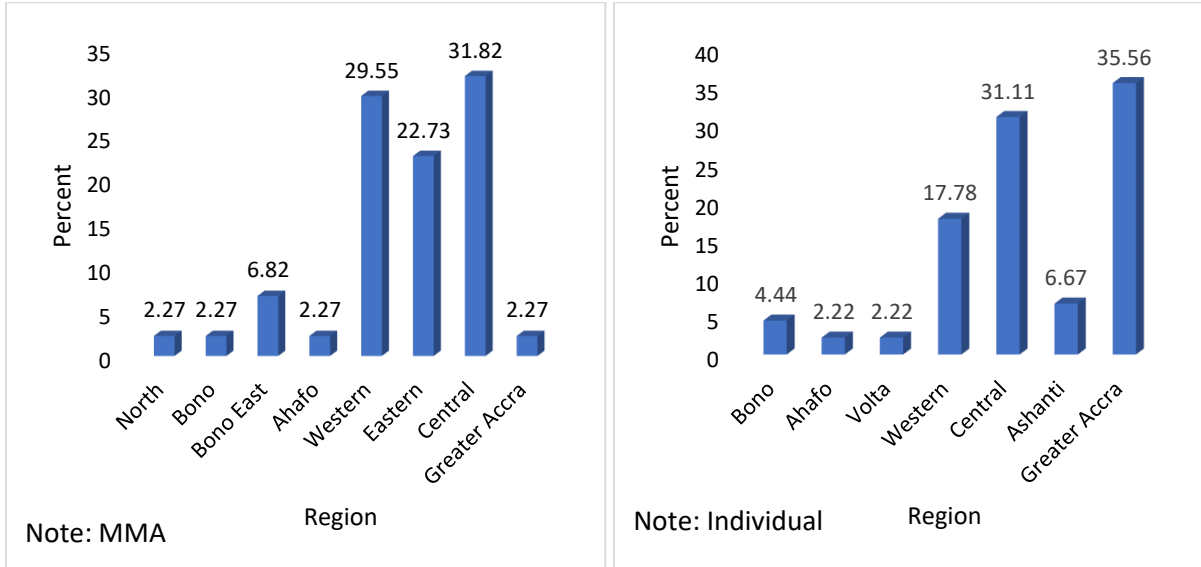
Note: Individual

Figure A3-3

Share of mobile money accounts operated by agents
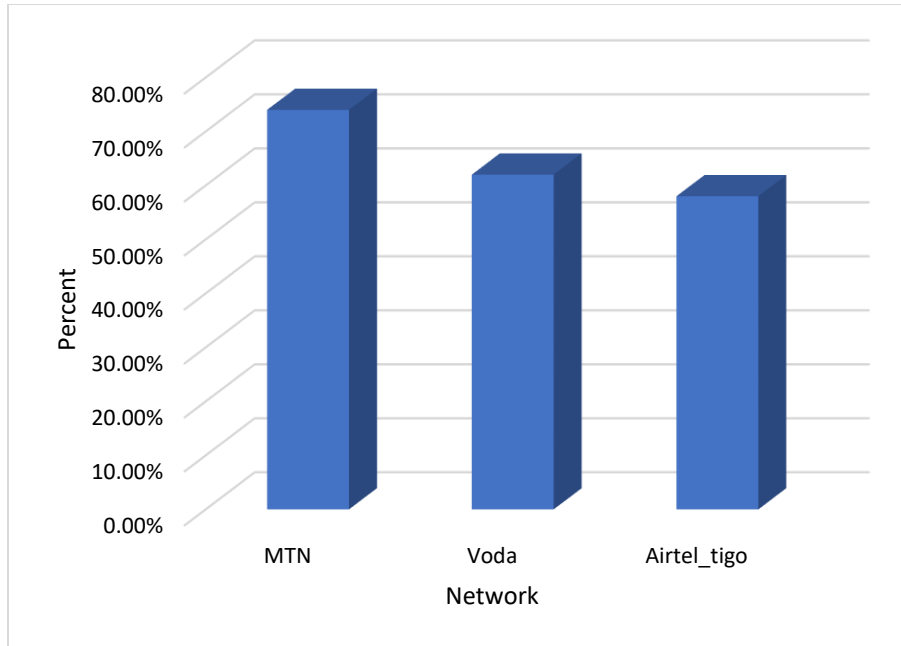
Figure A3-4

Share of mobile money accounts by individuals
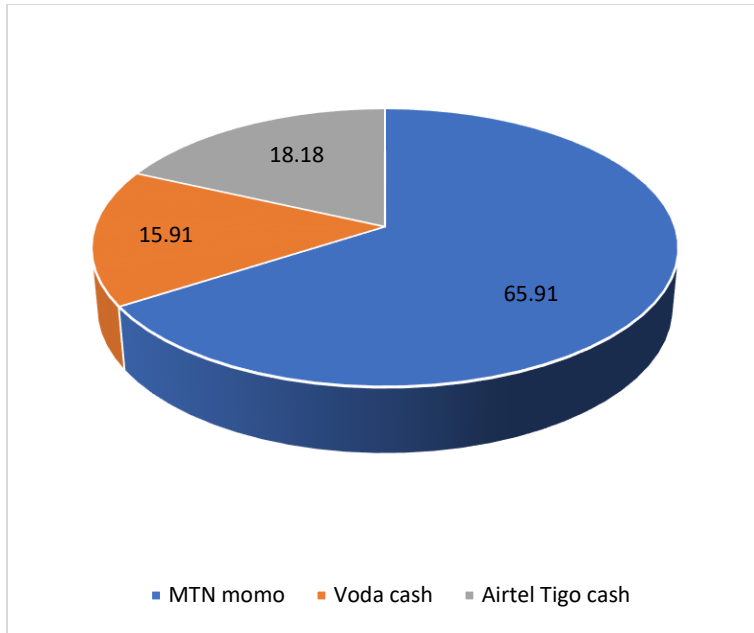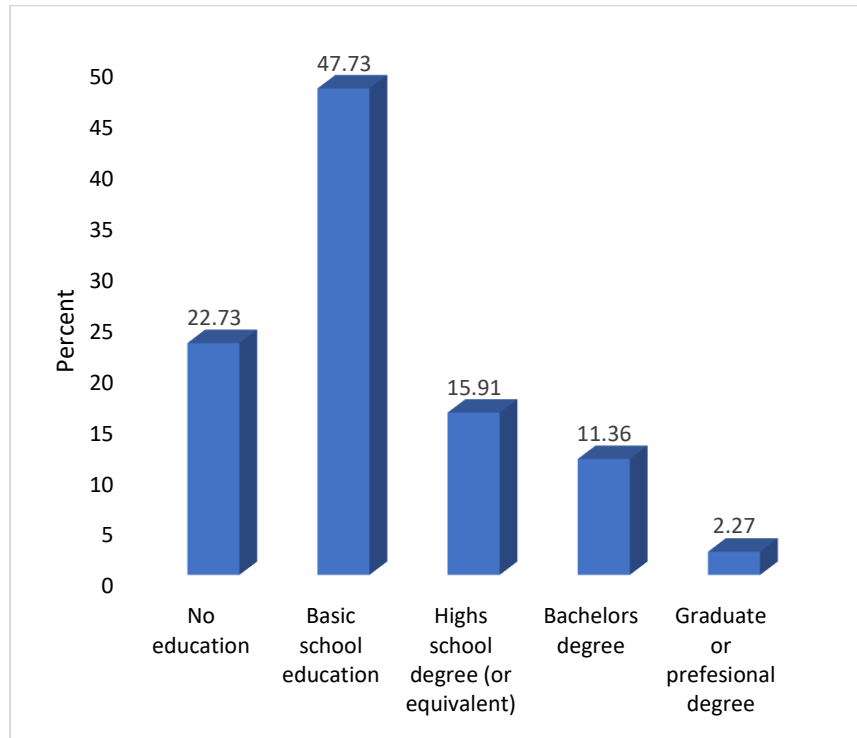
Figure A3-5

Level of education by individual
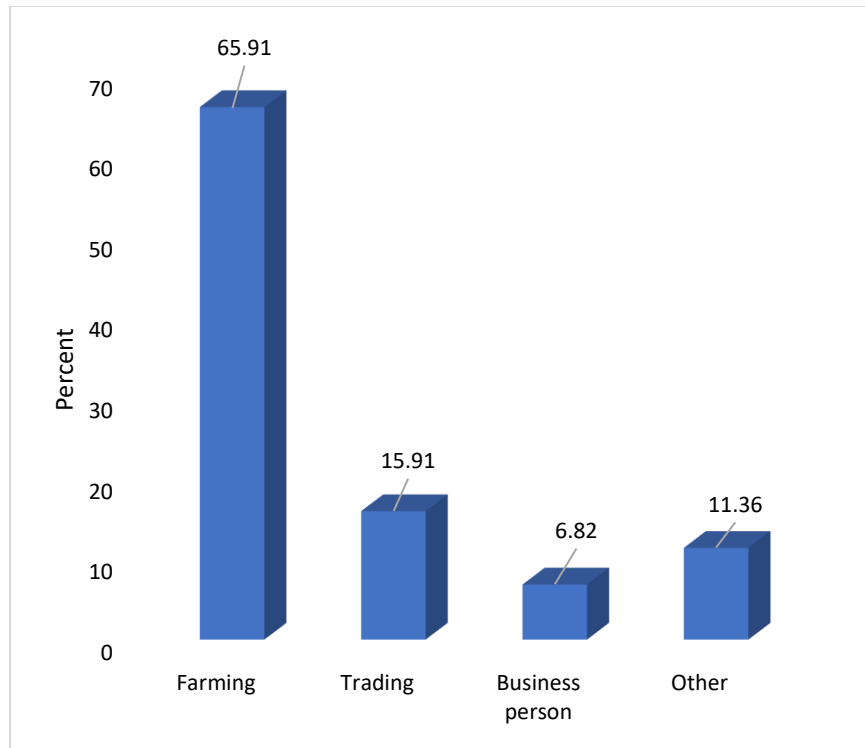
Figure A3-6

Distribution of economic activity

Figure A3-7

Response from respondents about the benefits and why they use mobile money
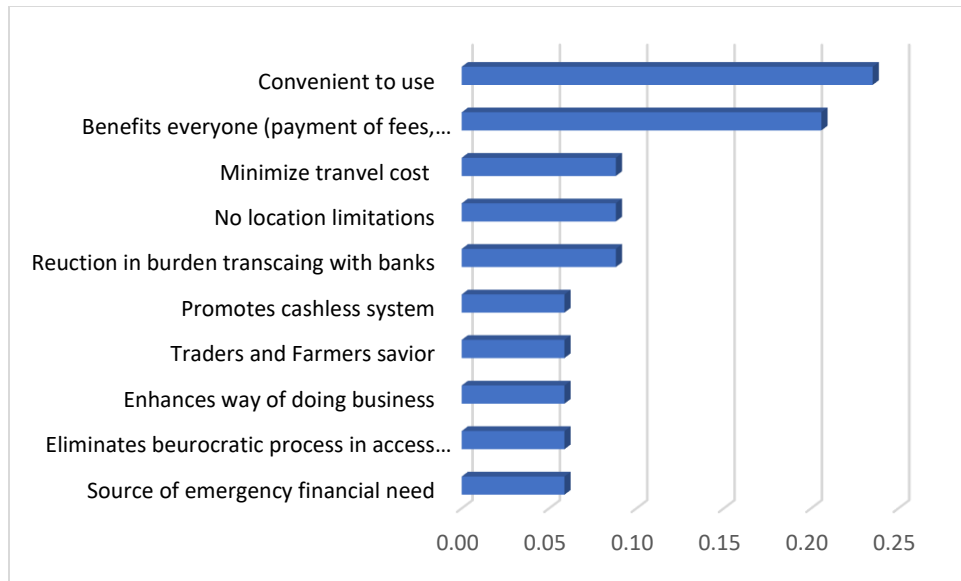
Source: Authors field study report, 2021

Figure A3-8

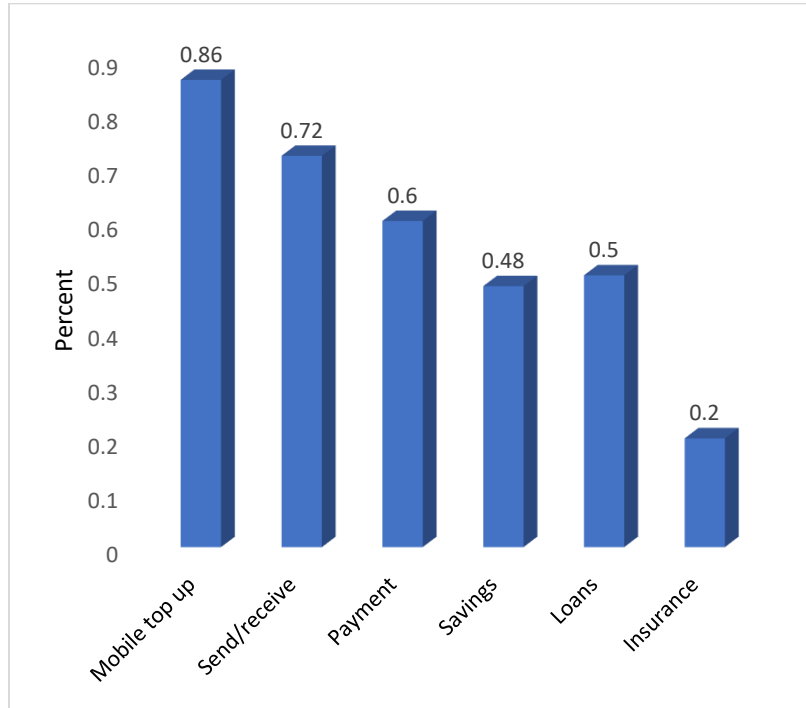Usefulness of mobile money
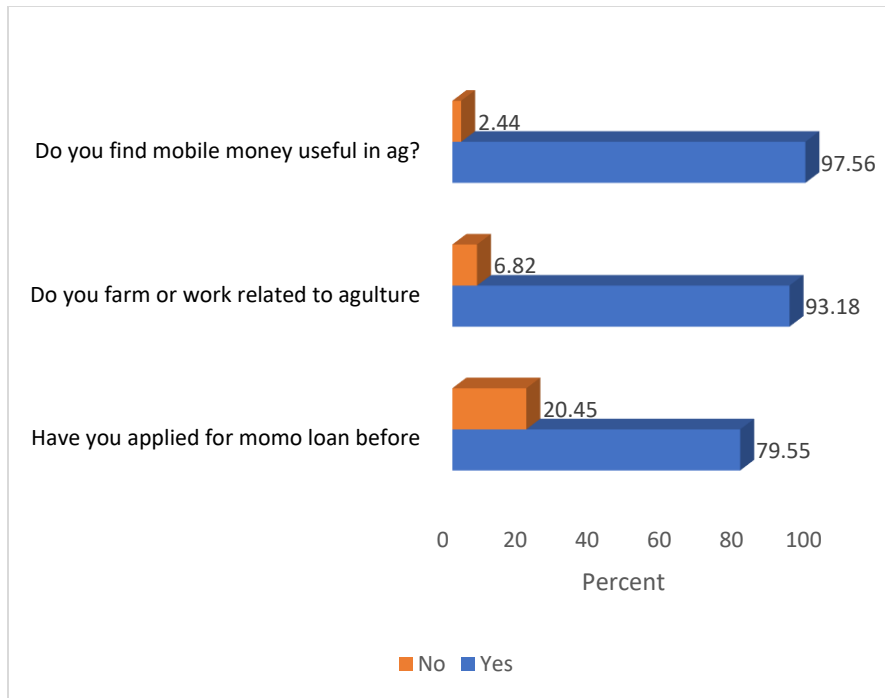
Figure A3-9

Uses of mobile money

Distribution of Mobile Money Agents overtime
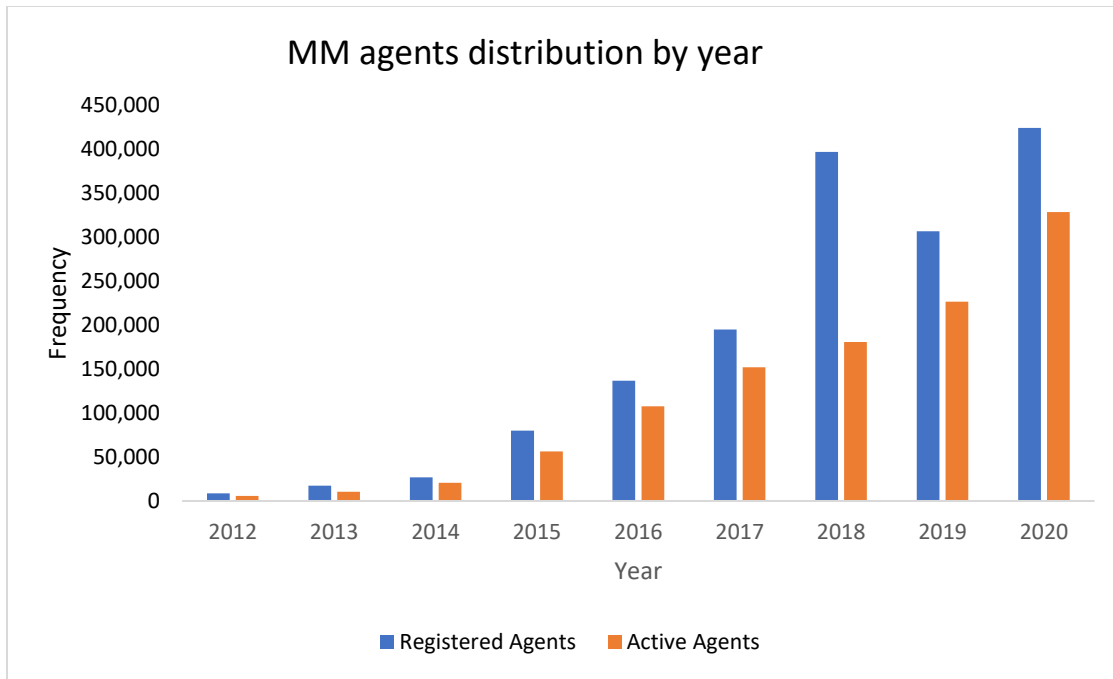

MM agents distribution by year
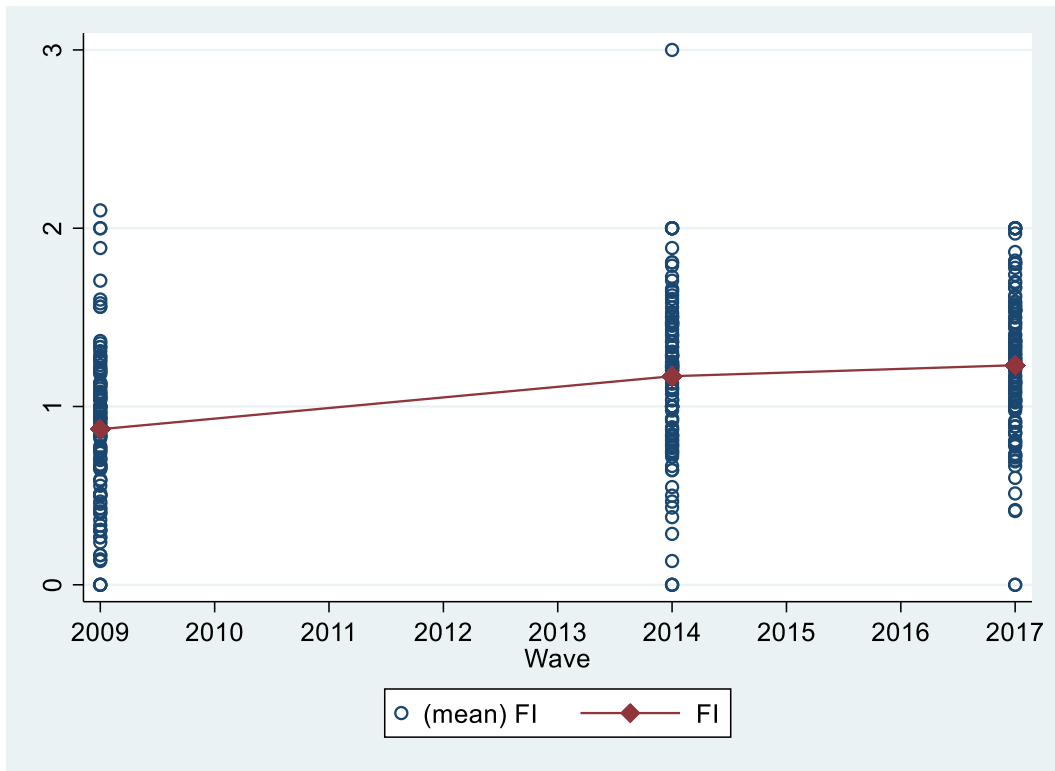
Figure A3-11

Distribution of Financial inclusion across waves

Figure A3-12

Distribution of Ag-investment across waves